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Essays on International Economics and Housing Economics

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by

Seungyub Han

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ABSTRACT OF THE DISSERTATION

Essays on International Economics and Housing Economics

by

Seungyub Han
Doctor of Philosophy in Economics
University of California, Los Angeles, 2024
Professor Andrew Atkeson, Co-Chair
Professor Lee Ohanian, Co-Chair

This dissertation consists of three chapters on international economics and housing economics. These chapters explore the intersection between housing economics and international macroeconomics and analyze various economic implications of the housing market. The first chapter studies the housing market's role in international business cycles. The second chapter examines the links between housing purchase and portfolio choices. The third chapter studies the effect of land supply policies on regional economies.

In Chapter 1, I analyze the role of housing market in international business cycles. Despite its distinctive features—such as large expenditure shares and inelastic supply—housing service has received scant attention in the international macroeconomics literature. To fill this gap, I examine the role of housing in international business cycles for eurozone countries. I show that housing rents exhibit larger variations than the prices of tradables and other nontradables, both in cross-country and time series. In addition, among all prices, housing rent stands out as the dominant contributor to both the Balassa-Samuelson effect and the negative Backus-Smith correlation. By simulating eurozone economies using a two-country model with a realistically calibrated housing sector, I show that the cross-country distribution of sectoral productivities, inelastic housing supply, and its interaction with the wealth effect via incomplete markets are key to understanding the empirical moments of real exchange rates. Compared with the standard model, the model with the housing sector generates larger variations of the real exchange rate, a stronger Balassa-Samuelson effect, and more realistic Backus-Smith correlations.

In Chapter 2, I study the effect of housing on households' portfolio choices. Although numerous studies have examined the crowding-out effect of housing on stock holdings via the house price risk channel and the liquidity constraint channel concurrently, separate influences on the crowding-out effect via the two channels have received less attention. In this paper, by exploiting a unique Korean housing tenure type called *jeonse*, which affects a household's investment decision only through the liquidity constraint channel, I study both effects separately. A calibrated life-cycle portfolio choice model with endogenous housing tenure choice and stock market participation shows that the liquidity constraint channel only affects young households and households with a low net wealth-to-income ratio and does not affect old or wealthier households. The house price risk channel, on the other hand, affects all types of households, including households with a high wealth-to-income ratio. Regressions using a household level panel survey show that the crowding-out effect of jeonse exists only for households with a low net wealth-to-income ratio and young households, whereas the crowding-out effect of homeownership affects all types of households.

In Chapter 3, we explore the effect of two different types of land use policies on regional economies by using regional level data of South Korea. We analyze the effect of conventional land-use restrictions in existing cities as well as the effect of unique land-supply policies, motivated by the South Korean government's 2nd New Town Project which built new cities from the scratch, supplying 666,000 houses near Seoul Metropolitan Area (SMA). We estimate the effect of such policies on the aggregate and regional economies, considering both the efficiency gain from the resource reallocation and externalities from regional decline. If the government introduces tighter land-use restrictions in SMA and relaxes land-use restrictions in other regions, regional population will more evenly distribute at the cost of aggregate GDP loss and universal housing price increases. Our back-of-the-envelope calculation indicates that the 2nd New Town Project was cost effective as it permanently increased steady state real aggregate GDP flow by 0.4%, for the one-time cost amounting 4.05% of GDP. It however exacerbated regional decline by decreasing overall rural population share by 4%.

The dissertation of Seungyub Han is approved.

Stavros Panageas

Oleg Itskhoki

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University of California, Los Angeles

2024

To my mom and dad, who have always been there for me.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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CHAPTER 1

Housing Rent, Inelastic Housing Supply, and International Business Cycles

1.1 Introduction

Understanding international business cycles is of paramount interest to many economists, both for academic inquiry and policy recommendations. In particular, the real exchange rate, defined as the relative price levels across countries, is a crucial general equilibrium object that influences core model mechanisms, including international risk sharing and trade. This indicates that a comprehensive grasp of the real exchange rate is essential for sound policy recommendations and legitimate academic research. Unfortunately, our understanding of real exchange rates is still limited, as evidenced by the various international macroeconomic puzzles described by Itskhoki (2021).

One of the potential causes for the limited understanding of real exchange rates might stem from the abstraction of housing. Most international macroeconomic models neglect housing, assuming that a housing service is the same as other nontradable services. However, housing deserves separate attention. As one of the most important components of household consumption, housing service can significantly impact the aggregate economy. According to a recent EU Statistics of Income and Living Conditions Survey (EU-SILC), households in European countries allocate approximately 20% to 23% of their disposable income to housing rents. Moreover, housing service differs markedly from other goods and services. Its supply is highly inelastic due to long construction periods and heavy reliance on land as the primary input for construction, coupled with limited land availability, factors often exacerbated by urbanization and stringent land-use regulations. Ignoring its economic significance and unique characteristics can lead to a limited understanding of international business cycles.

This paper addresses this gap by focusing specifically on housing services and distinguishing them from other nontradable services. In particular, I investigate the role of housing rent in three empirical aspects of real exchange rates: cross-sectional and time-series variations, the Balassa-Samuelson effect, and the Backus-Smith correlation. To conduct this analysis, I use the Eurostat-OECD Purchasing Power Parity database, which contains detailed relative price information. This database covers 224 items and represents an entire consumption basket. Notably, it includes data on pure housing rent, excluding maintenance fees and utility costs. Furthermore, it not only tracks relative price changes but also provides relative price levels. By categorizing goods and services as tradable items, nontradable items, and housing services, I effectively decompose the aggregate real exchange rate into three components: tradable real exchange rate, nontradable real exchange rate, and rent real exchange rate. As a result, the aggregate real exchange rate becomes an expenditure-weighted sum of these three components; this creates an ideal environment for examining the role of housing rent in the dynamics of real exchange rates.

I focus on eurozone countries in which the nominal exchange rates among countries are set at one, which eliminates the influence of nominal exchange rates on real exchange rates. It is widely recognized that nominal exchange rates can be affected by monetary policies, financial shocks, and potentially nonfundamental shocks. If the real exchange rates were primarily driven by nominal exchange rates, this could complicate examination of the connection between the housing sector and real exchange rates. In addition, my goal is to investigate the real supply and demand aspects of the housing service, rather than delving into housing-related financial market features such as mortgages. These render the eurozone area an ideal environment for studying the role of housing on real exchange rates. This strategy aligns with the approach used by Berka et al. (2018), which has proven to be fruitful.

Descriptive statistics analysis reveals that the rent real exchange rate exhibits larger variations and persistence in both cross-section and time-series than those of tradables and nontradables. Furthermore, by conducting a variance decomposition of the aggregate real exchange rate, I find that the rent real exchange rate contributes 33% of the aggregate real exchange rate variation across different countries (cross-sectional variation) and accounts for up to 60% of the aggregate real exchange rate variation over time (time-series variation), with the specific percentage varying by country. An intriguing observation is that in the time-series dimension, the rent real exchange rate displays very large fluctuations in countries significantly affected by demand shocks, such as Greece and Ireland. This implies the importance of inelastic nature of housing supply.

Furthermore, I augment this panel data on sectoral real exchange rates with data on relative real GDP per capita to investigate the Balassa-Samuelson effect. This effect is the empirical regularity with which countries with higher real GDP per capita tend to exhibit higher price levels, which is well documented by Rogoff (1996). The Balassa-Samuelson hypothesis is the most well-known theory to explain such a phenomenon. It posits that higher relative productivity in the tradable sector pushes up production factor prices, which pushes up nontradable prices and the overall price level. Although this is considered to primarily be applicable between developed and developing countries in the long run, recent research by Berka et al. (2018) indicates that it also holds among eurozone countries in the short run. I extend their work by specifically examining the role of housing rent. My panel regression analysis reveals that a 1% higher real GDP per capita than the eurozone average corresponds to a 0.25% higher price level than the eurozone average. In addition, I further dissect the contribution of each sector's real exchange rate to this aggregate effect. Remarkably, even when accounting for the modest 16% expenditure weight associated with rent, 0.122% of the 0.25% total relative price increase can be attributed to the relative rent increase. This constitutes nearly half of the overall effect. Notably, this is due to the fact that a 1% higher relative real GDP per capita translates to a 0.76% higher relative rent level. These findings underscore the significance of housing services in shaping the Balassa-Samuelson effect.

I also incorporate relative real consumption data in my dataset to examine the Backus-Smith correlation, which is the time-series link between the growth of the real exchange rate and real relative consumption. Typically, empirical data reveal this correlation to be close to zero or even negative. This suggests that countries' consumption increases more than the foreign when their price levels increase more than the foreign, which implies the deviation from the perfect risk sharing. Contrary to this, Backus and Smith (1993) demonstrated that a standard two-country model with a complete market predicts this correlation to be 1. This became a significant puzzle when attempts to modify the model's prediction closer to data proved difficult, even under the assumption of an incomplete market. Several promising solutions have been proposed—yet no previous research has considered the impact of the rent real exchange rate. However, the rent real exchange rate turns out to be very important. My panel regression analysis for eurozone countries indicates that when a country's consumption grows 1% more than the eurozone average, its real exchange rate appreciates by 0.14%, which implies a negative Backus-Smith correlation.[1] Remarkably, 0.126% of this 0.14% appreciation stems from the rent real exchange rate. This is striking, because it is the number we get even after we account for the relatively low expenditure weight of housing rent compared with that of tradables or nontradables. This again highlights the pivotal role of housing rent.

Motivated by these observations, I develop a two-country model that incorporates a realistically calibrated housing sector by combining two models from Berka et al. (2018)

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[1] Devereux and Hnatkovska (2020) argue that following the introduction of the euro, the average Backus-Smith correlations across eurozone countries turned positive, increasing from -0.19 to 0.05, compared to the pre-euro period. They also found that eight out of the twelve eurozone countries exhibited positive Backus-Smith correlations after the introduction of the euro by using data from 2000 to 2007. However, in my dataset, which spans from 2000 to 2019, nine out of twelve countries show negative Backus-Smith correlations, with an average of -0.06. This is still negative and near zero, being starkly different from 1. This suggests that while the nominal exchange rate plays a significant role, there are other mechanisms at work that contribute to the negative Backus-Smith correlation.

and Davis and Heathcote (2005). Also, I assume an incomplete market between countries to examine the role of the wealth effect studied by Corsetti et al. (2008), since an inelastic supply of housing naturally implies the importance of a demand shock via the wealth effect. As Itskhoki (2021) underscores, real exchange rates are shaped through general equilibrium forces. This requires examination of real exchange rates from a general equilibrium viewpoint. To achieve this, I simulate my model using sectoral productivity shocks—namely, those in the tradable, non-tradable, and construction sectors—directly calibrated from the EUKLEMS database. By simulating under varied calibrations of the housing market, I delve into the role housing plays in the dynamics of real exchange rates.

Simulations of my model reveal its capability to generate significant variations in the rent real exchange rate. To generate substantial time-series variations, the wealth effect turns out to be crucial. The inelastic supply of housing services—attributed to land being a primary input for construction and the minor flow of new housing relative to existing housing stock—reduces the volatility of the rent real exchange rate that arises from the productivity shock under a complete market. However, it amplifies the effect of relative demand changes from the wealth effect of Corsetti et al. (2008) due to its inelastic supply. Consequently, for the model to generate substantial rent real exchange rate volatility similar to what we observe in the data, wealth effect is necessary.

Model simulations also provide valuable insights for the Balassa-Samuelson effect. Simulations show that housing's heavy reliance on land as the primary input actually dampens the textbook Balassa-Samuleson hypothesis mechanism because land is not used in the tradable sector in the model. However, the model still generates the strong Balassa-Samuelson effect via housing rents as in the data, and it comes from the cross-country distribution of sectoral productivities. The sectoral productivity levels of eurozone countries, directly calibrated from the EUKLEMS database, reveal a pattern in which countries with highly productive tradable sectors also tend to exhibit high productivity in the nontradable sector, yet they demonstrate relatively lower productivity levels in the construction sector. This amplifies the textbook Balassa Samuelson hypothesis mechanism via the rent real exchange rate. This observation aligns with the recent findings of stagnant productivity in the construction sector documented by Goolsbee and Syverson (2023). On the top of these findings, the wealth effect from an incomplete market amplifies the model-generated Balassa-Samuelson effect across all sectors, with outcomes that surpass empirical estimates.

Lastly, incorporating a housing sector improves my model's ability to address the Backus-Smith puzzle. Although the standard model cannot, my model accurately replicates the panel regression results in the data and generates most of the negative Backus-Smith correlation through the rent real exchange rate component. This is primarily due to inelastic housing supply. It renders the aggregate supply more inelastic, which causes the aggregate price level to be more responsive to relative demand shifts. Consequently, price levels rise more when relative consumption increases via demand shifts from wealth effect, which generates a stronger negative Backus-Smith correlation. Furthermore, the now more inelastic aggregate supply diminishes the impact of nontradable sector and construction sector productivity shocks, which typically act as potent supply shocks and generate a positive Backus-Smith correlation.

This paper builds on a large literature on the secular movements of the real exchange rate. The relative price of the nontradable sector was initially thought to be important in aggregate real exchange rate dynamics. However, Engel (1999) documented that the bulk of US real exchange rate variation comes from relative prices of the tradable sector, under a floating exchange rate regime. Several studies suggest that differences in the consumer prices of traded goods across countries are due to the distribution margin (e.g., Burstein et al. 2003, Burstein et al. 2005, Betts and Kehoe 2006). On the other hand, other studies analyze firms' pricing behaviors based on variable markups (e.g., Atkeson and Burstein 2008, Gopinath and Itskhoki 2010). On the top of all these, Mussa (1986) documented large real exchange rate volatility under a floating exchange rate compared with that under a fixed exchange rate regime. My paper contributes to the literature by examining the importance of housing rent in real exchange rate movements under a fixed exchange rate regime.

My paper also intersects with the extensive literature on the Balassa-Samuelson effect. A foundational prediction of the Balassa-Samuelson hypothesis is that countries with higher real GDP per capita, which is employed as a proxy for tradable sector productivity, should exhibit more appreciated real exchange rates. Rogoff (1996) validated this by demonstrating a pronounced Balassa-Samuelson effect in a cross-sectional analysis of 1990 data. Bordo et al. (2017) identified a long-run correlation between relative income and real exchange rates across a panel of 14 countries in relation to the US. Several other studies have directly probed the nexus between real exchange rates and sectoral productivities rather than GDP per capita and resulted in a spectrum of outcomes (e.g., Lee and Tang 2007, Choudhri and Schembri 2014, Gubler and Sax 2019). In a recent contribution to the literature, Berka et al. (2018) examine eurozone countries' real exchange rates and sectoral productivity. Their findings suggest that the Balassa-Samuelson effect permeates the eurozone—even in the short run and within a time-series framework—when factoring in the labor wedge. I extend their work by distinctly focusing on housing rent and show that housing contributes to over half of the entire Balassa-Samuelson effect. By simulating the model with a realistically calibrated housing sector, I show that the cross-country distribution of sectoral productivities and the wealth effect are the key forces generating the Balassa-Samuelson effect in eurozone countries.

Lastly, this paper builds on literature on the Backus-Smith puzzle. While the correlation between real exchange rates and relative consumption is negative or near zero in the data, Backus and Smith (1993) found that a standard two-country model with a complete market predicts this correlation will be 1. Because this model prediction largely depends on the complete market assumption, Chari et al. (2002) constructed a two-country model with an incomplete market under monetary policy shocks. However, they again generated a correlation closer to 1. Later, Corsetti et al. (2008) generated a negative correlation under an incomplete market by assuming either very persistent productivity shocks or very low substitutabiltiy between home and foreign tradable goods. Benigno and Thoenissen (2008) generated a negative correlation by using the Balassa-Samuelson mechanism. Other papers use home production (e.g., Karabarbounis 2014) or non-rational expectations (e.g., Lambrias 2020) to resolve the Backus-Smith puzzle. Devereux and Hnatkovska (2020) point out that the role of the nominal exchange rate is important for a negative Backus-Smith correlation, and the most recent development in the literature is that of Itskhoki and Mukhin (2021), who resolve many international macroeconomic puzzles via financial frictions. My paper contributes to this literature by inspecting the role of housing rents in the Backus-Smith puzzle. While the importance of nominal exchange rate has been discussed in the literature, my paper shows that there are still negative Backus-Smith correlations among eurozone countries, albeit with a somewhat reduced magnitude. Moreover, I show that, among all relative prices, rent real exchange rate is the one that contributes most. Lastly, I theoretically contribute to this literature by showing how a realistically calibrated housing sector can help the standard model produce improved predictions for the Backus-Smith puzzle.

The paper is structured as follows. Section 2 details the data sources and describes how I construct sectoral real exchange rates. I also state the basic properties of sectoral real exchange rates and conduct panel regression analyses to identify the role of the rent real exchange rate in both the Balassa-Samuelson effect and the Backus-Smith puzzle. In Section 3, I outline the model that incorporates a housing sector. Section 4 presents the calibration of the model and sectoral productivity shock processes. I also report the simulation analysis result to elucidate the role of the housing sector in real exchange rate dynamics. Finally, in Section 5, I offer conclusions and propose extensions and questions for future research.

1.2 Data: Housing Rents and Real Exchange Rates

1.2.1 Real Exchange Rates in Eurozone Countries

Data Source and Coverage I construct the aggregate and sectoral real exchange rates of eurozone countries using the Eurostat-OECD Purchasing Power Parity (Eurostat PPP) database, which contains the cross-country relative price levels of 224 items and covers a whole consumption basket of European countries. These include all types of goods and services, such as food, clothing, transportation, education, and health care services. Most importantly, they provide the relative prices of *Actual Rentals for Housing* and *Imputed Rentals for Housing*. These two relative prices are for housing rents that do not include any other costs, such as maintenance fees or utility costs. This enables cleaner identification of housing service prices. The full list of goods and services in the database is in the appendix.

Reporting frequency is annual. I use data from 2000 to 2019 to examine the period after introduction of the euro and before the COVID-19 outbreak. In addition, I only use data on the 12 countries that introduced the euro in 2000: Austria, Belgium, Germany, Greece, Spain, Finland, France, Ireland, Italy, Luxembourg, the Netherlands, and Portugal. This is because fixed exchange rate countries provide a better identification environment for studying the role of housing rent in the dynamics of real exchange rates by eliminating the noise from nominal exchange rates.

Superiority of the Eurostat PPP Database Before jumping into the actual data, it is worth emphasizing the quality of the data I use. As is well explained by Berka et al. (2018), the Eurostat PPP database offers a number of advantages compared with the datasets used in other research. First, to construct the Eurostat PPP database, each country conducts a national survey that covers all items in their consumption baskets. This implies that the database covers the overall price levels of the economy. Compared with research that uses price data from a single supermarket chain (Gopinath et al. 2011), from a single international retailer of household goods (Haskel and Wolf 2001, Baxter and Landry 2017), or from a few online retailers (Cavallo et al. 2014), the Eurostat PPP database offers better coverage. Second, the Eurostat PPP database guarantees better cross-country comparability. For example, though some research has used price data that cover a comprehensive set of items, such as the Economist Intelligence Unit survey (Engel and Rogers 2004, Crucini and Shintani 2008), such data lack the validity of cross-country comparability. In contrast, the Eurostat PPP database is organized under a single entity, Eurostat, which guarantees more homogeneous data collection procedures across countries (e.g., the selection of items and outlets where prices are measured). In addition, the Eurostat PPP database undergoes an internal review process every year to check the comparability and completeness of the dataset. The fact that I use only eurozone countries itself should also increase cross-country comparability, since they share similar spending patterns and cultural and legal backgrounds.

In particular, housing rent data in the Eurostat PPP database offers the most credible cross-country comparability. The housing rent level is notoriously difficult to measure for cross-country comparison. To overcome this, every year Eurostat asks all member countries to derive rent-level data based on their internal rent survey. Most reporting countries use rent survey data for their national account construction, which demonstrates how precise and detailed the data are. In addition, Eurostat provides members with detailed instructions on how to compute the rent price level.[2] Lastly, they conduct an annual internal review to examine the cross-comparability and consistency of the dataset. All of these procedures ensure that the cross-comparability of this dataset is superior.

Construction of Real Exchange Rates This database provides the price level index (PLI) for 224 items that cover a whole consumption basket. A PLI (p_{ijt}) for item i and country j is defined as the log relative price of item i in country j relative to that of the

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[2] While collecting rent data, the quality of houses is also taken into account. They are classified by the number of rooms, type of house (apartment, single house, etc.), and features (central heating system, etc.) to derive a quality-based quantity index. For more information, refer to the OECD and Eurostat (2012)

EU 15 average (geometric average).

$$p_{ijt} = log(\frac{P_{iEU15t}}{P_{ijt}}) \quad \text{where} \quad P_{iEU15t} = \prod_{k \in EU} P_{ikt}^{\frac{1}{15}}.$$

For example, if the croissant price is 1.2 euros in France but its EU 15 average price is 1 euro, the PLI of croissants in France is given as $0.079 = log(\frac{1.2}{1.0})$. Note that this contains information not only on the relative growth rate of the prices but also the relative levels of the prices. For every item in the consumption basket, I can observe how expensive that item is in a certain country compared with the EU 15 average.

The database also contains the expenditure weight of each item for each country. As is usual, the expenditure weight (γ_{ijt}) for item i and country j is defined as follows:

$$\gamma_{ijt} = \frac{EXP_{ijt}}{\sum_{i=1}^{224} EXP_{ijt}}, \quad \sum_{i=1}^{224} \gamma_{ijt} = 1.$$

By using these PLIs and expenditure weights, I construct aggregate real exchange rates as follows. Note that since PLI is defined as the price level compared with the EU 15 average, this real exchange rate is between country j and the EU 15 average:[3]

$$q_{j,t} = \sum_{i=1}^{224} \gamma_{ijt} p_{ijt} = log(\frac{\prod_{i=1}^{224} P_{iEU15t}^{\gamma_{ijt}}}{\prod_{i=1}^{224} P_{ijt}^{\gamma_{ijt}}}).$$

In this definition, the real exchange rate is effectively the expenditure-weighted geometric average of the relative prices of goods and services. Intuitively, this implies the relative overall price level of country j compared with that of the EU 15 average. Going one step further, I can decompose this aggregate real exchange rate into sectoral real exchange

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[3] This means that I use the country j's expenditure weights to calculate the average price level of the EU 15 countries. As it will be shown in Figure 1.2, there is no much cross-country difference in expenditure weights.

rates as follows:

$$
\begin{aligned}
q_{jt}^{T} &= \frac{\sum_{i \in T} \gamma_{ijt} p_{ijt}}{\sum_{i \in T} \gamma_{ijt}} \qquad \text{(159 Items)}, \quad (\sum_{i \in T} \gamma_{ijt} = \gamma_j^{T}), \\
q_{jt}^{NT} &= \frac{\sum_{i \in NT} \gamma_{ijt} p_{ijt}}{\sum_{i \in NT} \gamma_{ijt}} \qquad \text{(63 Items)}, \quad (\sum_{i \in NT} \gamma_{ijt} = \gamma_j^{NT}), \\
q_{jt}^{R} &= \frac{\sum_{i \in H} \gamma_{ijt} p_{ijt}}{\sum_{i \in H} \gamma_{ijt}} \qquad \text{(2 Items)}, \quad (\sum_{i \in H} \gamma_{ijt} = \gamma_j^{R} = 1 - \gamma_j^{T} - \gamma_j^{NT}).
\end{aligned}
$$

In essence, these are again the expenditure-weighted geometric averages of the prices of a certain group of goods and services. It shows that I classify 159 items as tradable, 63 items as nontradable, and 2 items as housing rents. For this classification, I closely follow the approach of Berka et al. (2018).[4] Two housing-service related items are *Actual Rentals for Housing* and *Imputed Rentals for Housing*. By construction, I arrive at the following decomposition of the aggregate real exchange rate:

$$
q_{jt} = \gamma_j^{T} q_{jt}^{T} + \gamma_j^{NT} q_{jt}^{NT} + \gamma_j^{R} q_{jt}^{R},
$$

where $\gamma_j^{R} = 1 - \gamma_j^{T} - \gamma_j^{NT}$. Note that $q_{jt} < 0$ implies that country j's overall price level is higher than the EU 15 average, and $\Delta q_{jt} < 0$ implies the appreciation of country j's real exchange rate.

Properties of Real Exchange Rates and Expenditure Weights I start with the descriptive statistics in Table 1.1. The upper panel of the table provides information on each country and the lower panel provides information on the average of each country's statistics. Together, they provide information on the overall characteristics of real exchange rates in the eurozone.

The first table in the upper panel shows how each country's sectoral price level compares with the EU 15 average. Ireland is in the first row, with a 13.2% higher price level than the EU 15 average, and Portugal is in the last row, with a 24.4% lower price level than the

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[4] The classification procedure is detailed in the appendix.

EU 15 average. An interesting observation is that countries with a higher overall price level have higher prices for nontradable services and also more expensive rent.

To understand the overall characteristics of sectoral real exchange rates, see the lower panel of Table 1.1. The first important observation is the q^R shows the largest volatility in both the cross-section and time series compared with q^T and q^{NT}. As is well known, housing service supply is inelastic, and thus any demand shocks likely generate a large price response rather than a quantity response. Note that Δq^R also shows the largest volatility compared with Δq^T and Δq^{NT} both in cross-section and time-series. Lastly, q^R is also the most persistent compared with other sectoral productivities. Because of the slow response of supply to any shock, price changes via certain shocks are likely to last longer unless the shock itself is temporary.

Table 1.1: Descriptive Statistics of Real Exchange Rates

	Mean				*Standard deviation*				*Autocorrelation*(1)			
Country	$\bar{q}$	$\bar{q^T}$	$\bar{q^{NT}}$	$\bar{q^R}$	$std(q)$	$std(q^T)$	$std(q^{NT})$	$std(q^R)$	$\rho(q)$	$\rho(q^T)$	$\rho(q^{NT})$	$\rho(q^R)$
Ireland	-0.132	-0.102	-0.140	-0.187	0.034	0.021	0.035	0.128	0.737	0.500	0.731	0.866
Finland	-0.124	-0.093	-0.138	-0.187	0.021	0.028	0.034	0.022	0.823	0.919	0.725	0.681
Luxembourg	-0.047	0.080	-0.059	-0.425	0.040	0.015	0.087	0.039	0.954	0.692	0.965	0.564
France	0.002	0.023	0.002	-0.057	0.014	0.027	0.034	0.030	0.536	0.813	0.801	0.888
Belgium	0.005	0.006	0.006	-0.003	0.012	0.019	0.017	0.028	0.677	0.736	0.774	0.899
Netherlands	0.010	0.027	0.010	-0.038	0.026	0.015	0.035	0.055	0.866	0.585	0.770	0.954
Austria	0.028	0.017	-0.047	0.273	0.015	0.014	0.018	0.053	0.715	0.690	0.732	0.920
Germany	0.030	0.033	0.029	0.020	0.023	0.015	0.028	0.068	0.912	0.644	0.885	0.979
Italy	0.068	0.008	0.100	0.222	0.018	0.018	0.021	0.049	0.693	0.723	0.416	0.682
Spain	0.162	0.147	0.176	0.172	0.032	0.025	0.047	0.070	0.858	0.877	0.814	0.869
Greece	0.211	0.134	0.254	0.364	0.050	0.041	0.062	0.200	0.863	0.916	0.839	0.944
Portugal	0.244	0.118	0.313	0.641	0.016	0.022	0.045	0.121	0.530	0.607	0.768	0.965

Aggregate	$std(mean_i)$	$mean(std_i)$	$mean(autocorr_i)$
q	0.119	0.025	0.764
q^T	0.079	0.022	0.725
q^{NT}	0.144	0.039	0.768
q^R	0.286	0.072	0.851

$q_{it} = ln(P_{EU15t}/P_{it})$, $q^T_{it} = ln(P^T_{EU15t}/P^T_{it})$, $q^{NT}_{it} = ln(P^{NT}_{EU15t}/P^{NT}_{it})$, $q^R_{it} = ln(P^R_{EU15t}/P^R_{it})$, where P_{EU15t} is the aggregate price level of 15 European countries. The data period is from 2000 to 2019 and data are at annual frequency. Countries in the upper panel are sorted in the order of price levels.

Figure 1.1 shows movements of the sectoral real exchange rates of all eurozone countries. I set the ranges of the y-axes in all graphs the same to facilitate comparison across sectors. An interesting pattern is that the variation of q^T is very small in both the cross-section and time series, even compared with other nontradable items. In addition, it even shows the sign of the convergence of price levels as the year progresses. Most importantly, we can clearly see the large variation of q^R in both the cross-section and time series, as captured in Table 1.1. These volatile dynamics of q^R are most prominent in countries that experienced significant demand shocks during the eurozone crisis (e.g., Portugal, Ireland, and Greece).

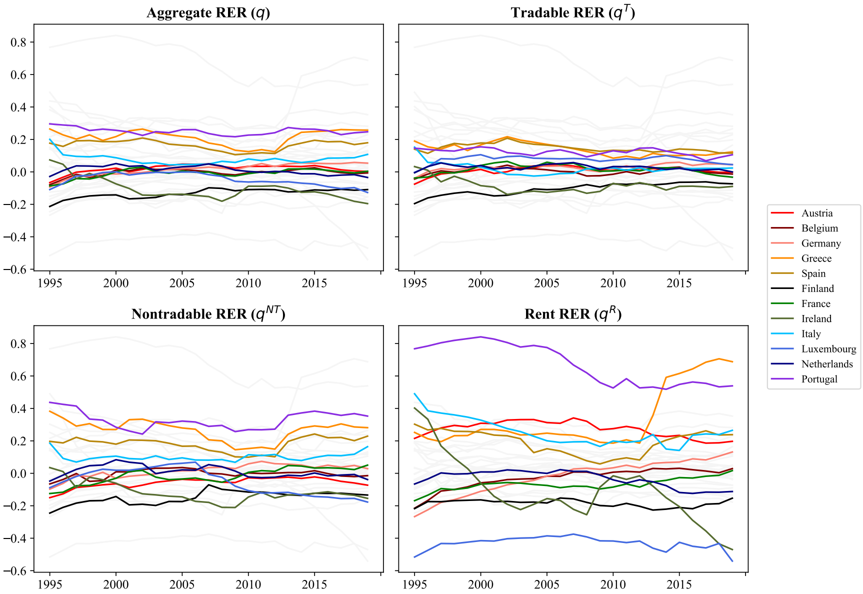

Figure 1.1: Properties of Real Exchange Rates

Figure 1.2 shows the dynamics of the sectoral expenditure weights of all countries. Again, I set the ranges of the y-axes in all graphs the same to facilitate comparison across sectors (except for the total expenditure weight, which is by definition 1.) A notable pattern is that the expenditure weights of tradables are decreasing, while the expenditure weights for nontradables and housing rents are increasing. Also, note that rent expenditure weights are roughly in the range of 15%-20%, which is a substantial weight for only two items. Though there is cross-country heterogeneity in expenditure weights, overall heterogeneity is not that significant. In addition, the relative size of each sector's expenditure weight is roughly same across countries, which implies that we do not need to be particularly concerned, and average expenditure weights across time can be used without affecting the data more than slightly.

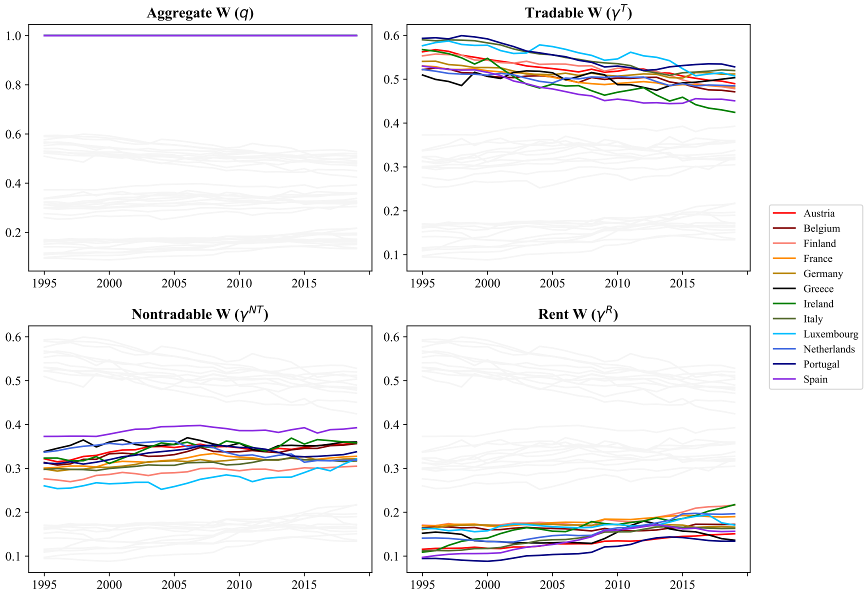

Figure 1.2: Properties of Expenditure Weights

Variance Decomposition While the q^R shows very large cross-country and time-series variations, it also has the lowest expenditure weight compared with tradables and nontradables. Thus, it might be the case that in the end, relative rents do not affect the dynamics of the aggregate real exchange rate much. To get a sense of the quantitative importance of the relative rents, I conduct the following variance decomposition. Any variance of $Var(q)$ can be decomposed as follows:

$$Var(q) = Cov(q, \gamma^T q^T + \gamma^{NT} q^{NT} + \gamma^R q^R) = \gamma^T Cov(q, q^T) + \gamma^{NT} Cov(q, q^{NT}) + \gamma^R Cov(q, q^R).$$

By dividing both sides by $Var(q)$, I arrive at the following:

$$1 = \gamma^T Corr(q, q^T) \frac{std(q^T)}{std(q)} + \gamma^{NT} Corr(q, q^{NT}) \frac{std(q^{NT})}{std(q)} + \underbrace{\gamma^R Corr(q, q^R) \frac{std(q^R)}{std(q)}}_{\text{Share of } q^R \text{ in } RER \text{ Variation}}.$$

According to this decomposition, the contribution of the rent real exchange rate can be calculated as $\gamma^R Corr(q, q^R) \frac{std(q^R)}{std(q)}$. Note that this measure also takes the expenditure weight into account. I apply this decomposition to both cross-section and time-series variation. For the cross-section, I decompose the cross-country variation of the average aggregate real exchange rate, $Var(\bar{q})$. This exercise demonstrates how important housing rent is in accounting for price-level differences across countries. The left panel in Figure 1.3 shows the result. We observe that the rent real exchange rate accounts for 33% of the total variations. Considering its 16% expenditure weight, which is substantially smaller than that of tradables and non-tradables, the fact that q^R accounts for one-third of the total variation is remarkable.

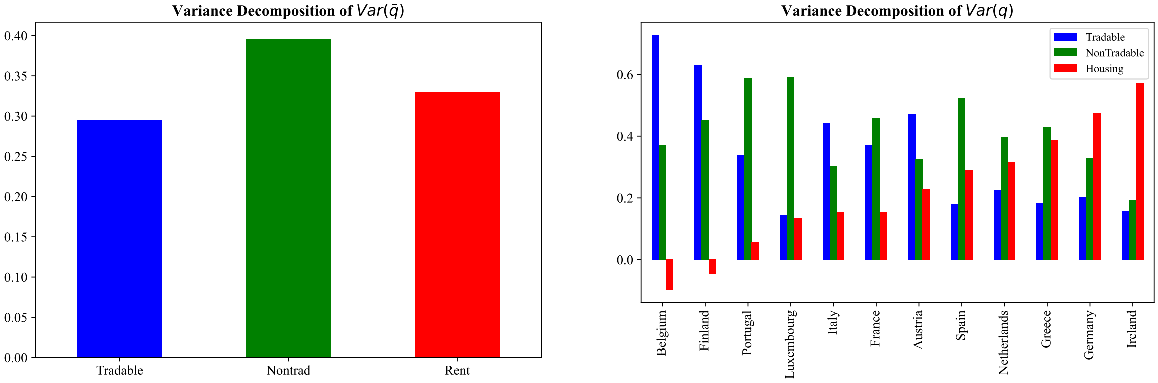

Figure 1.3: Variance Decompositions of RER

On the top of it, for time-series variation, I apply this decomposition to each country j's time-series variation, $Var(q_{jt})$. This exercise shows how rent real exchange rate affects the time-series variation of total real exchange rate in each country. The right panel in Figure 1.3 shows the results. Though there are countries in which the contributions of the real exchange rates are lower than their expenditure shares, we see that there are countries in which more than half of the total variation comes from rent real exchange rates. Again, given the 15%-20% expenditure weight of housing rents, this shows the significant role of rent real exchange rates. In particular, countries that experienced large demand shocks but have no rent control exhibit larger roles for q^R.

This is in contrast to the findings of Engel (1999), whereby the relative price of the tradable is the one that drives the time-series standard deviation of the real exchange rate. This is probably because Engel (1999) examined the floating exchange rate regime and I examined the fixed exchange rate regime. Berka et al. (2018) examined the important role of the relative price of the nontradable under fixed exchange rates. However, they did not decompose it into housing and non-housing components, thereby overlooking the importance of housing rents. Building on their work, I further dissect the nontradable prices into non-housing nontradable prices and housing rents. I demonstrate that the significance of housing rents, which are arguably influenced by different mechanisms compared to other nontradables, is comparable to that of all other non-housing nontradables. This result implies that housing rent deserves more attention in the real exchange rate literature. In addition, the rent expenditure weights provided by the Eurostat PPP database much lower than what we see in the household survey.[5] This implies that any empirical implications of q^R I find with the Eurostat PPP database can be considered to be a lower bound.

1.2.2 Housing Rent, the Balassa-Samuelson Effect, and the Backus-Smith Puzzle

Now I combine my panel dataset of sectoral real exchange rates with those of real GDP per capita and real consumption to explore the Balassa-Samuelson effect and the Backus-Smith correlation. Both datasets are from the national account of each country and are in real terms to measure volume changes.[6]

To render these variables consistent with my definition of real exchange rates, I define relative real GDP per capita (y) and relative real consumption (c) as follows:

$$\begin{aligned} y_{jt} &= log(Y_{jt}/Y_{EU12t}), \\ c_{jt} &= log(C_{jt}/C_{EU12t}). \end{aligned}$$

Note that Y_{EU12t} and C_{EU12t} are the geometric averages of 12 eurozone countries' real

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[5] For European countries, households' actual expenditure weights on rents are much larger than Eurostat PPP data imply if I use EU-SILC household survey data. The rent expenditure weight is higher for poorer households. I provide graphical descriptions of households' expenditure weights on rents in the appendix.

[6] For real GDP per capita, I use *real GDP per capita in PPP-adjusted EU15* and, for real relative consumption, I use *real final consumption expenditure of households, chain-linked volumes (2010), million euro.* Some prior research has used per capita consumption for the Backus-Smith correlation, and the results do not change much when I use per capita consumption. Tables based on per capita consumption are provided in the appendix.

GDP per capita and real aggregate consumption. Δy_{jt} (Δc_{jt}) represents the relative growth rate of real GDP per capita (real aggregate consumption) relative to that of the EU 12 average. Unlike the case of real exchange rates, $\Delta y_{jt} > 0$ ($\Delta c_{jt} > 0$) implies that country *j*'s real GDP per capita (real aggregate consumption) is growing faster than the average of the 12 eurozone countries.

Cross-sectional Variation VS Time-series Variation To examine the Balassa-Samuelson effect, Rogoff (1996) used the cross-section data of countries in 1990, exploiting cross-sectional-level variation. On the other hand, Corsetti et al. (2008) calculated each country's time-series correlation between its real exchange rate growth and relative consumption growth, effectively exploiting the time-series dimension of the data. While these two moments concern variations in different dimensions, what I have is panel data that capture both cross-section and time-series variations. Running a pooled OLS might prevent me from observing the empirical patterns of interest.

To avoid such problems, I run the following four regressions:

$$\bar{q}_j = \beta \bar{x}_t + \eta_t \qquad \text{(Country Average)}, \tag{1.1}$$

$$q_{jt} = \alpha_t + \beta x_{jt} + \epsilon_{jt} \qquad \text{(Time Fixed Effect)}, \tag{1.2}$$

$$\Delta q_{jt} = \Delta \beta x_{jt} + \epsilon_{jt} \qquad \text{(Growth Rate)}, \tag{1.3}$$

$$q_{jt} = \alpha_j + \beta x_{jt} + \epsilon_{jt} \qquad \text{(Country Fixed Effect)}. \tag{1.4}$$

The regressions in Equation (1) and (2) capture cross-sectional-level variations. By averaging out across time in each country or by using the time-fixed effect, I remove time-series variations and capture only cross-country variations. The Balassa-Samuelson effect is expected to appear in these two regressions and the Backus-Smith correlation is expected not to appear.

On the other hand, the regressions in Equation (3) and (4) capture time-series variations. By using it in growth rate form or by using the country-fixed effect, I remove the cross-country level variations.[7] The Balassa Samuelson effect may appear here as Berka et al. (2018) finds out, and the Backus-Smith correlation is expected to appear for these regressions.

Note that fixed effects are not used to remove any potential endogeneity stemming from unobserved heterogeneity. I am primarily interested in the correlation relationship, and these fixed effects are used to capture the variations of interest in different dimensions. In addition, using these regressions, I can check the significance of β under either time- or country-clustered standard deviations, exploiting all data more systematically than calculating correlation for each country. I will apply all of these regressions to both the Balassa Samuelson effect and the Backus-Smith correlations, and see from which variations those relationships emerge.

Regression-based Decomposition Before directly jumping into the actual regression, I explain how I capture the role of rent real exchange rate for any empirical patterns. In fact, regression analysis provides very intuitive decomposition of the relationships. For example, if I am interested in the relationship between a variable of interest (x) and the aggregate real exchange rate (q), I can perform the following regression analysis:[8]

$$q_{jt} = \alpha + \beta x_{jt} + \epsilon_{jt}.$$

In this regression, β, which is $\frac{Cov(q,x)}{Var(x)}$, summarizes the relationship between q and x. Also, to examine the relationship between x and each sector's real exchange rate

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[7] There is no significant cross-country heterogeneity in growth rates of aggregate and sectoral real exchange rates.

[8] This applies to all four regression forms discussed in the previous paragraph because all regressions are effectively OLS regressions in levels, growth rates, or demeaned values.

(q^T, q^{NT}, q^R), I can perform the following regression analysis:

$$\begin{aligned} q^T_{jt} &= \alpha + \beta^T x_{jt} + \epsilon_{jt}, \\ q^{NT}_{jt} &= \alpha + \beta^{NT} x_{jt} x + \epsilon_{jt}, \\ q^R_{jt} &= \alpha + \beta^R x_{jt} + \epsilon_{jt}. \end{aligned}$$

Then, given that $q = \gamma^T q^T + \gamma^{NT} q^{NT} + \gamma^R q^R$ and the linearity of the OLS estimator, the following holds:

$$\beta = \gamma^T \beta^T + \gamma^{NT} \beta^{NT} + \gamma^R \beta^R.$$

This procedure effectively decomposes the relationship between x and q represented by β into the weighted sum of the relationship between x and each sector's real exchange rate. This regression-based decomposition yields intuitive assessment of the role of each sector's real exchange rate. $\gamma^R \beta^R$ will be the contribution of q^R to the aggregate empirical relationship summarized by β. By using this decomposition, I will examine how much the rent real exchange rate contributes to the Balassa-Samuelson effect and the Backus-Smith correlation.

Housing Rents and the Balassa-Samuelson Effect First, I examine the Balassa-Samuelson effect in eurozone countries. As a motivating figure, I generate a scatter plot in which the average relative real GDP per capita of each country $(\bar{y}_j)$ is on the x-axis and each country's average aggregate real exchange rate $(\bar{q}_j)$ and sectoral real exchange rates $(\bar{q}^T_j, \bar{q}^{NT}_j, \bar{q}^R_j)$ are on the y-axis in Figure 1.4.

As we can clearly see in the left panel, countries with higher relative GDP per capita show higher relative price levels ($q < 0$). This implies that the Balassa-Samuelson effect exists in eurozone countries. Then, the right panel shows where such a relationship comes from. We can see that the relative price levels of tradables (q^T, denoted by the blue line) do not increase much, even if the country has a high GDP per capita. On

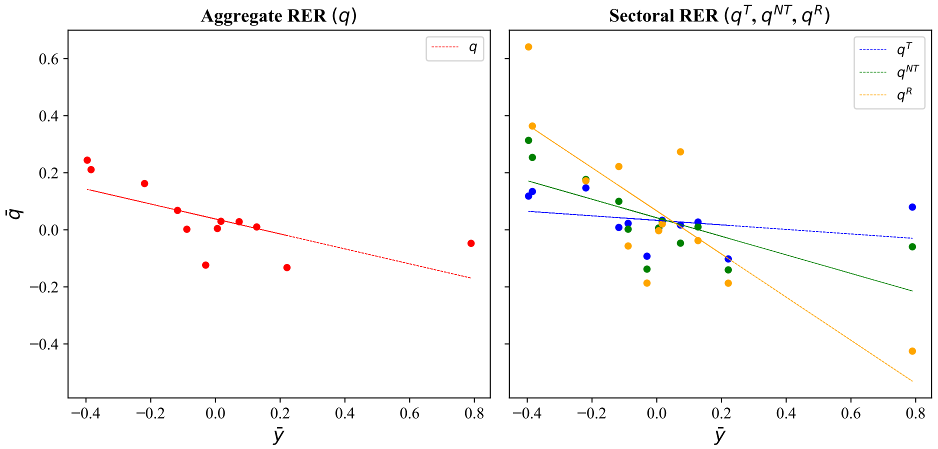

Figure 1.4: The Balassa-Samuelson Effect in Eurozone Countries

the other hand, rent real exchange rates (q^R, denoted in yellow) exhibit a steep increase and decrease depending on the country's relative GDP per capita, which implies the important role of relative rents in the Balassa-Samuelson effect.

To examine the data more systematically, by using four types of regressions stated in equation (1.1), (1.2), (1.3), and (1.4) for all real exchange rates, I examine the relationship between aggregate and sectoral real exchange rates (q, q^T, q^{NT}, q^R) and relative real GDP per capita (y). Results of the regressions are reported in Table 1.2.

In the first two regressions that capture cross-sectional variations, as expected, β is estimated as -0.26 statistically significantly. This implies that a country with 1% higher relative GDP per capita has the 0.26% higher relative price levels, which proves the existence of the Balassa-Samuelson effect in eurozone countries. Another interesting observation is that q^R has very large coefficients compared with the other two sectoral real exchange rates, while q^T's coefficient is not even significant in the country-average regression.

The two remaining regressions, which capture time-series variations, offer further evidence of the significance of housing. Given that the Balassa-Samuelson effect is widely accepted as a long-term empirical pattern (Rogoff 1996), it's unsurprising that the overall Balassa-

Table 1.2: Balassa-Samuelson Effect Regressions

Cross-section					
		$\bar{q}$	$\bar{q}^T$	$\bar{q}^{NT}$	$\bar{q}^R$
Country Average	$\bar{y}$	-0.26*	-0.08	-0.33*	-0.76***
		(0.14)	(0.13)	(0.18)	(0.19)
	R^2	0.43	0.08	0.45	0.64
	N	12	12	12	12
		q	q^T	q^{NT}	q^R
Time Fixed Effect	y	-0.26***	-0.07***	-0.31***	-0.75***
		(0.01)	(0.01)	(0.01)	(0.03)
	R^2	0.45	0.08	0.45	0.64
	N	240	240	240	240

Time-series					
		Δq	Δq^T	Δq^{NT}	Δq^R
Growth Rate	Δy	0.07*	0.11***	0.13**	-0.17**
		(0.04)	(0.03)	(0.07)	(0.08)
	R^2	0.02	0.04	0.02	0.02
	N	240	240	240	240
		q	q^T	q^{NT}	q^R
Country Fixed Effect	y	-0.11***	0.08*	-0.08	-0.67***
		(0.04)	(0.05)	(0.10)	(0.22)
	R^2	0.07	0.07	0.02	0.25
	N	240	240	240	240

$q = ln(P_{EU15t}/P_{it})$, $q^T = ln(P^T_{EU15t}/P^T_{it})$, $q^{NT} = ln(P^{NT}_{EU15t}/P^{NT}_{it})$, $q^R = ln(P^R_{EU15t}/P^R_{it})$ where P_{EU15t} is the price level of 15 European countries' average. $c = ln(C_{it}/C_{EU12t}), y = ln(Y_{it}/Y_{EU12t})$ where C_{EU12t}, Y_{EU12t} are geometric averages of C, Y over 12 eurozone countries. Data period is from 2000 to 2019 and data are at annual frequency. All standard error are computed using a panel-corrected standard errors method under the assumption of period correlation (cross-sectional clustering). Parentheses below estimates include standard deviations. * means 10% significance, ** means 5% significance, *** means 1% significance.

Samuelson effects observed in these regressions are not pronounced.[9] However, it is surprising that housing continues to play a significant role even in short-term, year-to-year fluctuations, with countries experiencing rapid growth also seeing faster increases in housing prices.

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[9] Berka et al. (2018) show that the Balassa-Samuelson hypothesis actually also works in dynamics. The difference between their regressions and mine is that they directly use sectoral productivity levels from the EUKLEMS in the data and not relative real GDP per capita. Their regressions work with the data until 2007. However, once the time period after 2008 is included, they no longer work. This is likely because, after 2008, the economy was primarily driven by financial sector shock and not productivity shocks, as also explained by Berka et al. (2018).

Given that the cross-sectional pattern is stronger, I conduct the regression-based decomposition described in the previous paragraph for two regressions for cross-sectional variations. Left panel in Figure 1.5 shows the result. Each bar is each sectoral real exchange rate's β multiplied by the sectoral expenditure weight γ, so the sum of the blue, green, and red bar should be equal to the black bar.

Because β^T is not significant, this decomposition shows that almost half of the Balassa-Samuelson effect actually comes from the rent real exchange rate. While the rent expenditure weight is less than half the expenditure weight of other nontradables, its contribution to the Balassa-Samuelson effect is more than that. This implies the important role of housing rent in the Balassa-Samuelson effect.

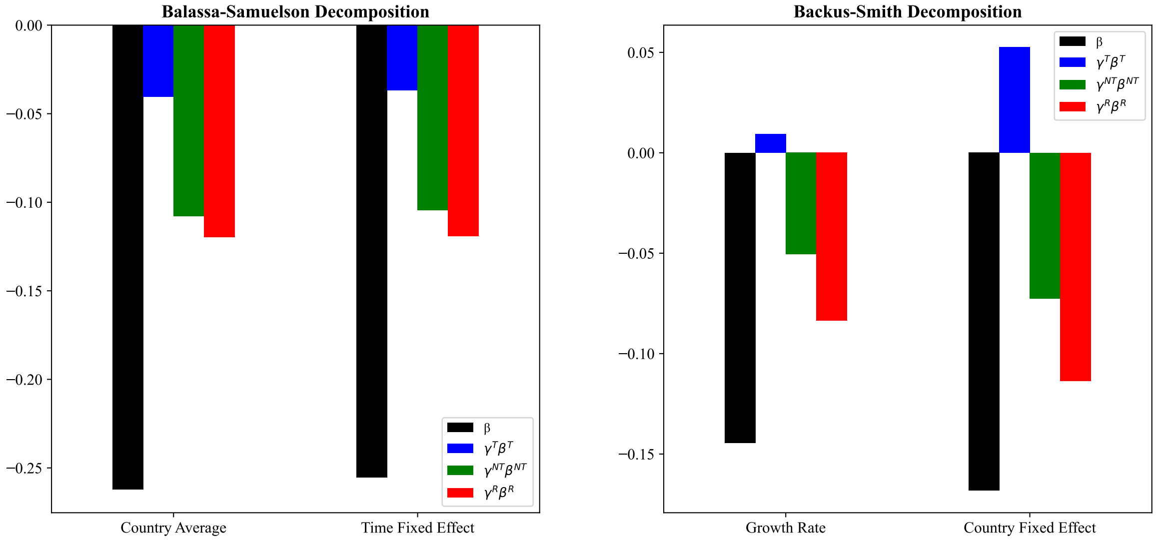

Figure 1.5: β Decompositions for the Balassa-Samuelson Effect and the Backus-Smith Puzzle

Housing Rents and Backus-Smith Correlations For the last empirical analysis, I will examine the role of housing rents in the Backus-Smith correlation, which is one of the most important international macroeconomics puzzles (Backus and Smith 1993, Chari et al. 2002, Corsetti et al. 2008, Benigno and Thoenissen 2008, Karabarbounis 2014, Itskhoki and Mukhin 2021, Itskhoki 2021). Again, by exploiting the regression-based decomposition, I will examine which sectoral real exchange rate is responsible for the negative Backus-Smith correlations in the data.[10]

Before moving to the regression analysis, following the literature, I calculate the Backus-Smith correlation of the aggregate and sectoral real exchange rates for each country in the eurozone. Table 1.3 shows these correlations for each country. Though not all countries show negative correlations, nine countries out of 12 show the near-zero or negative correlations between real relative consumption and real exchange rates, which manifests the presence of negative Backus-Smith correlations among eurozone countries. On average, the Backus-Smith correlations are -0.059, which are far from the 1 implied by the standard model.[11]

However, again, this is not a systematic way to examine the correlation between relative consumption and the real exchange rate. Consequently, as I did for the Balassa-Samuleson effect, I run the four regressions to examine the relationship between changes in aggregate and sectoral real exchange rates (q, q^T, q^{NT}, q^R) and real relative consumption (c). Table 1.4 reports the results.

Unlike the case of the Balassa-Samuelson effect, now the cross-sectional regressions do not show any significant results. However, this time, regressions that capture time-series variations show significant results. In the time-series dimension, when a country's aggregate consumption grows 1% more than EU 12 average, the country's price level

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[10] Corsetti et al. (2012) conducted an analysis similar to mine to identify which sectoral prices drive the Backus-Smith correlation in the data. Due to a lack of data, they first get data on P^T and estimate the changes in nontradable price P^{NT} as a residual by subtracting P^T from aggregate price changes. Here, I have sectoral real exchange rates based on item-level relative price data. My approach should be more precise and reliable—but their analyses are superior, in the sense that they use quarterly frequency data. Also, they use the producer price index or prices in dock, which allow them to separate the effect of the distribution margin from tradable good prices.

[11] Devereux and Hnatkovska (2020) ran fixed-effect regressions for a very large number of sub-regions across Japan, the US, and many other European countries. They found that the negative Backus-Smith correlation exists between countries while the risk-sharing is working between regions in a same country, showing that the border effect is important for the negative Backus-Smith correlation. On the top of that, they argue that nominal exchange rate accounts for one third of such border effect. As they argued, the role of the nominal exchange rate is important. If I include the data for periods when there was no euro (1995-1999), the Backus-Smith correlations get much more negative. The negative Backus-Smith correlations that I found in periods after the introduction of euro can be understood as a remaining part of the border effect.

Table 1.3: Backus-Smith Correlations

	$Corr(\Delta c, \Delta q)$	$Corr(\Delta c, \Delta q^T)$	$Corr(\Delta c, \Delta q^{NT})$	$Corr(\Delta c, \Delta q^R)$
Austria	-0.066	-0.031	0.131	-0.489
Belgium	-0.029	0.047	-0.087	-0.118
Finland	0.246	0.481	-0.027	-0.020
France	0.307	0.219	0.467	-0.162
Germany	-0.205	-0.012	-0.122	-0.551
Greece	-0.075	0.090	-0.110	-0.080
Ireland	-0.418	-0.218	-0.242	-0.541
Italy	0.135	0.048	0.288	0.011
Luxembourg	-0.082	0.302	-0.159	-0.260
Netherlands	-0.039	-0.149	0.176	-0.299
Portugal	-0.275	-0.183	-0.137	0.052
Spain	-0.203	0.114	-0.272	-0.235
Average	-0.059	0.059	0.008	-0.224

$q = ln(P_{EU15t}/P_{it})$, $q^T = ln(P^T_{EU15t}/P^T_{it})$, $q^{NT} = ln(P^{NT}_{EU15t}/P^{NT}_{it})$, $q^R = ln(P^R_{EU15t}/P^R_{it})$ where P_{EU15t} is the price level of 15 European countries' average. $c = ln(C_{it}/C_{EU12t}), y = ln(Y_{it}/Y_{EU12t})$ where C_{EU12t}, Y_{EU12t} are geometric averages of C, Y over 12 eurozone countries. Data period is from 2000 to 2019 and data are at annual frequency. Results from using consumption per capita are in the appendix.

gets more expensive by 0.14% than other countries. In addition, we can see that q^R is the one that has significant β^R estimates in both regressions, and the estimated sizes are very large.

Given that the time-series pattern is stronger, I conduct regression-based decomposition again for two regressions for time-series variations. The right panel in Figure 1.5 shows the results. In both cases, while the tradable real exchange rate component shows positive correlations, nontradables and the rent real exchange rate show negative correlations. In particular, the red bar is the biggest even though the γ^R is only 0.16. This shows how important the rent real exchange rate is important in understanding the Backus-Smith correlation.

1.3 Model: Inelastic Housing Supply and Real Exchange Rates

Motivated by the empirical evidence that suggests the crucial role of housing rent, to explore its role in the international business cycles I construct a standard two-country DSGE model and extend it in several dimensions. First, I assume that both the home and

Table 1.4: Backus-Smith Correlation Regressions

Cross-section					
		$\bar{q}$	$\bar{q}^T$	$\bar{q}^{NT}$	$\bar{q}^R$
Country Average	$\bar{c}$	0.03	0.00	0.03	0.07
		(0.02)	(0.02)	(0.02)	(0.05)
	R^2	0.07	0.01	0.07	0.09
	N	12	12	12	12
		q	q^T	q^{NT}	q^R
Time-FE	c	0.02	0.00	0.03	0.07
		(0.02)	(0.02)	(0.02)	(0.06)
	R^2	0.07	0.01	0.06	0.09
	N	240	240	240	240

Time-series					
		Δq	Δq^T	Δq^{NT}	Δq^R
Growth Rate	Δc	-0.14**	0.02	-0.15***	-0.53***
		(0.07)	(0.05)	(0.06)	(0.23)
	R^2	0.03	0.00	0.01	0.06
	N	240	240	240	240
		q	q^T	q^{NT}	q^R
Country-FE	c	-0.16**	0.10*	-0.21	-0.72**
		(0.07)	(0.06)	(0.14)	(0.37)
	R^2	0.09	0.05	0.06	0.17
	N	240	240	240	240

$q = ln(P_{EU15t}/P_{it})$, $q^T = ln(P^T_{EU15t}/P^T_{it})$, $q^{NT} = ln(P^{NT}_{EU15t}/P^{NT}_{it})$, $q^R = ln(P^R_{EU15t}/P^R_{it})$ where P_{EU15t} is the price level of 15 European countries' average. $c = ln(C_{it}/C_{EU12t}), y = ln(Y_{it}/Y_{EU12t})$ where C_{EU12t}, Y_{EU12t} are geometric averages of C, Y over 12 eurozone countries. Data period is from 2000 to 2019 and data are at annual frequency. All standard error are computed using a panel-corrected standard errors method under the assumption of period correlation (cross-sectional clustering). Parentheses below estimates include standard deviations. * means 10% significance, ** means 5% significance, *** means 1% significance.

a foreign country have tradable, nontradable, and construction sectors. In addition, there is a distribution margin for consuming retail tradable goods, as in Berka et al. (2018). Second, I incorporate housing in the model following Davis and Heathcote (2005). Each country needs to accumulate housing stock so that they can obtain housing services from it. Importantly, to produce houses, they need to use residential-zoned land as a production input, which is under fixed supply. In addition, it takes one period to build houses. Lastly, I assume an incomplete market between two countries so that the two countries can insure their risks only through noncontingent bonds, as in Corsetti et al. (2008). Because I primarily use data on eurozone countries, which use the same currency (euro), I have not modeled any monetary component in the model. I present only the home country, and the foreign economy is same as the home country because this model has a symmetric structure.

1.3.1 Households

The home country's infinitely lived representative household maximizes the life-time utility defined as

$$U = \sum_{t=0}^{\infty} E_t[\beta^t(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\psi}}{1+\psi})], \quad \beta < 1, \tag{1.5}$$

where C_t in Equation 1.5 is the aggregate consumption bundle, and N_t is the home labor supply. Note that the labor disutility function is separable from the consumption utility function.[12]

When optimizing this lifetime utility, the representative household faces the following budget constraints:

$$s.t. \quad P_tC_t + D_{t+1}/R_{t+1} + P_{RI,t}I_{RI,t} = W_tN_t + P_{R,t}H_{t-1} + P_{l,t}l_t + D_t - \frac{\phi^c}{2}D_{t+1}^2, \tag{1.6}$$

$$H_t = (1-\delta)H_{t-1} + I_{RI,t}. \tag{1.7}$$

P_t means the price of the aggregate consumption bundle, which can be interpreted as an aggregate price index. Households can save by investing in the noncontingent international bond market. D_{t+1} represents the amount of bond purchased by the household, where R_{t+1} is the return on it. $I_{RI,t}$ implies the residential investment, and it enters into the law of motion of housing capital. H_t denotes the housing capital which will be available in time $t+1$. W_t represents the wage earned by supplying labor, H_{t-1}

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[12] While many papers studying real exchange rate dynamics, such as Chari et al. (2002), use a separable utility like my model, others, such as Karabarbounis (2014), use non-separablility between consumption and leisure to generate the Backus-Smith correlation even under a complete market. This breaks the one-to-one relationship between relative price and consumption under a complete market, whereby leisure also affects marginal utilities.

means the housing stock they currently have, $P_{R,t}$ is the housing rent, and l_t and $P_{l,t}$ imply the residential-zoned land supply by the household and the price of it.[13] Lastly, when households save and borrow through noncontingent international bonds, there is a convex cost associated with owning them, which is denoted as $\frac{\phi^c}{2}D_{t+1}^2$. This method is one of those suggested by Schmitt-Grohé and Uribe (2003) to guarantee a unique steady state in a two-country model.

The aggregate consumption bundle is defined as the CES aggregation of a housing service $(C_{R,t})$ and non-housing consumption bundle $(C_{NR,t})$, as in equation (1.8).

$$C_t = (\gamma_R^{\frac{1}{v}} C_{R,t}^{1-\frac{1}{v}} + (1-\gamma_R)^{\frac{1}{v}} C_{NR,t}^{1-\frac{1}{v}})^{\frac{v}{v-1}}. \tag{1.8}$$

Housing service is assumed to be proportional to the housing stock (H_t), which implies that $C_{R,t} = H_{t-1}$. v is the elasticity of substitution between housing service and the non-residential consumption bundle and γ_R is the relative weight of housing service in the aggregator.

The non-residential consumption bundle is defined over a tradable consumption bundle $(C_{T,t})$ and nontradable consumption bundle $(C_{NT,t})$, as in equation (1.9).

$$C_{NR,t} = ((1-\gamma_{NT})^{\frac{1}{\theta}} C_{T,t}^{1-\frac{1}{\theta}} + \gamma_{NT}^{\frac{1}{\theta}} C_{NT,t}^{1-\frac{1}{\theta}})^{\frac{\theta}{\theta-1}}. \tag{1.9}$$

θ is the elasticity of substitution between tradable consumption bundle $(C_{T,t})$ and nontradable consumption $(C_{NT,t})$, while γ_{NT} is the relative weight of nontradable consumption. The tradable consumption bundle again has additional layers, as in equation (1.10):

$$C_{T,t} = (\omega_H^{\frac{1}{\lambda}} C_{H,t}^{1-\frac{1}{\lambda}} + (1-\omega_H)^{\frac{1}{\lambda}} C_{F,t}^{1-\frac{1}{\lambda}})^{\frac{\lambda}{\lambda-1}}. \tag{1.10}$$

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[13] The constant land supply assumption is standard in the literature. (Davis and Heathcote 2005, Favilukis et al. 2012, Kaplan et al. 2020) The assumption is that government zoned land as residential-zoned land through an administrative procedure and provides that to households. Also, the deconstruction of old houses can offer new available land to households.

$C_{T,t}$ is defined as an aggregation of a (retail) home-tradable consumption bundle $(C_{H,t})$ and a (retail) foreign-tradable consumption bundle $(C_{F,t})$. ω_H is the relative weight of $C_{H,t}$, and ω_H larger than 0.5 implies homebias in tradable consumption. λ is the elasticity of substitution between the home tradable consumption bundle and foreign tradable consumption bundle.

Both (retail) home and foreign-tradable consumption bundles are defined as the aggregation between each wholesale tradable good ($X_{H,t}$, $X_{F,t}$) and distribution margin services ($V_{H,t}$, $V_{F,t}$), as in equation (1.11) and equation (1.12).

$$C_{H,t} = ((1-\chi_{NT})^{\frac{1}{\phi}} X_{H,t}^{1-\frac{1}{\phi}} + \chi_{NT}^{\frac{1}{\phi}} V_{H,t}^{1-\frac{1}{\phi}})^{\frac{\phi}{\phi-1}}, \tag{1.11}$$

$$C_{F,t} = ((1-\chi_{NT})^{\frac{1}{\phi}} X_{F,t}^{1-\frac{1}{\phi}} + \chi_{NT}^{\frac{1}{\phi}} V_{F,t}^{1-\frac{1}{\phi}})^{\frac{\phi}{\phi-1}}. \tag{1.12}$$

In other words, for households to consume the traded goods, this requires the use of nontradable services.[14] This distribution margin is justified by the distribution cost incurred by local input, such as labor for transporting goods. $\chi_{NT,t}$ defines the relative importance of the distribution margin and ϕ is the elasticity of substitution between tradable goods and the distribution margin.

This consumption structure implies the aggregate price index P_t and non-resident consumption price index as $P_{NR,t}$, as in equation (1.13) and equation (1.14).

$$P_t = (\gamma_R P_{R,t}^{1-v} + (1-\gamma_R) P_{NR,t}^{1-v})^{\frac{1}{1-v}}, \tag{1.13}$$

$$P_{NR,t} = ((1-\gamma_{NT}) P_{T,t}^{1-\theta} + \gamma_{NT} P_{NT,t}^{1-\theta})^{\frac{1}{1-\theta}}. \tag{1.14}$$

Note that $P_{R,t}$ is the housing rent, which is my major focus. Equation (1.13) and equation (1.14) imply that the aggregate price level is a weighted average of the price of the tradable, the nontradable, and the rent.

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[14] The importance of the distribution margin has been examined in numerous studies such as Burstein et al. (2003) and MacDonald and Ricci (2005). This is an important model component for matching the behavior of tradable real exchange rates in the data.

The tradable consumption bundle price index $P_{T,t}$ is defined as in equation (1.15), while the non-tradable consumption bundle price $P_{NT,t}$ is just the price of nontradable goods.

$$P_{T,t} = (\omega_H \tilde{P}_{H,t}^{1-\lambda} + (1-\omega_H)\tilde{P}_{F,t}^{1-\lambda})^{\frac{1}{1-\lambda}}. \tag{1.15}$$

Because I assume the presence of the distribution margin, I know that the retail price of home tradable $\tilde{P}_{H,t}$ and foreign tradable $\tilde{P}_{F,t}$ should contain distribution margins. These are well denoted in equations (1.16) and (1.17).[15]

$$\tilde{P}_{H,t} = ((1-\chi_{NT})P_{H,t}^{1-\phi} + \chi_{NT}P_{NT,t}^{1-\phi})^{\frac{1}{1-\phi}}, \tag{1.16}$$
$$\tilde{P}_{F,t} = ((1-\chi_{NT})P_{F,t}^{1-\phi} + \chi_{NT}P_{NT,t}^{1-\phi})^{\frac{1}{1-\phi}}. \tag{1.17}$$

These price indices are combined to generate sectoral real exchange rates, as follows:

$$Q_t = \frac{P_t^*}{P_t} \quad (q_t = log(Q_t)), \tag{1.18}$$
$$Q_t^T = \frac{P_{T,t}^*}{P_{T,t}} \quad (q_t^T = log(Q_t^T)), \tag{1.19}$$
$$Q_t^{NT} = \frac{P_{NT,t}^*}{P_{NT,t}} \quad (q_t^{NT} = log(Q_t^{NT})), \tag{1.20}$$
$$Q_t^R = \frac{P_{R,t}^*}{P_{R,t}} \quad (q_t^R = log(Q_t^R)). \tag{1.21}$$

1.3.2 International Asset Market

I assume an incomplete market so that both countries' households can insure themselves against the shock only via noncontingent bonds. As famously noted by Corsetti et al. (2008), introducing an incomplete market generates wealth effects from the tradable sector productivity shock. Of the methods for ensuring a stationary equilibrium in a two-country incomplete market model suggested by Schmitt-Grohé and Uribe (2003), I

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[15] This implies that not only the terms of trade ($\frac{P_t^F}{P_t^H}$) but also the nontradable real exchange rate ($q_t^{NT} = \frac{P_{N,t}^*}{P_{N,t}}$) affects the tradable real exchange rate (q_t^T).

chose the convex portfolio adjustment cost. Assuming symmetric economies, optimality conditions for international saving and borrowing D_t, D_t^* is as in equation (1.22).

$$R_t = E_t[\frac{1}{\beta}(\frac{C_t^{-\sigma}}{C_{t+1}^{-\sigma}})(\frac{P_{t+1}}{P_t})(\phi^c D_{t+1}+1)] = E_t^*[\frac{1}{\beta^*}(\frac{(C_t^*)^{-\sigma}}{(C_{t+1}^*)^{-\sigma}})(\frac{P_{t+1}^*}{P_t^*})(\phi^c D_{t+1}^*+1)]. \quad (1.22)$$

Once I ignore the ϕ^c, which will be calibrated as tiny, I see that the relationship between relative consumption and the real exchange rate holds under expectation, not state by state. This allows me to deviate from perfect risk sharing and provides an environment for generating the negative Backus-Smith correlation.

1.3.3 Intermediate Good Production

Moving toward to the production side, I have three sectors—tradable, nontradable, and construction—as in equations (1.23), (1.24), and (1.25).

$$Y_{H,t} = A_{H,t} N_{H,t}^{\alpha^H}, \quad (1.23)$$

$$Y_{N,t} = A_{N,t} N_{N,t}^{\alpha^N}, \quad (1.24)$$

$$Y_{CR,t} = A_{CR,t} N_{CR,t}^{\alpha^{CR}}. \quad (1.25)$$

There are no adjustment costs for labor reallocation, and I assume there is no non-residential capital for brevity. The foreign country has a symmetric production structure.

Each sector has its own sectoral productivity. I assume they are AR(1) processes, as follows:

$$ln(A_{H,t}) = ln(\bar{A}_H) + \rho_H(ln(A_{H,t-1}) - ln(\bar{A}_H)) + \epsilon_{H,t}, \quad (1.26)$$

$$ln(A_{N,t}) = ln(\bar{A}_N) + \rho_N(ln(A_{N,t-1}) - ln(\bar{A}_N)) + \epsilon_{N,t}, \quad (1.27)$$

$$ln(A_{CR,t}) = ln(\bar{A}_{CR}) + \rho_{CR}(ln(A_{CR,t-1}) - ln(\bar{A}_{CR})) + \epsilon_{CR,t}. \quad (1.28)$$

1.3.4 Housing Construction

To construct new houses ($I_{RI,t}$), real estate developers in each country combine land and construction goods. τ implies the share of residential zoned-land for the housing production.

$$I_{RI,t} = Y_{CR,t}^{1-\tau} l_t^{\tau}. \tag{1.29}$$

The law of motion for housing stock is stated in equation (1.30). As is clear in the law of motion, it takes one period to build new houses, and new houses become available for consumption only after one period.[16] In addition, housings depreciate by δ_h per period. Later, in the calibration section, I show how δ_h is connected to the residential structure depreciation δ_s.

$$H_{t+1} = (1 - \delta_h)H_t + I_{RI,t}. \tag{1.30}$$

In my model, $Y_{CR,t}$ is effectively the residential investment, which does not include the land component.[17] In addition, I only focus on residential buildings because I cannot observe commercial rents in the data. The construction sector in my model is a residential building construction sector.

I assume that land is supplied in the fixed amount every period. Following Davis and Heathcote (2005), I do not attempt to model the supply of residential-zoned land, which requires consideration of infrastructure development and the zoning process. I assume that through deconstruction of existing buildings and the government's new zoning

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[16] For a model with longer periods to build houses and its impact on macro variables, refer to Bahadir and Mykhaylova (2014).

[17] Davis and Heathcote (2005) allow the real estate developer to combine manufacturing goods, services, and construction goods to generate residential investment. On the other hand, Kaplan et al. (2020) model a housing sector in which households combine lands and labor to produce housing.

assignment, a constant amount of residential zoned land is supplied.

$$l_t = \bar{l}. \tag{1.31}$$

The Role of Land in Housing Supply Elasticity The role of land in housing production is easy to see if I fix the price of construction goods. If we assume that $P_t^{CR} = \bar{P}^{CR}$ and $l = \bar{l}$, the real estate developer's first-order conditions imply the following:

$$Y_t^{CR} = \left(\frac{\bar{P}^{CR}}{l^{\tau}(1-\tau)P_t^{RI}}\right)^{-\frac{1}{\tau}}. \tag{1.32}$$

Substituting this in the production function of the real estate developer, I can calculate the housing supply function as below.

$$I_t^H = (P_t^H)^{\frac{1-\tau}{\tau}}(1-\tau)^{\frac{1-\tau}{\tau}}(\bar{P}^{CR})^{\frac{\tau-1}{\tau}}\bar{l}. \tag{1.33}$$

This implies the following housing supply elasticity:

$$\frac{\partial ln(I^H)}{\partial ln(P^H)} = \frac{1-\tau}{\tau}. \tag{1.34}$$

This implies that the larger the land input share, the more housing supply elasticity decreases, which implies a steeper supply curve. Note that this is the supply for the new housing flow, not the total housing service supply. For the housing service supply, in the short run, the elasticity is 0 because it takes one period to build a house. In addition, depending on δ, new housing flows might be very small compared to the total housing stock. This makes aggregate housing service supply even more inelastic.

1.3.5 Relative Output and Relative Consumption

To study the Balassa-Samuelson effect and the Backus-Smith correlation, I need to define the relative real output per capita (y_t) and relative real consumption growth (Δc_t) in the model. First, I define an output (per capita) (Y_t) as follows:[18]

$$Y_t = P_t C_t + P_{RI,t} I_{RI,t} + P_{H,t}(Y_{H,t} - C_{H,t}) - P_{F,t}(Y^*_{F,t} - C_{F,t}). \tag{1.35}$$

Then, I construct relative output per capita y as follows:

$$y_t = ln(Y_t) - ln(Y^*_t). \tag{1.36}$$

Also, I use the home country aggregate consumption bundle as a numeraire by normalizing $P_t = 1$. For relative consumption growth (Δc_t), I use each country's aggregate consumption as follows.

$$\Delta c_t = \Delta(ln(C_t) - ln(C^*_t)). \tag{1.37}$$

1.3.6 Equilibrium of the Model and Solution Methods

Since the equilibrium definition of my model is very standard, for the sake of brevity I skip the definition of model equilibrium. The model is solved using the first-order approximation with Dynare.

1.4 Quantitative Analysis: Model-simulated Real Exchange Rates

In this section, by using the structural model, I provide a more detailed quantitative analysis of the relationship between housing and the real exchange rate empirically examined in Section 2. A proper examination of the relationship between housing and the real exchange rate requires a general equilibrium perspective. Given this, I solve and simulate a model-produced sample with the same dimensions as the data. My simulation procedure closely follows the strategy of Berka et al. (2018). Although my model has only two countries, I can map the simulated data onto the empirical data by

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[18] Note that $P_{H,t} = P^*_{H,t}$ and $P_{F,t} = P^*_{F,t}$. In my model, I do not assume any other frictions such as variable mark-up. The law of one price holds for every good in the model.

treating the model home country as the relevant EU country, and assuming the model foreign country as the EU average. This gives me simulated panel data on 8 countries for a 20-year period.[19] Using these simulated data, I replicate the empirical analysis I did in the earlier section and explore the role of the housing sector in real exchange rate determination.

1.4.1 Model Calibration

To render my simulation analysis quantitatively realistic, proper calibrations of both on the model parameters and shock processes are important. Note that my calibration strategy targets to match the housing-related moments and productivity shock processes are directly from data. Empirical moments of the real exchange rates are not targeted in my calibration. Table 1.5 provides model calibration details.

Non-housing Parameters The upper panel of Table 1.5 shows my calibration for non-housing parameters. I use $\beta = 0.99$, assuming quarterly frequency in the model, and match the long-run real interest rate among eurozone countries. For the coefficient of relative risk aversion and Frisch elasticity of labor supply, I set $\sigma = 2$ and $\psi = 1$, which are standard values used in DSGE modeling. For the relative weight between the tradable and nontradable, I set $\gamma^{NT} = 0.4$ to match the expenditure shares of each in the data. The elasticity of substitution between the tradable and the nontradable is set as $\theta = 0.7$, following Berka et al. (2018). Given the presence of a distribution margin that generates home bias by itself and the homogeneity of eurozone countries, I set $\omega^H = 0.5$, which implies no home bias in the retail level. Elasticity between the home tradable and the foreign tradable (which is also called trade elasticity) is set as $\lambda = 8$, following Berka et al. (2018). Trade elasticity has been known to be small in the short run, at lower than 1,

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[19] For the model simulation, I use only eight eurozone countries, which provide the industry-level productivity data in EUKLEMS 2023. These are Austria, Belgium, Spain, Finland, France, Germany, Italy, and the Netherlands. The calibration will also be based on these countries.

Table 1.5: Model Calibration

Parameters	**Variable**	**Value**	**Reference**
1. Non-Housing Parameters			
Household			
Discount factor, yearly	β	0.99	
Relative risk aversion	σ	2	
Macro Frisch elasticity	ψ	1	
Non-Residential Consumption Aggregator			
Non-Tradable weight	γ^{NT}	0.4	Berka et al. (2018)
ES between traded and non-traded	θ	0.7	Berka et al. (2018)
Tradable Consumption Aggregator			
Home-bias	ω^{H}	0.5	No Homebias
ES between retail H and F	λ	8	Corsetti et al. (2010)
Distribution Margin			
Distribution Margin Weight	χ^{NT}	0.32	Goldberg and Campa (2010)
ES betwen retail and distribution service	ϕ	0.25	Berka et al. (2018)
Production			
Elasticity of Labor	α	1	Berka et al. (2018)
International Financial Market			
Portfolio Adjustment Cost	ϕ^{C}	0.001	Benigno and Thoenissen (2008)
2. Housing Parameters			
Residential Consumption			
Housing Service Weight	γ^{R}	0.25	
ES between housing and non-housing	v	0.85	Davidoff and Yoshida (2013)
Residential Building Production			
Land Input Share	τ	0.35	Combes et al. (2021)
Depreciation Rate of Residential Structure	δ^{S}	0.0037	

and large in long run, at larger than 1.[20]. Because my trade elasticity, λ, is the elasticity between the retail home and foreign goods and both of these retail contain the domestic distribution margin, it is not exactly the same as the trade elasticities used in other research.[21] For weights for the distribution margin, I use the estimates of Goldberg and Campa (2010) and calculate the average of eight eurozone countries' distribution margin for household consumption. This implies $\chi^{NT} = 0.32$. Lastly, regarding the portfolio adjustment cost, following Benigno and Thoenissen (2008), I set ϕ^{C} equal to 0.001.[22]

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[20] Corsetti et al. (2008) use 0.5 for their first case and 4 for their second case. Cross-country estimates imply elasticity larger than 1 (Broda and Weinstein 2006), while the time-series estimates based on the response of import quantities to the exchange rate suggests elasticity less than 1 (Feenstra et al. 2018, Amiti et al. 2022)

[21] Corsetti et al. (2010) show that this implies a lower elasticity of substitution between traded wholesale goods, due to the presence of distribution services.

[22] Rabanal and Tuesta (2010) provides estimates of 0.007 for quarterly data, but there is no big difference in model-simulated results.

Housing Parameters The lower panel of Table 1.5 shows my calibration for housing parameters. Calibrating housing-related parameters is difficult, and papers in the literature use different values. These parameters include the weight of residential consumption (i.e., housing service) in the aggregate consumption CES aggregator (γ^R), the elasticity of substitution between residential consumption and non-residential consumption (v), the land input share in the housing production function (τ), and the residential structure depreciation rate (δ^S).

Several papers provide information on these parameters. For example, Combes et al. (2021) show that τ in France is roughly 35% using detailed French housing construction data, which include house prices, land sizes, and land prices. However, papers that study the US housing market, such as Kaplan et al. (2020) and Favilukis et al. (2012), use 0.25 and 0.1 for τ, which are very different from 0.35. Also, for v, Davidoff and Yoshida (2013) suggest that this should range between 0.4 and 0.9 using aggregate time-series data under a non-homothetic preference assumption. However, this is contradicted by Davis and Ortalo-Magne (2021), who show that the housing rent expenditure share is constant across regions over time and suggest using Cobb-Douglas specifications.

Given the absence of consensus on these parameters, I decided to use the strategy of Davis and Heathcote (2005). While I use parameter values that are in ranges suggested by the literature, I choose parameter values that replicate the housing-related empirical moments of eight countries in the steady state. For example, Davis and Heathcote (2005) choose parameters that match empirical moments such as households' working hours, the value of residential structure capital over GDP, and the capital and labor input share in each sector.

I target five empirical moments related to the housing sector: (1) the value of residential structure capital stock over GDP ($RCOY$), (2) residential investment over GDP ($RIOY$), (3) share of construction sector labor over total labor ($NConRatio$), (4) household expenditure share on housing rents (REW), and (5) new housing construction flow over housing stock ($HFoHS$).

This requires that I identify proper model counterparts for those empirical moments. First, for the residential structure capital over GDP ($RCOY$), I define the net stock of residential structure, S, as follows under the assumption that residential structure depreciates by δ_s per period. Under the steady state, I can define S as follows:[23]

$$S = \sum_{k=1}^{\infty}(1-\delta_s)^k Y_{CR_{t-k}}. \tag{1.38}$$

In the steady state, $P_{CR}S = \frac{P_{CR}Y_{CR}}{\delta_s}$ and $P_{RI}H = \frac{P_{RI}I_{RI}}{\delta_h}$ hold from the law of motion for housing stock and residential capital structure. Also, $P_{RI}I_{RI} = \frac{P_{CR}Y_{CR}}{(1-\tau)}$ holds from the optimal condition of the real estate developer. Combining all these, under the steady state, the following holds:[24]

$$\frac{P_{CR}S}{P_{RI}H} = \frac{(P_{CR}Y_{CR})/\delta_s}{P_{CR}Y_{CR}/((1-\tau)*\delta_h)} = \frac{(1-\tau)*\delta_h}{\delta_s} = \frac{(1-\tau)*(1-(1-\delta_s)^{1-\tau})}{\delta_s}. \tag{1.39}$$

Consequently, residential structure capital stock over GDP $(RCOY)$ in my model will be defined as

$$RCOY = \frac{(1-\tau)*(1-(1-\delta_s)^{1-\tau})}{\delta_s}\frac{P_{RI}H}{PY}. \tag{1.40}$$

Second, I define the residential investment over GDP $(RIOY)$ as follows:

$$RIOY = \frac{P_{CR}Y_{CR}}{PY}, \tag{1.41}$$

because Y_{CR} is the residential investment in my model. Third, the share of labor in the construction sector over total labor $(NConRatio)$ is defined as

$$NConRatio = \frac{N_{CR}}{N_H + N_N + N_{CR}}. \tag{1.42}$$

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[23] Land is not included in residential capital stock, according to the most recent national accounting system.

[24] As explained by Davis and Heathcote (2005), $1-\delta_h = (1-\delta_s)^{1-\tau}$.

It is especially important to match this moment because it determines the size of the effect of the construction sector productivity shock on the aggregate economy via the labor market in the model. Fourth, the household expenditure weight on housing rents (REW) is defined as follows:

$$REW = \frac{P_R C_R}{PC} = \frac{P_R H}{PC}, \tag{1.43}$$

under the assumption that housing service flow is proportional to the housing stock.

Lastly, I define new housing flow over housing stock ($HFoHS$) in quantities as follows:

$$HFoHS = I_H / H. \tag{1.44}$$

To replicate these moments, I set $\gamma^R = 0.25$. In addition, I set elasticity of substitution between housing and non-housing consumption as $v = 0.85$. This is also chosen to match the increasing patterns of rent expenditure weights over time in all eurozone countries in Figure 1.2. For the land input share in housing production, in the end, I set $\tau = 0.35$ following Combes et al. (2021). This is much larger than the values used by Kaplan et al. (2020) or Favilukis et al. (2012), who study the US housing market. However, it is well known that eurozone countries have substantially lower housing supply elasticities compared with that of the US. In addition, while there is large heterogeneity across eurozone countries' housing supply elasticities,[25] a recent estimate suggests that France's housing supply elasticity is in the middle among the eurozone countries. This again makes using $\tau = 0.35$ proper. Last, for the residential structure depreciation rate, I use $\delta^S = 0.0037$, which implies a 1.48% depreciation rate every year.

Table 1.6 shows how my model performs in terms of replicating these moments of

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[25] There is substantial heterogeneity across countries regarding the long-run price elasticity of the housing supply. Caldera and Åsa Johansson (2013) estimate elasticities across countries. European countries such as Austria (0.234), Belgium (0.315), Finland (0.988), France (0.363), Germany (0.428), Ireland (0.631), Italy (0.258), the Netherlands (0.186), and Spain (0.452) show much lower estimates than the US (2.014)

average of eurozone countries in the steady state. As can be seen in the table, the model successfully replicates most of the moments. In particular, it replicates the fact that housing is very inelastically supplied ($HFoHS$), the housing rent accounts for a substantial portion of the aggregate expenditure (REW), and the residential construction sector accounts for a small portion of the aggregate labor market ($NConRatio$).

Table 1.6: Housing Sector Moments: Data vs Model Steady State

	Data	**Model**
Supply side		
Residential Capital over GDP ($RCOY$)	1.457	1.403
Residential Investment over GDP ($RIOY$)	0.029	0.021
Labor Share of Construction Sector ($NConRatio$)	0.017	0.025
Housing Flow over Housing Stock ($HFoHS$)	0.009	0.009
Demand side		
Housing Rent Expenditure Share (REW)	0.161 (0.212)	0.170
Tradable Expenditure Share	0.516	0.497
Nontradable Expenditure Share	0.328	0.331

Data period for 8 Eurozone countries is (2000-2019). Note that the construction sector in my model is effectively the residential construction sector, not the total construction sector. According to the European Construction Industry Federation, 50.4% of total construction is estimated to be residential construction in 2022. So, I use the half of the value of the corresponding construction sector for construction sector-related variables when I match the empirical moments of the construction sector in my model.

Sectoral Productivity Shocks In my simulation, I use sectoral productivity shocks as the main drivers of international business cycles. To estimate each sector's productivity, I closely follow the estimation procedure used by Berka et al. (2018) and extend their estimates up to 2019. The appendix details the procedure I used to estimate these processes. Here, I provide a brief description.

To estimate sectoral productivity shock processes, I use the GGDC 1997 database and EUKLEMS 2023. GGDC 1997 provides all industries' productivity levels.[26] Then, for each country, by dividing each industry's productivity by that of the geometric average of the 11 European countries that provide productivity data in EUKLEMS 2023, I calculate each industry's relative productivity level against that of the average of 11 European

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[26] This is a given industry's productivity relative to that industry in the US. But this cancels out if I divide that productivity by that of the Europe 11 average (relative to the US).

countries. Then, using the EUKLEMS 2023 database, which provides the industry-level growth rate for each country, I calculate the productivity growth rate of each industry relative to that of 11 European countries' average.

By combining these relative levels and relative growth rates, I can construct panel data for each industry's relative productivity of each country against the 11 European countries' average. Lastly, by classifying these industries into tradable, nontradable, and construction sectors, and by averaging with the value-added of each sector as a weight, I obtain panel data for sectoral productivity levels (tradable sector, nontradable sector, and construction sector) relative to those of the 11 European countries' average.[27]

The log of these estimated relative sectoral productivities are presented in Figure 1.6. We can see that both the tradable and construction sectors have larger cross-country and time-series variations than that of the nontradable sector.

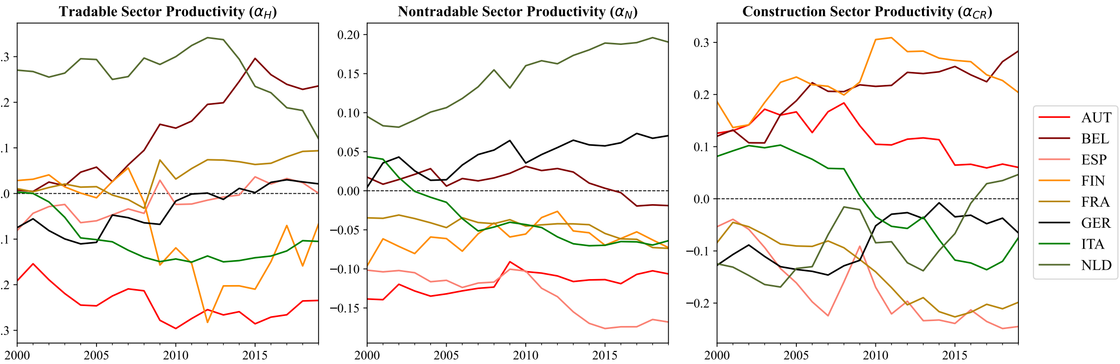

Figure 1.6: Sectoral Productivities

Given this panel data, I estimate sectoral productivity shock processes for each country. Note that what I have estimated are the productivity level of each sector of a certain country relative to that of the 11 European countries' average. Thus what I will estimate are the following relative sectoral productivity shock processes, where $\alpha_{Y,jt} = ln(\frac{A_{Y,jt}}{A_{Y,EUt}})$

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[27] The industry classifications of EUKLEMS are a bit different from those of GGDC 1997 database. However, they are closely related. Consequently, as I explain in detail in appendix, I generated a sectoral concordance table and use that accordingly. I have a total 12 tradable industries, 9 nontradable industries, and 1 construction industry.

for $Y \in \{H, N, CR\}$. Data are from 2000 to 2019 at annual frequency.

$$\alpha_{H,it} - \bar{\alpha}_H = \rho_H(\alpha_{H,it-1} - \bar{\alpha}_H) + \epsilon_{h,it},$$
$$\alpha_{N,it} - \bar{\alpha}_N = \rho_N(\alpha_{N,it-1} - \bar{\alpha}_N) + \epsilon_{n,it},$$
$$\alpha_{CR,it} - \bar{\alpha}_{CR} = \rho_{CR}(\alpha_{CR,it-1} - \bar{\alpha}_{CR}) + \epsilon_{cr,it}.$$

Note that while my data are at annual frequency, the model simulation will be conducted at quarterly frequency, so I convert estimated parameters to quarterly frequencies. In particular, I take the quadratic root of ρ to render it at quarterly frequency. Also, the variance-covariance matrix of the shock processes is estimated under the assumption that the shock is i.i.d at quarterly frequency. In addition, I allow covariance relationships among the productivity processes of all sectors and countries. Table 1.7 reports the results of the estimation. Several interesting patterns emerge. First, as the productivity itself is defined as relative productivity, it is natural that the cross-country averages of $\alpha_H, \alpha_N, \alpha_{CR}$ are close to 0. Also, the relative productivities of both the tradable sector and construction sector show much larger cross-sectional and time-series variations compared with those of the nontradable sector. This aligns with estimates from previous research.

Table 1.7: Estimated Sectoral TFP Processes

	A. Cross-section			B. Time-series					
	Mean values			AR(1) Coefficients			Standard Deviations		
	$\bar{a}_H$	$\bar{a}_N$	$\bar{a}_{CR}$	ρ_H	ρ_N	ρ_{CR}	σ_H	σ_N	σ_{CR}
AUT	-0.241	-0.118	0.119	0.918	0.894	0.966	2.367	0.936	2.344
BEL	0.135	0.011	0.205	0.983	0.976	0.971	2.700	0.907	2.017
ESP	-0.018	-0.132	-0.172	0.873	0.987	0.945	2.409	0.951	3.499
FIN	-0.080	-0.060	0.231	0.939	0.769	0.946	6.198	1.262	2.804
FRA	0.040	-0.046	-0.139	0.925	0.997	0.989	2.716	0.583	1.862
GER	-0.034	0.046	-0.080	0.973	0.905	0.962	2.198	1.206	2.228
ITA	-0.106	-0.036	-0.003	0.951	0.959	0.987	1.326	0.708	2.402
NLD	0.264	0.145	-0.080	0.990	0.986	0.986	2.919	1.153	3.359
AVG	-0.005	-0.024	0.010	0.944	0.934	0.969	2.854	0.963	2.564

Simulation Procedure Given the calibrated sectoral productivity shock processes and the model calibration explained above, I simulate the eight countries whose productivity data are available. The simulated periods are 80 quarters, as in the data (2000-2019). In my simulation, the core assumption is that each of these eight countries is a home country and the eurozone average is a foreign country. Under this assumption, because the sectoral productivity shock processes are estimated in units of each country's sectoral productivity relative to that of the eurozone average, the simulated shocks will only be fed into the home country, while the foreign country does not receive any shocks during the simulation. Only the transmissions of home country shocks affect the foreign country. After each simulation, I collect only the home country's aggregate real exchange rates, sectoral real exchange rates, relative real GDP per capita, and relative real consumption. This gives me simulated panel on such variables, and this simulated panel is comparable to what I have in actual data.

Given the panel data from each simulation, I replicate the empirical analysis that I performed in the empirical section, and I repeat the whole procedure 500 times. This repetition gives me the distributions of the parameters of interest, such as cross-sectional and time-series variations of the real exchange rates, Balassa-Samuelson regression coefficients, and Backus-Smith regression coefficients. Such distributions will be compared with actual data estimates. Also, this procedure will be repeated in a different calibration environment to understand how the housing market affects real exchange rate dynamics.

One thing to note is that were during this simulation, none of the empirical moments of the real exchange rate were targeted. This simulation exercise should be understand as exploring how far we can go in explaining the role of housing rent in the real exchange rate by combining the standard model of the housing market and the two-country international business cycle model given the productivity processess externally calibrated from the dataset.

1.4.2 Simulation Result: Model-generated Real Exchange Rates

In this subsection, I provide the simulation results. Following the same order as in the empirical section, I present results in the order of cross-section and time-series variations of RER, the Balassa-Samuleson effect, and the Backus-Smith correlation.

1.4.2.1 Housing and Variations of RER

Table 1.8 compares cross-section and time-series variations of model-generated real exchange rates under different calibrations with those of the actual data. While the upper panel provides the estimates for cross-sectional variations, the lower panel provides estimates for time-series variations.

Table 1.8: Simulated Cross-sectional and Time-series Variations of RER

	(1) **Data**	(2) **Bond Baseline**	(3) **Arrow-Debreu Baseline**	(4) **Arrow-Debreu** ($\tau = 0.01$)	(5) **Arrow-Debreu** ($\delta = 0.99$)	(6) **Arrow-Debreu** (τ=0.01, δ=0.99)	(7) **Arrow-Debreu** $(7) + (\bar{A}_j^{CR} / \bar{A}_{EU}^{CR} = 1)$
Cross-section							
$\sigma_j(q_{jt})$	0.121	0.085	0.053	0.059	0.057	0.067	0.053
$\sigma_j(q_{jt}^T)$	0.081	0.039	0.028	0.027	0.028	0.027	0.027
$\sigma_j(q_{jt}^{NT})$	0.149	0.121	0.087	0.084	0.085	0.084	0.083
$\sigma_j(q_{jt}^R)$	0.297	0.197	0.134	0.212	0.149	0.214	0.126
Time-series							
$\sigma_t(q_{jt})$	0.025	0.033	0.022	0.023	0.025	0.028	0.028
$\sigma_t(q_{jt}^T)$	0.022	0.018	0.013	0.013	0.013	0.012	0.012
$\sigma_t(q_{jt}^{NT})$	0.039	0.054	0.041	0.039	0.039	0.038	0.038
$\sigma_t(q_{jt}^R)$	0.072	0.038	0.009	0.053	0.050	0.075	0.076

Data and the Baseline Model Column (1) shows the variations of RER in the data and column (2) shows model-generated variations of RER under the baseline calibration. In the upper panel for the cross-section, we see that my baseline model can generate substantial cross-sectional variations. In addition, the relative sizes of variations of sectoral real exchange rates are also consistent with the data, and show the largest variations in q^R. Moving to the lower panel, we see that the baseline model produces substantial time-series variation, which is comparable to the data. However, one limitation is that my model generates much stronger variations in the nontradable real exchange rate than that of the rent real exchange rate compared with the data. This may be because my model does not have housing-finance component or any direct demand shock in the model. (e.g., cyclicality in fiscal policies in Greece or foreign capital inflows in Ireland.)

Role of a Wealth Effect To examine why my model generates such variations, first, I assume a complete market instead of an incomplete market and simulate the data. An incomplete market generates a deviation from perfect risk-sharing, which opens room for the wealth effect and demand shocks to drive international business cycles. For example, if the home country receives a tradable sector productivity shock and gets wealthier than the other, its aggregate demand increases more than that of the other country. This demand differential will make both consumption and price increase more than those of the other country, which results in real appreciation. The result is reported in column (3). Compared with column (2), we can see a large decrease in all variations. This proves that the wealth effect boosts the variations in all dimensions. The most striking change comes from the time-series variation of the rent real exchange rate, $\sigma_t(q^R_{jt})$, which drops from 0.038 to 0.009. This is a much larger drop compared with those of other sectoral real exchange rates and arises from the inelastic supply of housing service.

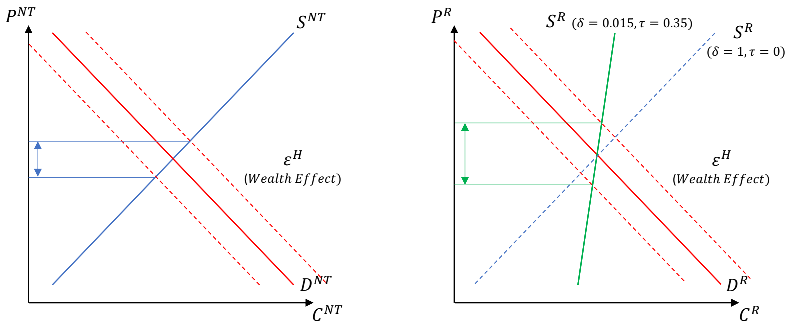

Figure 1.7: Wealth Effect on Nontradable (Left) and Housing Service (Right) Market

With Figure 1.7, this is easier to understand. If housing construction does not require land ($\tau = 0$), and housing flow in each period is equal to the housing stock ($\delta = 1$), the housing service supply curve would be same as that of the nontradables as the blue-dotted line show in the right panel of Figure 1.7. However, in my model, because of the large reliance on the land input, which is under fixed supply, even though the rent (P^R) increases, the supply cannot increase much. In addition, because housing service comes from the housing stock—which is much larger than the per period new housing flow—even P^R increases, and again supply cannot increase in a short time. This makes the housing service supply much more inelastic than that of the nontradable, which results in a steeper supply curve. Then, even though the home country has slightly higher demand than the foreign, the rent real exchange rate can respond very strongly. Once we assume a complete market, we eliminate such channel, which disproportionately reduces the time-series standard deviations of q^R.

Housing and Other Nontradables These characteristics of housing services also affect the responses of the nontradable sector and rent real exchange rate to productivity shocks on nontradable and construction sector. In my model, a positive nontradable sector productivity shock directly generates a large supply increase, and shifts the supply curve substantially. However, the rent real exchange rate does not shift much in response to the positive construction sector shock, as in Figure 1.8.

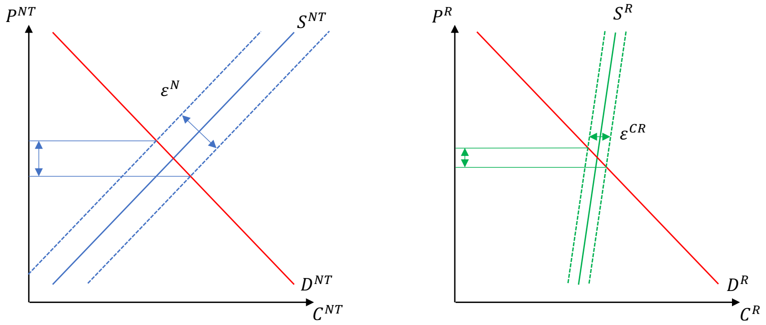

Figure 1.8: Productivity Shocks on the Nontradable (Left) and Housing Service (Right) Market

The intuition is again simple. Even though production in construction goods (e.g., cement) increases via the productivity increase, land to build on is limited.[28] Consequently, the housing quantity itself cannot increase much. In addition, given that the housing stock is much larger than the flow, any temporal relative productivity gain cannot increase the housing stock and housing services meaningfully in a short time. This explains why the rent real exchange rate time-series standard deviation is so low under a complete market.

This becomes clearer when we simulate the model with different values of τ and δ under a complete market. To examine the role of land, I change the land input share (τ) from 0.35 to 0.01 so that a housing construction no longer requires land, while still assuming a complete market. The result is reported in column (4). We can see that both cross-section and time-series variations of q^R increase once we set $\tau = 0.01$. With high τ, land dampens the effect of the construction sector productivity shock, as explained in Figure 1.8, but now the land is not used when $\tau = 0.01$. In addition, when τ is high, housing service is less exposed to the conventional Balassa-Samuelson hypothesis mechanism. This is because, though the positive tradable sector productivity shock may push up the wage, the marginal production cost of the housing service not only depends on wages but also the price of land, which is not exposed to the tradable sector productivity shock. However, once τ is set to 0.01, such dampening effect disappears, which generates the additional fluctuations.

Moving to the second characteristic, I change the depreciation rate (δ) from 0.00375 to 0.99 so that housing stock is not accumulated. This again renders housing service similar to other nontradables. Unlike in the case of τ, it increases only the time-series variations of the real exchange rate significantly. The larger stock compared with the small flows cause any temporal change in the productivity shock to affect the housing service supply only small, and in turn the relative price changes little. However, with high δ, such dampening effect disappears. In column (6), I combine two of these changes, and the

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[28] Urbanization and stringent land-use regulations in cities put effective limits on land supply in almost every city.

effect gets stronger only in the time series.

Note that columns (4), (5), and (6) are under a complete market. So this is mainly about the productivity increase, the Balassa-Samuelson hypothesis mechanism, and the substitution effect within the country given the aggregate constant relative demand of two countries. These patterns together imply that specific characteristics of the housing service dampen the textbook Balassa-Samuelson hypothesis mechanism and the substitution effect. On the other hand, it amplifies the reponse of q^R to the wealth effect.

Role of the Cross-sectional Distribution of Sectoral Productivities A remaining puzzling observation is that, even though I render housing service similar to other nontradable services by setting τ as 0.01 and δ as 0.99, we still observe more substantial variations in q^R than q^{NT} or q^T in both dimensions. It turns out that the larger time-series variation simply comes from the larger standard deviations of the construction sector productivity shocks, as in Table 1.7. However, cross-sectional variation requires additional analysis. In column (7), I remove the differences in relative construction sector productivity across countries by setting relative $\frac{A_j^{CR}}{\bar{A}_{EU}^{CR}}$ as 1 for all j. This dampens a substantial amount of the cross-sectional variations. However, it still shows substantial cross-sectional variations in q^R. It turns out that this comes from the cross-country distributions of sectoral productivities, which will be explored in more depth in the section on the Balassa-Samuelson effect.

Role of the Housing Market Given such sources of variations of the real exchange rates, I examine the role of the housing market here. Table 1.9 shows the simulated variations of real exchange rates under different weights of housing in aggregate consumption.

With column (3) as the baseline calibration, I study what happens if housing either becomes less important ($\gamma^R = 0.01$) or more important ($\gamma^R = 0.45$) in the aggregate consumption bundle. Simulations show that more weights in housing service increase both the cross-sectional and time-series variations of the aggregate real exchange rate even though the latter shows only small changes. This demonstrates how housing can

Table 1.9: Simulated Cross-sectional and Time-series Variations of RER: Role of Housing

	(1) **Data**	(2) **Bond** ($\gamma^R = 0.01$)	(3) **Bond** ($\gamma^R = 0.25$)	(4) **Bond** ($\gamma^R = 0.45$)
Cross-section				
$\sigma_j(q_{it})$	0.121	0.073	0.085	0.106
$\sigma_j(q_{it}^T)$	0.081	0.039	0.039	0.039
$\sigma_j(q_{it}^{NT})$	0.149	0.122	0.121	0.123
$\sigma_j(q_{it}^R)$	0.297	0.198	0.197	0.200
Time-series				
$\sigma_t(q_{it})$	0.025	0.032	0.033	0.034
$\sigma_t(q_{it}^T)$	0.022	0.017	0.018	0.018
$\sigma_t(q_{it}^{NT})$	0.039	0.053	0.054	0.055
$\sigma_t(q_{it}^R)$	0.072	0.035	0.038	0.039

be an important source of variations of the real exchange rates. This mainly arises from its importance in the aggregation consumption and inelastic supply. In addition, a large portion is from the cross-country distribution of sectoral productivities. This implies that in each economy, each sectors characteristics—such as the necessity of specific inputs, supply elasticity, distribution of sectoral productivities, and its importance in consumption—may have a substantial impact on the models predictions on aggregate real exchange rate behaviors.

1.4.2.2 Housing and the Balassa-Samuelson Effect

In the previous section, we examined unconditional variations of the real exchange rates, and one striking feature of the model prediction was that cross-sectional variations of the rent real exchange rate were still substantially larger than the other nontradables, even though I rendered housing service very similar to the other nontradables by setting $\tau = 0.01, \delta = 0.99$ and removing the cross-sectional heterogeneity in the relative productivities of the construction sector. This turns out to be related to the Balassa-Samuelson effect. To study this, I examine the relationship between model generated real GDP per capita (y) and real exchange rates (q, q^T, q^{NT}, q^R). In particular, I replicate the following country average cross-sectional regressions I did in the empirical analysis section by using the model-simulated real exchange rate and relative GDP per capita:

$$\begin{aligned}
\bar{q}_j &= \alpha + \beta \bar{y}_j + u_j, \\
\bar{q}_j^T &= \alpha^T + \beta^T \bar{y}_j + u_j^T, \\
\bar{q}_j^{NT} &= \alpha^{NT} + \beta^{NT} \bar{y}_j + u_j^{NT}, \\
\bar{q}_j^R &= \alpha^R + \beta^R \bar{y}_j + u_j^R.
\end{aligned}$$

Table 1.10 shows the simulated β for each sector. Note that while column (1) reports the regression result with data, other columns are from model simulations. Columns other than the data column contain the mean value of the 500 simulations, and the parentheses below contain the 0.1 quantile and 0.9 quantile of the 500 simulations.

Table 1.10: Simulated Balassa-Samuelson Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Data	**Bond**	**Arrow-Debreu**	**Arrow-Debreu**	**Arrow-Debreu**	**Arrow-Debreu**	**Arrow-Debreu**	**Arrow-Debreu**
		Baseline	**Baseline**	($\gamma^R = 0.01$)	($\tau = 0.01$)	($\delta = 0.99$)	(τ=0.01, δ=0.99)	(7) + ($\bar{A}_j^{CR} / \bar{A}_{EU}^{CR} = 1$)
Gray **Bal/Sam**								
β	-0.26*	-0.57*	-0.17*	-0.06	-0.18*	-0.18*	-0.22*	-0.12
	(0.14)	(-0.76,-0.36)	(-0.27,-0.06)	(-0.17,0.04)	(-0.31,-0.05)	(-0.31,-0.03)	(-0.38,-0.06)	(-0.29,0.04)
β^T	-0.08	-0.21*	-0.04	-0.03	-0.04	-0.03	-0.02	-0.02
	(0.13)	(-0.32,-0.09)	(-0.11,0.03)	(-0.09,0.04)	(-0.11,0.04)	(-0.11,0.05)	(-0.09,0.07)	(-0.10,0.06)
β^{NT}	-0.33*	-0.65*	-0.13	-0.11	-0.12	-0.09	-0.05	-0.06
	(0.18)	(-0.96,-0.31)	(-0.34,0.09)	(-0.29,0.07)	(-0.34,0.12)	(-0.33,0.16)	(-0.28,0.22)	(-0.32,0.18)
β^R	-0.76***	-1.46*	-0.62*	-0.49*	-0.86*	-0.63*	-0.93*	-0.45
	(0.19)	(-1.64,-1.26)	(-0.82,-0.43)	(-0.67,-0.33)	(-1.19,-0.49)	(-0.95,-0.32)	(-1.38,-0.45)	(-0.89,0.01)

Data and the Baseline Model Column (1) and column (2) show how my baseline model performs compared with the data. My model overestimates the relationships between relative GDP per capita and all sectoral real exchange rates by a factor of two. One thing the model matches well is the relative importance of sectoral real exchange rates with respect to the overall Balassa Samuelson effect. Both in the data and the baseline model simulation, we see that β^R is the largest and should make the largest contribution to the aggregate β.

Role of a Wealth Effect To examine the role of a wealth effect, I simulate the model again but with the complete market. The result is reported in column (3). We can see that all β for sectoral real exchange rates become smaller, while only the β^R is significantly estimated. This again shows the role of the wealth effect in driving prices. Under an incomplete market, increased tradable sector productivity also increases the country's wealth and demand, which adds additional force for a price hike. This amplifies the model-generated Balassa-Samuelson effect. Assuming a complete market yields a better match with the overall data patterns. However, the role of nontradables seems to be underestimated compared with the data. This implies that the truth should lie between column (2) and column (3).

Role of the Housing Sector and Characteristics of Housing Having a better match with the data under the complete market assumption, I conduct a calibration where only γ^R changes from 0.25 to 0.01, which renders housing less important in the aggregate consumption bundle in column (4). It turns out that the model cannot generate the Balassa-Samuelson effect. This implies that there is a substantial role for housing service in generating the Balassa-Samuelson effect in the model.

To examine where it comes from, I again simulate the model by rendering housing similar to other nontradables by setting τ as 0.01 in column (5), δ as 0.99 in column (6) or τ as 0.01 and δ as 0.99 simultaneously in column (7). Other than these, the calibrations are the same as in column (3). In the case of columns (5) and (7) compared with column (3), we observe small, though not significant, increases in the model-generated Balassa Samuelson effect via q^R. This likely arises from the increased Balassa-Samuelson hypothesis mechanism, because the construction sector is fully exposed to it since they only use labor, and not land, which is not used in the tradable sector. On the other hand, low δ has no significant impact on the model-generated Balassa-Samuelson effect. This is because we are focusing on cross-sectional regressions by using the mean of each country, effectively comparing the steady states of all countries. Whatever δ is, the relative importance of land is fixed as τ. Thus the Balassa-Samuelson effect does not change. As we will see in the Backus-Smith puzzle section, the major contribution of δ is to the time-series dimension of the real exchange rate, since it defines the relative sizes of the housing stock and housing flows in the model dynamics.

Role of the Cross-sectional Distribution of Sectoral Productivities The above exercises leave a puzzling fact, as was the case with the cross-sectional variations of RER. It turns out that the unique characteristics of housing we are interested in actually dampen the Balassa-Samuelon effect via q^R in the model. Even though I set τ as 0.01 and δ as 0.99, which renders the housing service very similar to the other nontradable sector, we still observe a stronger Balassa-Samuelson effect via the rent real exchange rate, not via the nontradable real exchange rate.

It turns out that this strong role of housing rent is from the distribution of sectoral productivities. The productivity shock processes I directly calibrated from the EUKLEMS 2023 database show that $Corr(ln(\frac{\bar{A}_j^H}{\bar{A}_{EU}^H}), ln(\frac{\bar{A}_j^{NT}}{\bar{A}_{EU}^{NT}})) = 0.76$, while $Corr(ln(\frac{\bar{A}_j^H}{\bar{A}_{EU}^H}), ln(\frac{\bar{A}_j^{CR}}{\bar{A}_{EU}^T})) = -0.23$ for the eight countries I use for the simulation. Figure 1.9 shows how the tradable sector of each country is related to that of the nontradable or construction sector.[29] We can see very strong positive and negative correlation relationships among sectoral productivities. Figure 1.9 implies that a country with higher relative tradable sector productivity has higher relative nontradable sector productivity but relatively lower construction sector productivity. This causes the model to generate the Balassa-Samuelson effect primarily through the housing rents. Though the wage goes up due to high tradable sector productivity, high nontradable sector productivity prevents the nontradable real exchange rate from appreciating. However, even though the wage accounts for only 1-τ portion of the housing construction cost, because of the lower construction sector productivity the Balassa-Samuelson effect works strongly through the rent real exchange rate rather than other nontradables. Once I remove the cross-country-level heterogeneity of construction sector productivities, the model-generated Balassa-Samuelson effect disappears, and renders β^R not significant, as in column (8). However, our point estimate of β^R still has a very lower value than that of β^{NT}. This is because, again, $Corr(ln(\frac{\bar{A}_j^H}{\bar{A}_{EU}^H}), ln(\frac{\bar{A}_j^{NT}}{\bar{A}_{EU}^{NT}})) =$

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[29] This figure also includes three non-eurozone countries: Sweden, Denmark, and the UK. These are mean relative productivities that are directly calibrated from the data without any inference.

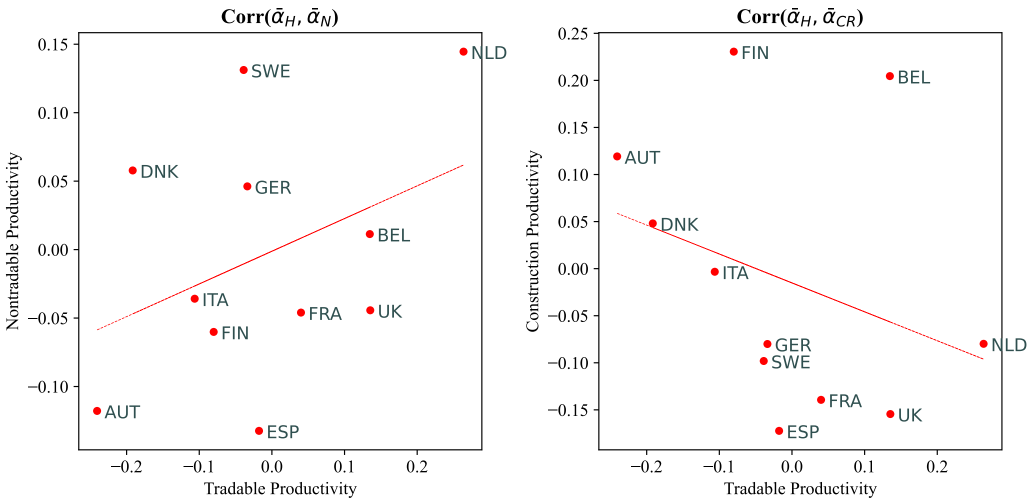

Figure 1.9: Cross-country Distributions of Sectoral Productivities

0.76. If I set $ln(\frac{\bar{A}_j^{NT}}{\bar{A}_{EU}^{NT}}) = 0$ for all countries, it would cause β^{NT} to be similar to that of β^R in column (7).

This connects to recent literature on stagnant productivity in the construction sector. Goolsbee and Syverson (2023) show that construction sector productivity has been decreasing in the US, but also in the EU 27 area as a whole. If the construction sector is the sector whose productivity does not grow in all countries while other nontradable sector productivity increases, the different growth rates of tradable sector productivity across countries should generate a strong Balassa-Samuelson effect via the rent real exchange rate. Because I have only eleven country observations of productivities, this naturally calls for more research on a more granular level to link the Balassa-Samuelson effect and construction sector productivities across regions.

Role of the Housing Market Table 1.11 shows how the model-generated Balassa-Samuelson effect changes as γ^R changes. We can clearly see that the model generates a stronger Balassa-Samuelson effect as the housing weight increases.

In summary, comparative statics simulations show that my model is able to generate a strong Balassa-Samuelson effect, especially via the housing sector, as in the data.

Table 1.11: Simulated Balassa-Samuelson Regressions: Role of Housing

	(1) **Data**	(2) **Bond** ($\gamma^R = 0.01$)	(3) **Bond** ($\gamma^R = 0.25$)	(4) **Bond** ($\gamma^R = 0.45$)
Balassa-Samuleson Effect				
β	-0.26* (0.14)	-0.45* (-0.63,-0.26)	-0.57* (-0.76,-0.36)	-0.72* (-0.93,-0.52)
β^T	-0.08 (0.13)	-0.24* (-0.34,-0.14)	-0.21* (-0.32,-0.09)	-0.19* (-0.31,-0.08)
β^{NT}	-0.33* (0.18)	-0.75* (-1.06,-0.44)	-0.65* (-0.98,-0.31)	-0.61* (-0.94,-0.26)
β^R	-0.76*** (0.19)	-1.51* (-1.69,-1.31)	-1.46* (-1.65,-1.26)	-1.43* (-1.65,-1.21)

Being different from our priors, the unique characteristics of housing service dampen the textbook Balassa-Samuelson hypothesis mechanism. A major portion of the Balassa-Samuelson effect comes from the wealth effect through an incomplete market and the cross-sectional distribution of sectoral productivities.

1.4.2.3 Housing and the Backus-Smith Puzzle

Lastly, I examine the role of housing in the Backus-Smith puzzle via model simulation. Using model-simulated data, I replicate the following four panel regressions as in the empirical analysis section:

$$\begin{aligned}
\Delta q_{jt} &= \alpha + \beta \Delta c_{jt} + e_{jt}, \\
\Delta q_{jt}^T &= \alpha^T + \beta^T \Delta c_{jt} + e_{jt}^T, \\
\Delta q_{jt}^{NT} &= \alpha^{NT} + \beta^{NT} \Delta c_{jt} + e_{jt}^{NT}, \\
\Delta q_{jt}^R &= \alpha^R + \beta^R \Delta c_{jt} + e_{jt}^R.
\end{aligned}$$

Table 1.12 presents replication results under different calibrations. First, column (2) clearly shows that under a complete market, my model cannot replicate the negative β. It generates β closer to σ, which is calibrated as 2 in my model. This is because the complete market condition implies that $ln(C_t/C_t^*) = \frac{1}{\sigma} ln(P_t^*/P_t)$ for every state and time. So, this exactly shows the Backus-Smith puzzle found by Backus and Smith

(1993). Moving to column (3), I assume an incomplete market but a very small housing expenditure share in the model by setting γ^R as 0.01. Though the model generates 0.38, which is much smaller than the case of column (1), it is still very far from its data counterpart, being statistically significantly different from 0. This again shows why the Backus-Smith puzzle is hard to resolve, even under the incomplete market assumption.

One of my main findings appears in column (4), where I set γ^R as 0.25, which is my baseline calibration generating a realistic rent expenditure share of 17% in the model. Now the model can replicate negative β, whose point estimate is very close to that of the data. In addition, such negative correlation comes largely from the β^R, whose value is -1.29. Though my model β^R is much bigger than its data counterpart, my model replicates the data pattern in which q^R accounts for a major portion of the negative Backus-Smith correlation.

Table 1.12: Simulated Backus-Smith Puzzle Regressions: Role of Housing

	(1) **Data**	(2) **Arrow-Deberu** (γ^R = 0.25)	(3) **Bond** (γ^R = 0.01)	(4) **Bond** (γ^R = 0.25)	(5) **Bond** (γ^R = 0.45)
Backus/Smith					
β	-0.14** (0.07)	1.99* (1.98,2.02)	$0.38^\star$ (0.09,0.68)	-0.12 (-0.53,0.28)	-0.51 (-1.14,0.07)
β^T	0.02 (0.05)	1.21* (1.20,1.23)	0.19 (0.04,0.37)	0.05 (-0.18,0.27)	0.04 (-0.31,0.36)
β^{NT}	-0.15** (0.06)	3.75* (3.72,3.79)	$0.68^\star$ (0.18,0.90)	0.22 (-0.46,0.90)	0.18 (-0.87,1.15)
β^R	-0.53** (0.23)	0.82* (0.81,0.83)	$-0.79^\star$ (-1.09,-0.51)	$-1.29^\star$ (-1.69,-0.89)	$-1.69^\star$ (-2.31,-1.11)

To understand why a realistically calibrated housing sector helps the model to generate a negative Backus-Smith correlation, we need to understand how model-generated real exchange rates and relative consumptions respond to each sectoral productivity shock. Note that these sectoral productivity shocks are the only sources of the business cycles in my model. The upper panel of the Figure 1.10 shows the impulse response functions (IRFs) of the aggregate real exchange rate (q) and the relative consumption (c) to a one standard deviation shock to each sector's relative productivity.

One notable observation is that the tradable sector shock decreases q (appreciates the real

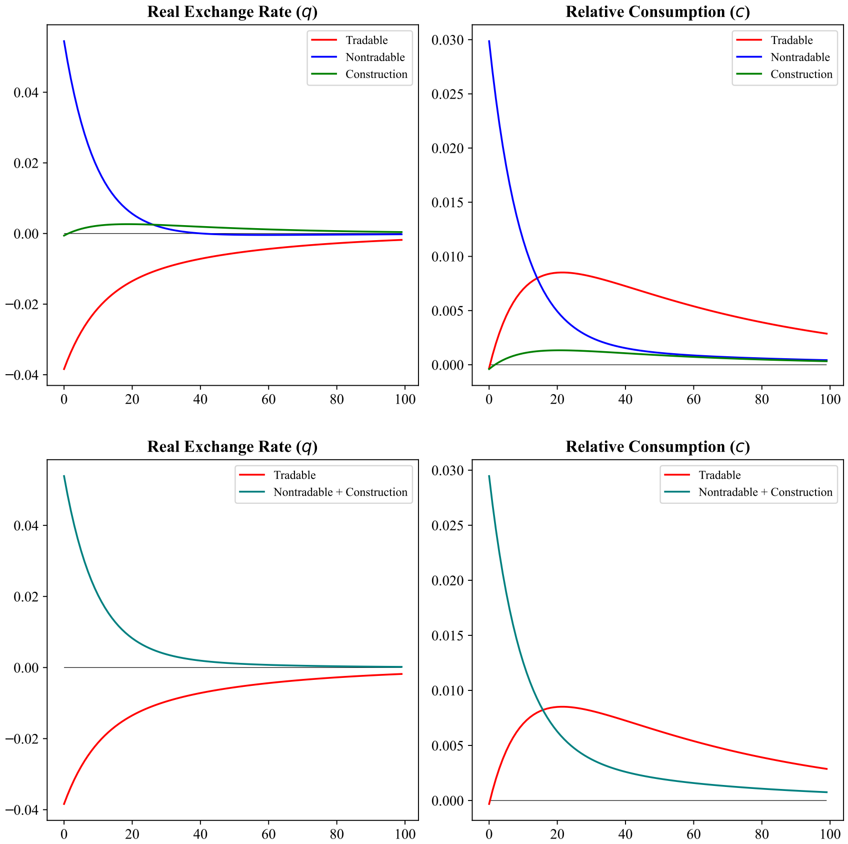

Figure 1.10: Model q and c Responses to Sectoral Productivity Shocks

exchange rate) and increases c (increases the relative consumption) while the nontradable sector shock and construction sector shock increase q (depreciate the real exchange rate) and increase c. Given that c moves in the same direction for all types of shocks, a sign of the model-generated $Corr(\Delta c, \Delta q)$ will depend on the relative size of the effect of tradable sector shock on q compared with those of the nontradable and construction sector shock.

Since the mechanism behind the effect of the nontradable sector shock and construction shock are similar, it becomes easier to understand once we combine these two forces into one force as in lower panel of Figure 1.10. We can consider two forces in the model, in which the tradable sector productivity shock generates $Corr(\Delta c, \Delta q) < 0$ and the sum of the nontradable and construction sector productivity shocks generate $Corr(\Delta c, \Delta q) > 0$.

Given these characteristics of the shocks, showing how the IRFs of q and c to such shocks change under different housing weights is the most straightforward way to check the role of housing in the Backus-Smith correlation. Figure 1.11 shows how these model responses change when γ^R changes from 0.01 to 0.45 in the model. Comparing the dotted line ($\gamma^R = 0.01$) with the solid line ($\gamma^R = 0.45$), we observe that the IRFs of q to all shocks are dragged down to lower values. In particular, while the effects of the nontradable and construction sector shocks get smaller, the effect of the tradable sector shock is sustained and the IRFs of q to that get more persistent. This means that under higher γ^R, the tradable sector shock effect gets amplified and the nontradable and construction sector shocks effect gets smaller, which causes the model to generate a more negative aggregate correlation between Δq and Δc.

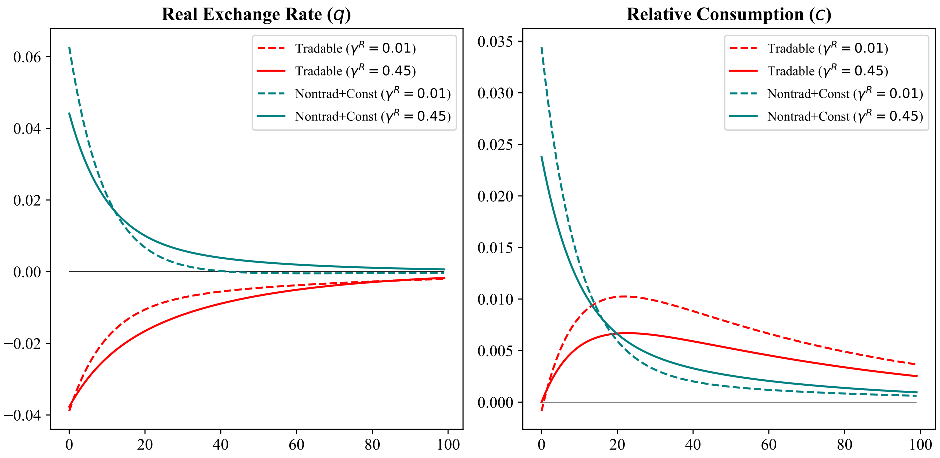

Figure 1.11: Role of Housing in IRFs of q and c

To understand why this happens, we need to know that Δq is a expenditure-weighted average of Δq^T, Δq^{NT}, and Δq^R in the model, since we used the first-order approximation method for the model solution. This implies that as γ^R gets larger, Δq will be affected more by Δq^R but less by Δq^T and Δq^{NT}. This implies that understanding the response of each sectoral real exchange rate's IRFs is important. Figure 1.12 shows the IRFs of sectoral real exchange rates to both the tradable sector shock (ϵ_h) or the sum of the nontradable and construction sector shocks ($\epsilon_n + \epsilon_{cr}$) under both a complete and incomplete market.

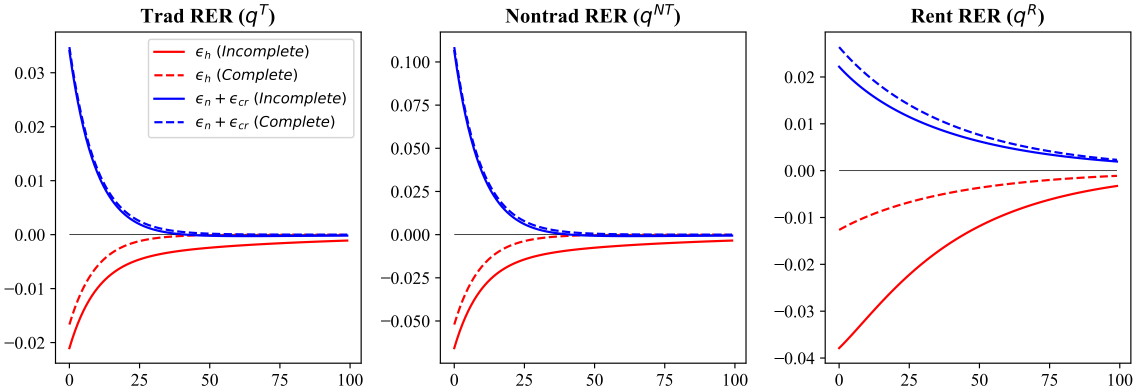

Figure 1.12: Impulse Response Functions of Sectoral Real Exchange Rates

Housing and Tradable Sector Productivity Shock First, we focus on the effect of the tradable sector shock. All sectoral real exchange rates appreciate to the positive tradable sector productivity shock. Two forces generate such appreciations. The first mechanism is the well-known textbook Balassa-Samuelson hypothesis. When the tradable sector gets a positive productivity shock, while the price of the tradable is sustained due to foreign demand, it increases the marginal product of labor, and pushes up wages. This increased wage again increases the marginal production cost of nontradables and housing construction via the labor market. Note that q^T also appreciates due to the distribution margin. The other mechanism is the wealth effect generated under an incomplete market. If the home country receives a positive tradable sector productivity shock, this makes the home country wealthier than the foreign country, and causes it to consume more than the foreign country. This pushes up the home country's demand for all goods and services more than the foreign country, which results in the home country's appreciation.[30]

While the Balassa-Samuleson hypothesis channel works under any risk-sharing assumption, the wealth effect only works under an incomplete market. This implies that the difference between IRFs under an complete market and incomplete market can be interpreted as

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[30] To make this wealth effect work, the calibration should be within a certain parameter region such as high substitutability between tradable goods. My calibration is within such region, and for more detail, refer to Corsetti et al. (2008).

the wealth effect. In Figure 1.12, it becomes clear that the q^R responds much more to the wealth effect than to other sectoral real exchange rates. The difference between the red dotted line and the red solid line is asymmetrically larger for q^R compared with q^T and q^{NT}. This arises from the fact that housing service supply is more inelastic than tradables or other nontradables, as we can see in Figure 1.7. On the top of this, we see that the q^R's impulse response function is most persistent. This is due to slower adjustment in the aggregate supply of the housing service.

On the other hand, comparing the dotted IRF of q^{NT} and q^R, we see that the textbook Balassa-Samuelson hypothesis mechanism works much less for q^R: q^{NT} appreciates almost 5%, while q^R only appreciates by 1%. This stems from residential-zoned land. While the land is important for housing production, it is not used in the tradable sector. Consequently, even though the tradable sector receives a positive productivity shock, it does not push up the price of land. Naturally, this leads to a smaller increase in the production cost of housing compared with that of the nontradables.

In summary, the unique characteristics of the housing service generate asymmetry between responses of q^R and those of q^T or q^{NT} to the change in the tradable sector productivity shock. This implies that when γ^R increases the response of q arises more from q^R, which generates the stronger response to the tradable sector shock and more negative Backus-Smith correlation forces.

Housing and Nontradable/Construction Sector Productivity Shock I move now to IRFs of sectoral real exchange rates to nontradable/construction sector shocks. While it is understandable that q^T shows little response to the productivity shocks, since its productivity is not directly affected, it is striking that q^R is not depreciating as much as q^{NT}.

Again, this recalls Figure 1.8. The large land input share (τ) and low depreciation rate of housing stock (δ) decrease the effect of the construction sector productivity shock on the supply of housing services. Consequently, the supply increase is limited and the price of housing service does not decrease much. If $\tau = 0$ and $\delta^S = 1$, the responses of q^R would be exactly same as those of q^{NT}.

In one sentence, the unique characteristics of housing service generate the asymmetry in which response of q^R to the productivity shock on its sector are much smaller than that of q^{NT}. This implies that when γ^R increases, q's response is more driven by that of q^R, which makes q responds less to sum of productivity shocks in nontradable and construction sector. In aggregate, this causes the model to generate smaller positive Backus-Smith correlation forces.

Housing, Inelastic Supply, and the Backus-Smith Puzzle In general equilibrium, two roles of housing explained above work simultaneously when the γ^R gets larger in the model. Consequently, the housing sector causes the model to generate a more negative Backus-Smith correlation in aggregate.

Table 1.13 shows how simulation results change when I change housing-related parameters. As the complete market case has no meaning, I show only bond-economy cases. Column (2) is the baseline case where γ^R is 0.25, which generates the results similar to those in the data. When I change the τ to 0.01, in column (3), the model generates a stronger negative Backus-Smith correlation. Given very low δ, its effect in dampening the nontradable/construction sector shock is limited. On the other hand, the tradable sector shock gets amplified via a stronger Balassa-Samuelson hypothesis mechanism with smaller land-input share. Altogether, this leads to a stronger negative Backus-Smith correlation.

Column (4) is the case in which I set δ as 0.99 so that housing service has elastic supply like other nontradables. As we can clearly see, the model generates positive β and even positive β^R. In this case, housing service no longer shows dampened responses to the construction sector productivity shocks, since their prices decrease directly once they receive the positive productivity shocks. In addition, q^R's large response to the wealth effect via the tradable sector shock will also go away. Consequently, the model completely lose its capacity to generate a negative β estimate. In column (5), once

I assume both low τ and high δ, the model gets further from the negative β. In column (3), because of low δ, τ could not play its role in dampening the response of q^R to the construction productivity shock. Now, given the high δ, it was doing its job by dampening the construction sector shocks but once τ is also set low, the model generates a stronger positive β than column (4). Lastly, in column (6), we can see that the cross-country distribution of sectoral productivities has no role in the Backus-Smith puzzle, since we are interested in more time-series dynamics and not cross-country level dynamics. These simulations show that the inelastic housing supply, dampened productivity shocks' supply effects, and their interaction with the wealth effect are the key mechanism for generating the negative Backus-Smith correlation in my model.

Table 1.13: Simulated Backus-Smith Puzzle Regressions: Role of Housing

	(1) **Data**	(2) **Bond** **Baseline**	(3) **Bond** $(\tau = 0.01)$	(4) **Bond** $(\delta = 0.99)$	(5) **Bond** (τ=0.01, δ=0.99)	(6) **Bond** $(7) + (\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1)$
Backus/Smith						
β	-0.14** (0.07)	-0.12 (-0.53,0,28)	-0.32 (-0.71,0.07)	0.62* (0.21,1.04)	1.18* (0.83,1.58)	1.21* (0.81,1.63)
β^T	0.02 (0.05)	0.05 (-0.18,0.27)	-0.09 (-0.29,0.12)	0.29* (0.09,0.49)	0.30* (0.15,0.47)	0.32* (0.13,0.50)
β^{NT}	-0.15** (0.06)	0.22 (-0.46,0.90)	-0.20 (-0.84,0.44)	0.95* (0.36,1.57)	0.95* (0.47,1.48)	1.00* (0.43,1.56)
β^R	-0.53** (0.23)	-1.29* (-1.69,-0.89)	-1.44* (-1.92,-0.95)	0.86* (0.17,1.57)	3.48* (2.72,4.27)	3.52* (2.73,4.38)

Lastly, I want to emphasize that this is a more general result than it seems. In this paper, I use housing service as a representative example because of its economic significance and unique characteristics. However, any goods and services can work similarly in the model, as long as they account for a large expenditure share (share of overall price level), their supply is very inelastic, and they require unique production factors that are immune to productivity gains.

Discussion of Corsetti et al. (2008) and Benigno and Thoenissen (2008) It is worthwhile to discuss the relationship between my findings and the lessons of Corsetti et al. (2008) and Benigno and Thoenissen (2008).

First, Corsetti et al. (2008) resolve the Backus-Smith puzzle under an incomplete market by making either the tradable goods very non-substitutable and pushing up the terms of trade or by making the productivity shock itself very persistent under high substitutability of the tradable goods, which causes the wealth effect itself to be stronger.

My work is the same as Corsetti et al. (2008), in the sense that it uses the wealth effect via an incomplete market. However, how I amplify the relative price responses to such a shock differ from their methods. Rather than affecting the terms of trade or amplifying the size of demand increase itself, I make the response of the aggregate price level to a given demand shock stronger by making the aggregate supply more inelastic. This is achieved by incorporating inelastically supplied housing service in the aggregate consumption with a significant expenditure share. This aggregate supply curve, which becomes more inelastic, causes the aggregate price level to increase much more to a given wealth effect, which in turn causes more negative Backus-Smith correlation.

Second, Benigno and Thoenissen (2008) resolve the Backus-Smith puzzle by pushing up the nontradable prices via the Balassa-Samuelson hypothesis mechanism, given the tradable sector shocks. Different with them, my model focuses more on dampening the effect of nontradable and construction sector productivity shocks by using the unique characteristics of housing. While the land input share dampens a bit of the supply effect from the construction sector shock, what matters most in my paper is the fact that housing is capital that is directly consumed. Its stock is much larger than the flow, and it needs to be accumulated throughout the long investment. This setup renders any positive productivity gain in the construction sector not capable of increasing the supply, which generates a weaker supply shock effect. This removes the forces generating the positive Backus-Smith correlation from the model.

This again differs from the sector-specific capital model. In the sector-specific capital model, though those sector-specific capitals are hard to adjust, these capitals are not the only input for producing those sectors' output. These sectors also use labor, which makes the supply a bit more elastic. However, the housing service comes only from the housing stock, and not additional labor. This causes the supply to be dramatically inelastic, which helps the model improve on the Backus-Smith puzzle.

1.5 Conclusion

This paper has examined the role of the housing sector in international business cycles, with a specific focus on its role in real exchange rate dynamics. By using disaggregated relative price level data from eurozone countries, I show that the relative rent is the most volatile component of the aggregate real exchange rate. Moreover, I find out that the rent real exchange rate contributes to over half of the Balassa-Samuelson effect and the negative Backus-Smith correlation within eurozone countries.

Building on these empirical findings regarding the significance of the rent real exchange rate and the housing sector, I construct a two-country, three-sector model in which the realistically calibrated housing sector is incorporated. Simulation of the model using sectoral productivity shocks, directly calibrated from the EUKLEMS database yields several insights into the roles of rent real exchange rates and the housing sector. The inclusion of a realistically calibrated housing sector enables the model to generate greater cross-sectional and time-series variations. This is attributed to variations in sectoral productivity levels and a larger standard deviation of shocks to construction sector productivity.

Furthermore, unique housing characteristics, such as the role of land and the substantial stock compared with the relatively small flow, have been identified as factors that mitigate the textbook Balassa-Samuelson hypothesis mechanism. Still, my model demonstrates that the strong Balassa-Samuelson effect via q^R stems from the negative correlation between relative tradable sector productivity and that of the construction sector. Also, the wealth effect via incomplete markets amplifies the Balassa-Samuelson effect across all sectors. Finally, the model that incorporates the housing sector yields improved predictions for the Backus-Smith correlation. The inelastic housing supply intensifies the model's response to wealth effects (demand shocks) and mitigates its response to positive nontradable and construction sector productivity shocks. These mechanisms have shifted the response of aggregate real exchange rates in a negative direction for all types of shocks, which aids the model in generating a Backus-Smith correlation that closely aligns with the empirical data.

These implications not only shed light on the role of the housing sector in real exchange rate dynamics within eurozone countries, but also offer broader insights about the functioning of international business cycle models. Although housing rent has been used as a representative example due to its economic significance, the underlying principles revealed in this study are applicable to any goods and services characterized by limited productivity growth, reliance on unique production inputs not used in other sectors, or a substantial stock relative to the flow. With respect to addressing the Balassa-Samuelson effect, further exploration of stagnant construction sector productivity—which is observed in the recent literature—will be crucial. In the context of the Backus-Smith puzzle, it would be valuable to investigate heterogeneity among countries in terms of expenditure weights and the relative economic importance of goods and services subject to inelastic supply.

1.A Additional Backus-Smith Correlations Table

Table 1.A.1: Backus-Smith Correlations (per capita consumption)

	$Corr(\Delta c, \Delta q)$	$Corr(\Delta c, \Delta q^T)$	$Corr(\Delta c, \Delta q^{NT})$	$Corr(\Delta c, \Delta q^R)$
Austria	-0.048	-0.000	0.095	-0.445
Belgium	0.033	0.085	-0.009	-0.095
Finland	0.202	0.443	-0.052	-0.044
France	0.193	0.063	0.337	0.028
Germany	-0.145	-0.004	-0.022	-0.555
Greece	-0.207	-0.065	-0.235	-0.135
Ireland	-0.597	-0.359	-0.297	-0.718
Italy	0.082	-0.205	0.429	0.144
Luxembourg	-0.051	0.076	-0.037	-0.102
Netherlands	-0.138	-0.381	0.031	0.143
Portugal	-0.207	-0.231	-0.005	0.087
Spain	-0.024	0.183	-0.104	-0.110
Average	-0.075	-0.033	0.011	-0.150

$cc^* = ln(C_{it}/C_{EU12t})$ where C_{EU12t} is a geometric means of C over 12 eurozone countries. C is final consumption expenditure per capita.

1.B OECD Eurostat PPP Basic Headings

For the quality of the data, refer to the metadata[31] provided by Eurostat. Table 1.B.1 provides the list of basic headings.

Table 1.B.1: Eurostat PPP Basic Headings

Class	Name	Class	Name	Class	Name
T	Rice	T	Electricity	T	Hotels, motels, inns and similar accommodation...
T	Flours and other cereals	T	Natural gas and town gas	T	Holiday centres, camping sites, youth hostels ...
T	Bread	T	Liquefied hydrocarbons (butane, propane, etc.)	T	Accommodation services of other establishments
T	Other bakery products	T	Liquid fuels	T	Electric appliances for personal care
T	Pizza and quiche	T	Solid fuels	T	Non-electrical appliances
T	Pasta products and couscous	T	Heat energy	T	Articles for personal hygiene and wellness, es...
T	Breakfast cereals	T	Household furniture	T	Jewellery
T	Other cereal products	T	Garden furniture	T	Clocks and watches
T	Beef and veal	T	Lighting equipment	T	Other personal effects
T	Pork	T	Other furniture and furnishings	NT	Cleaning, repair and hire of clothing
T	Lamb and goat	T	Carpets and other floor coverings	NT	Repair and hire of footwear
T	Poultry	T	Furnishing fabrics and curtains	NT	Services for the maintenance and repair of the...
T	Other meats	T	Bed linen	NT	Water supply
T	Edible offal	T	Table linen and bathroom linen	NT	Refuse collection
T	Dried, salted or smoked meat	T	Other household textiles	NT	Sewage collection
T	Other meat preparations	T	Refrigerators, freezers and fridge-freezers	NT	Other services relating to the dwelling n.e.c.
T	Fresh or chilled fish	T	Clothes washing machines, clothes drying machi...	NT	Repair of furniture, furnishings and floor cov...
T	Frozen fish	T	Cookers	NT	Repair of household textiles
T	Fresh or chilled seafood	T	Heaters, air conditioners	NT	Repair of household appliances
T	Frozen seafood	T	Cleaning equipment	NT	Domestic services by paid staff
T	Dried, smoked or salted fish and seafood	T	Other major household appliances	NT	Cleaning services
T	Other preserved or processed fish and seafood-...	T	Small electric household appliances	NT	Hire of furniture and furnishings
T	Milk, whole, fresh	T	Glassware, crystal-ware, ceramic ware and chin...	NT	Other domestic services and household services
T	Milk, low fat, fresh	T	Cutlery, flatware and silverware	NT	Medical services
T	Milk, preserved	T	Non-electric kitchen utensils and articles	NT	Dental services
T	Yoghurt	T	Repair of glassware, tableware and household u...	NT	Paramedical services
T	Cheese and curd	T	Major tools and equipment	NT	General hospitals
T	Other milk products	T	Small tools and miscellaneous accessories	NT	Mental health and substance abuse hospitals
T	Eggs	T	Cleaning and maintenance products	NT	Speciality hospitals
T	Butter	T	Other non-durable small household articles	NT	Nursing and residential care facilities
T	Margarine and other vegetable fats	T	Pharmaceutical products	NT	Maintenance and repair of personal transport e...
T	Olive oil	T	Other medical products	NT	Other services in respect of personal transpor...
T	Other edible oils	T	Therapeutic appliances and equipment	NT	Passenger transport by train
T	Other edible animal fats	T	New motor cars	NT	Passenger transport by underground and tram
T	Fresh or chilled fruit	T	Second-hand motor cars	NT	Passenger transport by bus and coach
T	Frozen fruit	T	Motor cycles	NT	Passenger transport by taxi and hired car with...
T	Dried fruit and nuts	T	Bicycles	NT	Passenger transport by sea and inland waterway
T	Preserved fruit and fruit-based products	T	Animal drawn vehicles	NT	Combined passenger transport
T	Fresh or chilled vegetables other than potatoe...	T	Tyres	NT	Other purchased transport services
T	Frozen vegetables other than potatoes and othe...	T	Spare parts for personal transport equipment	NT	Postal services
T	Dried vegetables, other preserved or processed...	T	Accessories for personal transport equipment	NT	Wired telephone services
T	Potatoes	T	Diesel	NT	Wireless telephone services
T	Crisps	T	Petrol	NT	Internet access provision services
T	Other tubers and products of tuber vegetables	T	Other fuels for personal transport equipment	NT	Bundled telecommunication services
T	Sugar	T	Lubricants	NT	Other information transmission services
T	Jams, marmalades and honey	T	Passenger transport by air	NT	Repair of audio-visual, photographic and infor...
T	Chocolate	T	Telephone and telefax equipment	NT	Maintenance and repair of other major durables...
T	Confectionery products	T	Equipment for the reception, recording and rep...	NT	Recreational and sporting services
T	Edible ices and ice cream	T	Equipment for the reception, recording and rep...	NT	Cinemas, theatres, concerts
T	Artificial sugar substitutes	T	Portable sound and vision devices	NT	Museums, libraries, zoological gardens
T	Sauces, condiments	T	Other equipment for the reception, recording a...	NT	Television and radio licence fees, subscriptions
T	Salt, spices and culinary herbs	T	Photographic and cinematographic equipment and...	NT	Hire of equipment and accessories for culture
T	Baby food	T	Personal computers	NT	Photographic services
T	Ready-made meals	T	Accessories for information processing equipment	NT	Other cultural services
T	Other food products n.e.c.	T	Software	NT	Education - HH
T	Coffee	T	Calculators and other information processing e...	NT	Restaurants, cafés and dancing establishments
T	Tea	T	Pre-recorded recording media	NT	Fast food and take away food services
T	Cocoa and powdered chocolate	T	Unrecorded recording media	NT	Canteens
T	Mineral or spring waters	T	Other recording media	NT	Hairdressing for men and children
T	Soft drinks	T	Major durables for outdoor recreation	NT	Hairdressing for women
T	Fruit and vegetable juices	T	Musical instruments and major durables for ind...	NT	Personal grooming treatments
T	Spirits	T	Games and hobbies	NT	Prostitution
T	Wine	T	Toys and celebration articles	NT	Repair of jewellery, clocks and watches
T	Beer	T	Equipment for sport, camping and open-air recr...	NT	Social protection
T	Tobacco	T	Garden products	NT	Life insurance
T	Narcotics	T	Plants and flowers	NT	Insurance connected with the dwelling
T	Clothing materials	T	Pets and related products	NT	Insurance connected with health
T	Garments for men	T	Veterinary and other services for pets	NT	Insurance connected with transport
T	Garments for women	T	Games of chance	NT	Other insurance
T	Garments for infants (0 to 2 years) and childr...	T	Books	NT	FISIM
T	Other articles of clothing and clothing access...	T	Newspapers	NT	Other financial services n.e.c.
T	Footwear for men	T	Magazines and periodicals	NT	Other services n.e.c.
T	Footwear for women	T	Miscellaneous printed matter	H	Actual rentals for housing
T	Footwear for infants and children	T	Stationery and drawing materials	H	Imputed rentals for housing
T	Materials for the maintenance and repair of th...	T	Package holidays		

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[31] https://ec.europa.eu/eurostat/cache/metadata/en/prc$_{p}pp_{e}sms.htmrelatedmd$1678716803148

1.C Relative Sectoral Productivity Estimation

In this section, I explain how I estimate the relative sectoral productivities of Eurozone countries. To estimate the sector-specific productivity shock process (i.e., tradable sector, nontradable sector and construction sector), I closely follow the procedure used by Berka et al. (2018) with a few modifications. The following is the overall procedure for calculating relative sectoral productivities.

1. Make a proper industry concordance between Groningen Growth and Development Centre (GGDC) 1997 and EUKLEMS & INTANProd 2023 in order to use the two datasets together.
2. Calculate the 1997 relative productivity level (against the 12 European countries) of each industry in each country by using the GGDC 1997 database.
3. Calculate the relative productivity growth of each industry in each country using EUKLEMS & INTANProd 2023 from 1995 to 2019.
4. Combining the levels and growth rates from the first and second steps and construct panel data on the relative productivity for each industry in each country from 1995 to 2019.
5. Aggregate industries into tradable, nontradable and construction sectors using industry-level value-added as weights.
6. Estimate the $AR(1)$ process for each sector and each country using the generated relative sectoral productivities from 2000 to 2019.

1.C.1 Sectoral Concordance

GGDC 1997 and EUKLEMS & INTANProd 2023 use different industry classification systems, as shown in Table 1.C.1 and Table 1.C.2. To align the two systems, I proceed as followings. First, I create concordance between industries as in Table 1.C.3. In some cases, to make mutually exclusive but informative connections, one industry in the GGDC industry classification system has been matched with two industries in the EUKLEMS classification system, or vice versa. When two industries in the GGDC are matched with one industry in the EUKLEMS, initial productivity levels are aggregated based on the sectoral output weights in that year. On the other hand, when two industries in the EUKLEMS are matched with one industry in the GGDC, each year's productivity growth rates are aggregated using the 2000-2019 average of the relative value-added weight of each sector.[32]

1.C.2 Relative Productivity Level: The GGDC 1997 Database

I calculate industry-level relative productivity across European countries using the GGDC 1997 TFP database. For industry i and country j, the GGDC database provides

$$C_{ij1997} = \frac{A_{ij1997}}{A_{iUS1997}}. \tag{1.45}$$

Among all productivity measures, I use **multi-factor productivity from the sectoral output-based** approach, which is used by Berka et al. (2018). The GGDC 1997 database provides data on a large set of industries. Table 1.C.1 shows the set of industries for which data are available. Of all available industries, to make a proper connection with the EUKLEMS 2023 database, I use only a subset of industries. Table 1.C.2 provides the set of industries for which the data are available for the EUKLEMS 2023 database, and Table 1.C.3 shows how I create a concordance between the GGDC 1997 database and the EUKLEMS 2023 database.

According to the concordance in Table 1.C.3, I need to aggregate *(13) Wood and products of wood and cork* and *(14) Pulp, paper, paper products, printing and publishing.* Also, I need to aggregate *(17) Rubber and plastics products* and *(18) Other non-metallic mineral products.* To aggregate these industries, I use the relative weights computed by their relative sectoral

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[32] This value-added weighted average allows the possibility that production inputs are not perfectly substitutable across industries, which is a more realistic approach than input-based aggregation methods.

output. To aggregate industries $i1$ and $i2$ into an industry named i, when $SO_{i1j1997}$ is the output for industry $i1$ in country j in 1997, I calculate the following:

$$C_{ij1997} = \frac{SO_{i1j1997}}{SO_{i1j1997} + SO_{i2j1997}} \frac{A_{i1j1997}}{A_{i1US1997}} + \frac{SO_{i2j1997}}{SO_{i1j1997} + SO_{i2j1997}} \frac{A_{i2j1997}}{A_{i2US1997}}. \tag{1.46}$$

This gives me cross-sectional data on relative productivities for all industries in Table 1.C.3 for all countries.

Given these, for each industry i, I calculate the simple average of Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Sweden, the United Kingdom, and Spain as follows:[33]

$$C_{iEU1997} = \frac{1}{12} \sum_{j} C_{ij1997} \sim \frac{A_{iEU1997}}{A_{iUS1997}}. \tag{1.47}$$

Then $C_{iEU1997}$ will be the average productivity of Europe for industry i relative to that of the US. Finally, by dividing C_{ij1997} by $C_{iEU1997}$, we have the relative productivity of industry i in country j against the European average.

$$\tilde{A}_{ij1997} = \frac{C_{ij1997}}{C_{iEU1997}}. \tag{1.48}$$

1.C.3 Productivity Growth Rate: The EUKLEMS & INTANProd 2023 Databases

For growth rates, I use the EUKLEMS & INTANProd 2023 release to construct the industry-level productivity growth rate. While Berka et al. (2018) use the March 2011 updated version of EUKLEMS, I use the latest version of the database to extend the periods. This database covers the period from 1995 to 2020 for 27 European countries: the UK, the US, and Japan, and covers 42 industries.[34]

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[33] These are the countries that provide industry-level productivity growth data in EUKLEMS 2023. For consistency, I calculate the European average using only these countries.

[34] This release is unique in the sense that it tried to incorporate intangible capital into growth accounting, which had not been tried before. In this appendix, I briefly discuss the parts that are related to my analysis. For more information, please refer to Corrado et al. (2023) and O'Mahony and Timmer (2009).

From the dataset, I use the value-added-based TFP index ($VATFP\_I$) and value-added in current prices (VA_CP) to calculate the industry-level productivity growth rate. $VATFP\_I$ shows how the productivity of a certain industry increases or decreases throughout the years. I set $VATFP\_I_{ij1997} = 100$ for all i and j.

As in the case of the GGDC 1997 database, I need to aggregate some industries to make a proper connection between the EUKLEMS & INTANProd 2023 and the GGDC database. In particular, for the EUKLEMS database, I need to aggregate *(12) Manufacture of computer, electronic and optical products* and *(13) Manufacture of electrical equipment*. Also, I need to aggregate *(17) Electricity, gas, steam and air conditioning supply* and *(18) Water supply; sewerage, waste management and remediation activities*. To aggregate these, I use the relative sizes of the time-series average of weights based on value-added in current prices.

$$\begin{aligned} VATFP\_I_{ijt} = & \frac{1}{T}\sum_t [\frac{VA\_CP_{i1jt}}{VA\_CP_{i1jt} + VA\_CP_{i2jt}}] VATFP\_I_{i1jt} \\ & + \frac{1}{T}\sum_t \frac{VA\_CP_{i2jt}}{VA\_CP_{i1jt} + VA\_CP_{i2jt}} VATFP\_I_{i2jt}. \end{aligned} \tag{1.49}$$

Then, for each industry, I calculate the European average index as follows:

$$VATFP\_I_{iEUt} = exp(\frac{1}{12}\sum_j ln(VATFP\_I_{ijt})). \tag{1.50}$$

Several observations are missing in the dataset. For example, the US has missing observation for *Electricity, gas, steam and air conditioning supply* but has one with a different name (likely because of the different classification system). I use the one with the different name. Spain has missing observations on *Manufacture of computer, electronic and optical products*, *Manufacture of electrical equipment*, and *Computer, electronic, optical products; electrical equipment*. I supplement these with the growth rates of the closest industries. Lastly, Belgium has missing observations for the growth rate of all industries from 1995 to 1998. I supplement these using the European average only for missing periods.

Lastly, given the calculated growth rate for each industry across countries, by using each country's and Europe 12 countries' average growth rate, I calculate the relative productivity growth rate for each industry as follows:

$$\tilde{A}_{ijt} = \tilde{A}_{ij1997} \frac{VATFP\_I_{ijt}}{VATFP\_I_{iEUt}}. \tag{1.51}$$

1.C.4 Aggregation of Industries into Sectors

Once each industry's productivity (relative to the US) throughout the years is constructed, I again aggregate these relative productivities of those industries into tradable, nontradable, and construction sector productivities. When I aggregate industries into a sector, I use the value-added weighted average of all industries' relative productivities, which are in one of three sectors (tradable/nontradable/construction.) Table 1.C.3 shows which industry belongs to which sector.[35] This value-added approach is based on the *bottom-up* approach explained by Corrado et al. (2023). Since this allows the imperfect substitution of inputs between sectors, which is more realistic, I proceed using the bottom-up method.[36]

In addition, I use a statistical module rather than an analytical module for comparability with previous research. However, productivity series generated from the statistical module and analytical module (which incorporates intangible capital in calculating industry productivity) show correlation higher than 0.98 between them, which implies that this should not be a big issue.

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[35] For the US, for industry 13, I use *Electricity, gas, steam; water supply, sewerage, waste management*. For other countries, I use *Electricity, gas, steam and air conditioning supply, Water supply; sewerage, waste management and remediation activities*. This difference comes from different industry classification systems in the US and Europe.

[36] Corrado et al. (2023, p. 36) explain how the industry aggregation can be implemented. There are two methods, *direct calculation* and *bottom-up*. The *Direct calculation* approach assumes a perfect mobility of input across industries, that labor and capital earn the same compensation in all industries, and that all industries have the same value-added function. So they aggregate all capital input, labor input, and value-added to calculate the TFP growth of the aggregate sector. The *Bottom-up* appraoch assumes that inputs are not perfectly mobile. Consequently, it adds capital input, labor input, and value-added as averages calculated with the weights of capital income, labor income, and value-added of a certain industry with respect to total industry. The aggregate TFP calculated using this approach reflects the value-added weighted contribution of industry-level TFP.

Given $\tilde{A}_{ijt}$ for all industry i, for country j, we have the following relative sectoral productivities. Note that the construction sector is equal to the construction industry.

$$\tilde{A}_{Tjt} = \frac{\sum_{i\in T}(\bar{VA}_{ij}\tilde{A}_{ijt})}{\sum_{i\in T}\bar{VA}_{ij}}, \quad \tilde{A}_{NTjt} = \frac{\sum_{i\in NT}(\bar{VA}_{ij}\tilde{A}_{ijt})}{\sum_{i\in NT}\bar{VA}_{ij}}, \quad \tilde{A}_{CRjt} = \tilde{A}_{CRjt}. \tag{1.52}$$

By taking log to these $\tilde{A}_{Tjt}, \tilde{A}_{NTjt}$, and $\tilde{A}_{CRjt}$, we have

$$a_{Tjt} = log(\tilde{A}_{Tjt}), \quad a_{NTjt} = log(\tilde{A}_{NTjt}), \quad a_{CRjt} = log(\tilde{A}_{CRjt}). \tag{1.53}$$

1.C.5 Estimation of Sectoral Productivities

Given these a_{Tjt}, a_{NTjt}, a_{CRjt} time series for all countries, I estimate the following AR(1) process as home country productivity relative to foreign country productivity using data from 2000 to 2019:

$$\begin{aligned}
\alpha_{T,jt} - \bar{\alpha}_T &= \rho_T(\alpha_{T,jt-1} - \bar{\alpha}_T) + \epsilon_{h,jt}, \\
\alpha_{N,jt} - \bar{\alpha}_N &= \rho_N(\alpha_{N,jt-1} - \bar{\alpha}_N) + \epsilon_{n,jt}, \\
\alpha_{CR,jt} - \bar{\alpha}_{CR} &= \rho_{CR}(\alpha_{CR,jt-1} - \bar{\alpha}_{CR}) + \epsilon_{cr,jt}.
\end{aligned}$$

After we estimate $\bar{a}_{Tj}$, ρ_{Tj}, $\bar{a}_{NTj}$, ρ_{NTj}, $\bar{a}_{CRj}$, ρ_{CRj}, we convert it to quarterly frequency parameters as follows: $\bar{a}_{Tj} = \bar{a}^q_{Tj}$, $\bar{a}_{NTj} = \bar{a}^q_{NTj}$, $\bar{a}_{CRj} = \bar{a}^q_{CRj}$, and $\rho^q_{Tj} = \rho^{(1/4)}_{Tj}$, $\rho^q_{NTj} = \rho^{(1/4)}_{NTj}$, $\rho^q_{CRj} = \rho^{(1/4)}_{CRj}$.

Lastly, by using the estimated residuals of all processes, I estimate the covariance-variance matrix for all sectors and countries (3 sectors × 8 industries.) I allow any potential positive correlation between productivity shocks across countries and sectors. Following Berka et al. (2018), I assume that $var(\epsilon_{h,jt}) = var(\epsilon^q_{h,jt})$ for all sector s.

1.C.6 Comparison with Berka et al. (2018)

First, the industry classification used here and the one used by Berka et al. (2018) are very similar. However, there are some differences due to differences in the versions of the EUKLEMS database used. First, I combine *Wood and of wood and cork* with *Pulp, paper, paper printing, and publishing* to obtain *Manufacturing—Wood, paper, printing and reproduction.* Second, *Chemical, rubber, plastics and fuel* is decomposed into *Chemicals and chemical products* and *Rubber, plastics products, and other non-metallic products*. Lastly, I add *Education* and *Health and social work* to the industry list since they account for a certain portion of households' expenditure.

There are other differences as well too. First, Berka et al. (2018) used output-based productivity growth data, while my growth rate data are value-added-based. I use such measures because the EUKLEMS 2023 release only provides value-added-based productivity growth rates. Second, for aggregating industries' growth rate into that of the sector, I use the period-average of each industry's relative weight calculated based on the value-added of sectors, while Berka et al. (2018) use the relative weights based on sectoral output in 1995. Lastly, I use only 11 countries for the EU average, as those are the only available countries.

Table 1.C.1: Sectors in the GGDC 1997 TFP Level Database

	GGDC Industry Classification
1	**TOTAL INDUSTRIES**
2	*MARKET ECONOMY*
3	ELECTRICAL MACHINERY, POST AND COMMUNICATION SERVICES
4	Electrical and optical equipment
5	Post and telecommunications
6	GOODS PRODUCING, EXCLUDING ELECTRICAL MACHINERY
7	TOTAL MANUFACTURING, EXCLUDING ELECTRICAL
8	Consumer manufacturing
9	Food products, beverages and tobacco
10	Textiles, textile products, leather and footwear
11	Manufacturing nec; recycling
12	Intermediate manufacturing
13	Wood and products of wood and cork
14	Pulp, paper, paper products, printing and publishing
15	Coke, refined petroleum products and nuclear fuel
16	Chemicals and chemical products
17	Rubber and plastics products
18	Other non-metallic mineral products
19	Basic metals and fabricated metal products
20	Investment goods, excluding hightech
21	Machinery, nec
22	Transport equipment
23	OTHER PRODUCTION
24	Mining and quarrying
25	Electricity, gas and water supply
26	Construction
27	Agriculture, hunting, forestry and fishing
28	MARKET SERVICES, EXCLUDING POST AND TELECOMMUNICATIONS
29	DISTRIBUTION
30	Trade
31	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
32	Wholesale trade and commission trade, except of motor vehicles and motorcycles
33	Retail trade, except of motor vehicles and motorcycles; repair of household goods
34	Transport and storage
35	FINANCE AND BUSINESS, EXCEPT REAL ESTATE
36	Financial intermediation
37	Renting of m&eq and other business activities
38	PERSONAL SERVICES
39	Hotels and restaurants
40	Other community, social and personal services
41	Private households with employed persons
42	*NON-MARKET SERVICES*
43	Public admin, education and health
44	Public admin and defence; compulsory social security
45	Education
46	Health and social work
47	Real estate activities

Table 1.C.2: Sectors in the EUKLEMS 2023 Release

	EUKLEMS 2023 Industry Classification
1	**Agriculture, forestry and fishing**
2	**Mining and quarrying**
3	**Manufacturing**
4	Manufacture of food products; beverages and tobacco products
5	Manufacture of textiles, wearing apparel, leather and related products
6	Manufacture of wood, paper, printing and reproduction
7	Manufacture of coke and refined petroleum products
8	Manufacture of chemicals and chemical products
9	Manufacture of basic pharmaceutical products and pharmaceutical preparations
10	Manufacture of rubber and plastic products and other non-metallic mineral products
11	Manufacture of basic metals and fabricated metal products, except machinery and equipment
12	Manufacture of computer, electronic and optical products
13	Manufacture of electrical equipment
14	Manufacture of machinery and equipment n.e.c.
15	Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment
16	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment
17	**Electricity, gas, steam and air conditioning supply**
18	**Water supply; sewerage, waste management and remediation activities**
19	**Construction**
20	**Wholesale and retail trade; repair of motor vehicles and motorcycles**
21	Wholesale and retail trade and repair of motor vehicles and motorcycles
22	Wholesale trade, except of motor vehicles and motorcycles
23	Retail trade, except of motor vehicles and motorcycles
24	**Transportation and storage**
25	Land transport and transport via pipelines
26	Water transport
27	Air transport
28	Warehousing and support activities for transportation
29	Postal and courier activities
30	**Accommodation and food service activities**
31	**Information and communication**
32	Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities
33	Telecommunications
34	Computer programming, consultancy, and information service activities
35	**Financial and insurance activities**
36	**Real estate activities**
37	**Professional, scientific and technical activities**
38	**Administrative and support service activities**
39	**Public administration and defence; compulsory social security**
40	Public administration, defence, education, human health and social work activities
41	**Education**
42	**Human health and social work activities**
43	Human health activities
44	Residential care activities and social work activities without accommodation
45	**Arts, entertainment and recreation**
46	Arts, entertainment, recreation; other services and service activities, etc.
47	**Other service activities**
48	**Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use**
49	**Activities of extraterritorial organisations and bodies**

Table 1.C.3: Sectoral Concordance

	EUKLEMS Industry	GGDC Industry	Industry Name	Sector
1	1	27	Agriculture, hunting, forestry and fishing	T
2	2	24	Mining and quarrying	T
3	4	9	Manufacturing - Food products, beverages and tobacco	T
4	5	10	Manufacturing - Textiles, textile products, leather and footwear	T
5	6	13 14	Manufacturing - Wood, paper, printing and reproduction	T
6	7	15	Manufacturing - Coke, refined petroleum products and nuclear fuel	T
7	8	16	Manufacturing - Chemicals and chemical products	T
8	10	17 18	Manufacturing - Rubber, plastics products, and other non-metallic products	T
9	11	19	Manufacturing - Basic metals and fabricated metal products	T
10	12 13	4	Manufacturing - Computer, electrical and optical equipment	T
11	14	21	Manufacturing - Machinery, nec	T
12	15	22	Manufacturing - Transport equipment	T
13	17 18	25	Electricity, gas, water supply, and waste management	NT
14	19	26	Construction	C
15	20	30	Wholesale trade, retail trade, and repair of vehicles	NT
16	24	34	Transport and storage	NT
17	30	39	Hotels and restaurants	NT
18	31	5	Information, post and telecommunications	NT
19	35	35	Finance and Business activities	NT
20	36	47	Real estate activities	NT
21	39	44	Public admin and defense; compulsory social security	NM
22	41	45	Education	NT
23	42	46	Health and social work	NT

CHAPTER 2

The Effect of Housing on Portfolio Choice: House Price Risk and Liquidity Constraint

2.1 Introduction

Housing has gotten a lot of attention from researchers as the single most important asset[1] for most households, and the crowding-out effect of housing on households' risky financial investment has been extensively studied. Most argue that housing crowds out demand for risky financial assets via the *liquidity constraint channel* and the *house price risk channel* (Grossman and Laroque 1990, Cocco 2005, Yao and Zhang 2005, Flavin and Yamashita 2002). Specifically, the liquidity constraint channel means that households are forced to hold a significant portion of their wealth as a form of illiquid housing assets[2] rather than as a form of liquid financial assets. The house price risk channel means that households are exposed to unexpected changes in housing prices after purchasing a house, which increases the risk in their overall portfolio.

However, past studies were not able to examine the distinct influences of each channel independently, because households are exposed to both channels when they buy a

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[1] According to Yao and Zhang (2005), the 2001 Survey of Consumer Finance (SCF) showed that more than 66% of households own their houses, and the values of those houses account for 55% of their total wealth. In comparison, about 50% of households hold risky financial assets, and those account for only 12% of total wealth.

[2] Boar et al. (2022) found that in the US, four-fifths of homeowners are liquidity constrained and are willing to give up 13 cents, on average, for every additional dollar of liquidity extracted from their homes. This demonstrates the substantial illiquidity of housing assets—and in countries with less developed housing finance markets, the illiquidity should be even more severe than that of the US.

house. Though Cocco (2005) and Yao and Zhang (2005) conducted brief assessments of the independent role of the house price risk channel, they did so by using model comparative statics rather than actual data and the heterogeneous implications of these two channels on different types of households were not completely investigated.

Without understanding the distinct influences of both channels independently, we cannot determine how housing choice differently affects households' stock investment depending on household characteristics such as age or liquidity constraints. Also, since the relative magnitude of each channel can differ depending on the household's characteristics, understanding each channel's contribution to the total crowding-out effect is important.

In this paper, I contribute to the literature by studying the separate influences of the two channels independently. I exploit a unique housing tenure type known as *jeonse*, which is unique to South Korea, to resolve this identification issue. Jeonse is a housing contract between a landlord and a jeonse tenant. At the beginning of the contract, they agree on the contract period and the size of the jeonse deposit. Usually, the contract period is 2 years and the jeonse deposit size is around 60%-70% of the house price. Once they agree, the jeonse tenant pays the jeonse deposit to the homeowner. In return, the jeonse tenant can reside in the house for the agreed contract period, and does not have to pay any rent during the contract period. Once the contract is finished, the homeowner must return exactly the same amount of jeonse deposit to the jeonse tenant, and the jeonse tenant must leave the house. In some sense, this is collateralized lending in which house is used as collateral and the housing service from the houses is interest. In this paper, I examine the crowding-out effect of housing from the jeonse tenant's perspective, and do not consider the landlord's problem.

On the one hand, households that use jeonse contracts for housing service effectively expose themselves to the liquidity constraint channel because in most cases, the jeonse deposit amounts to 60%-70% of the house price. Consequently, for most households using jeonse contracts, this deposit accounts for most of their net wealth or is even larger than their net wealth, which forces them to use the mortgage loan for preparing to pay the jeonse deposit. This means that a significant portion of their net wealth remains in the form of an illiquid jeonse deposit.

On the other hand, households that use jeonse contracts as tenants are not exposed to the house price risk channel because they will receive their jeonse deposit without any change. Unlike housing purchase, there is no uncertainty regarding how much they will get back. This effectively eliminates the house price risk channel and adds no additional risk to their overall portfolio.[3]

Given these jeonse contracts' unique nature, by comparing the portfolio patterns of renter and jeonse tenant, we can observe the crowding-out effect of jeonse, which is caused only via the liquidity constraint channel. In addition, if we compare the jeonse tenants' stock investment behavior with that of homeowners, it will demonstrate the additional role of the house price risk channel.

Surely, these all are endogenous choices. To clearlyăsee the separate effects of the two channels while controlling for the characteristics of households such as age, human capital, or level of wealth, I augment the life-cycle portfolio choice model used by Cocco (2005) and Yao and Zhang (2005). Whereas the models in those papers have only either a stock market participation cost or an endogenous housing tenure choice, my model features both components. In addition, to incorporate the intermittent exit and entry of households in the stock market, as in Brandsaas (2018), I use per-period stock market participation cost. Adding jeonse contract as a viable housing tenure option is also new to the literature.

The model implies a heterogeneous crowding-out effect, depending on households characteristics. I show that as households get less liquidity constrained, the crowding-out effect of jeonse, which consists of only the liquidity constraint channel, goes away. This means that young households or households with low wealth-to-income ratios are more likely

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[3] If homeowners refuse to pay back the jeonse deposit, the jeonse tenant has the right to auction the homeowner's house and get their money back. Because it is rare that a house price goes down lower than the jeonse deposit, most households in South Korea consider this contract to be risk free.

to be affected by this liquidity constraint channel. This is because young households and households with low wealth-to-income ratios have the largest portion of their lifetime wealth in the form of illiquid future labor income and only scant liquid assets.[4] Those types of households already suffer from the liquidity constraint, and the jeonse contract imposes additional liquidity constraints on them. On the other hand, the house price risk channel affects all types of households, and the effect does not disappear even though households are not at all liquidity constrained. Also, my results show that the magnitude of the house price risk channel is related to the covariance structure between housing return and stock return.

To see whether such patterns exist in the data, I analyze the South Korean household panel survey, which contains comprehensive information on the households housing tenure choices and risky financial asset holdings. By using two-way fixed effects, I estimate the crowding-out effect of jeonse and homeownership while controlling for individual fixed components such as attitude toward the stock market, peer effects, knowledge about the stock market, or year-specific components such as stock market boom in certain years.

I find that the crowding-out effect of from jeonse is weak and not recognizable for the jeonse tenants who are old or have high wealth-to-income ratios. Whereas the jeonse housing tenure indicator variables interacted with dummy variables for young households or households with low wealth-to-income ratio have a significant negative effect on risky financial asset holdings, when interacted with dummy variables for old households or households with high wealth-to-income ratios, they do not show any significant effects. Being a jeonse tenant decreases the risky financial asset over net wealth ratio (hereafter RFAR) by 0.8% for households in the bottom 20th to 40th percentiles of the net wealth-to-income ratio, and decreases the RFAR by 0.59% for households in the bottom 0th to 20th age percentiles. Since the renters' average RFAR is

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[4] Note that, in a life-cycle perspective, lower wealth-to-income ratio implies that the sum of their future incomes is relatively larger than what they currently have as a current liquid wealth. Usually, young households show low wealth-to-income ratios.

0.87% (including households not participating in stock market), this is an economically significant effect. However, for households in the top 20th percentile of the net wealth-to-income ratio or households in the top 20th percentile of the age, there is no crowding-out effect of being a jeonse tenant.

On the other hand, the crowding-out effect of homeownership, which likely contains the influence of both the house price risk channel and the liquidity constraint channel, persists and has a significantly negative effect on risky financial asset holdings. Homeownership decreases the RFAR by 0.78%, even for households in the top 20th percentile of the net wealth-to-income ratio and decreases the RFAR by 0.62% for households in the top 20th age percentile. The house price risk channel thus affects all types of households.

Model predictions and data patterns are consistent regarding the crowding-out effect of jeonse, which effectively only concerns the liquidity constraint channel. As households get wealthier or older, they are less affected by the liquidity constraint channel; they are affected more when they are young or have less present net wealth. This is the first paper to empirically suggest the evidence regarding the the existence of the liquidity constraint channel separate from the house price risk channel.

For the crowding-out effect of homeownership that contains both channels influences, data and model predictions are consistent in the sense that homeownership is predicted to affect all types of households. One notable difference is that while the model predicts that the crowding-out effect from homeownership gets smaller as households get less liquidity constrained, the data show that the effect does not decrease and, instead, increases. This is likely coming from the fact that richer households purchase more expensive houses, and more expensive houses' prices are more correlated with stock returns. This is because these houses prices behave more like financial assets, being more procyclical and volatile, since they are often purchased by investors and not normal households. This effectively increases the correlation between housing prices and stock returns, and the model predicts that higher correlation results in the larger crowding-out effect. To perfectly match the data, the model should feature different types of correlation structures of housing returns with stock returns, depending on the house price level, and this is not considered in my model.

In Section 2, I explore previous studies and describe in what respects my research differs. In Section 3, I explore the mechanism and economic significance of jeonse contracts. After that, I explain the liquidity constraint channel and house price risk channel in more detail. At the end of the section, I explain why jeonse contracts are only related to the liquidity constraint channel and how I will exploit jeonse to decompose these two main channels of the crowding-out effect. In Section 4, I set up the life-cycle portfolio choice model and examine what it says about these two main channels of the crowding-out effect. In Section 5, by using Korean household panel survey data, I empirically study the crowding-out effect. In Section 6, I compare and discuss the implications from the model and data analysis, and I conclude in Section 7.

2.2 Literature

This paper is related to the effect of housing on households' portfolio choices, especially risky financial asset demands. In an early paper, Grossman and Laroque (1990) analyzed household portfolio choices with durable consumption goods. They propose a household that consumes a single durable good and assume that the household needs to pay an adjustment cost when it adjusts its consumption of durable goods. They argue that the optimal consumption policy is characterized by three values: Two are threshold values and the other is the optimal consumption level. The interval created by the two threshold values always contains the optimal consumption level. Whenever a household changes the consumption level, it tries to target the optimal consumption level. However, the household decides to change the consumption level only when their current consumption level is out of the interval created by the threshold values. Though their current consumption level is not equal to the optimal consumption level, if the value is within the interval constructed by the threshold values they decide not to change their consumption level because the adjustment cost is too high. Then, for portfolio choice, the authors argue that a household becomes less risk-averse when their consumption level is closer to the threshold values and becomes more risk-averse when their consumption level is closer to the optimal consumption level. My model also captures such optimal housing consumption behavior. Once a household purchases a house, they sell it only when its value deviates too far from the optimal consumption level, which means that my model also contains the effect of housing on the investment decision Grossman and Laroque (1990) discuss.

Faig and Shum (2002) argue that households are more likely to hold liquid assets if they have some illiquid projects that require constant financing in the future. They also use 1995 Survey of Consumer Finance to do cross-section regression to see the effect of these projects such as a small business or home purchase. Their model predicts that more productive personal projects and larger penalties from discontinuing induce households to be risk-averse. Because housing is also one of the most important illiquid assets, Faig and Shum (2002) show that housing can crowd out risky financial asset investment.

Flavin and Yamashita (2002) solve a static portfolio choice problem given the house value over net wealth as a state variable. They assume that households are leveraged for this home purchase. Their model predicts that under reasonable risk aversion, high house value over net wealth (i.e, young households) induces households to hold a smaller ratio of risky assets compared with low house value over net wealth (i.e, old households). Their leveraged position increases the risk, which causes households to respond by reducing their stock holdings. Also, the leveraged position due to the mortgage actually induces the household to change not only the portfolio choice between risky asset and risk-free assets, but also the portfolio choice over risky assets.

The first comprehensive life-cycle context analysis for the effect of housing on portfolio choice was made by Cocco (2005). He finds that, due to a huge down payment for housing purchase, households end up having limited financial wealth to invest in stocks. This is connected to the liquidity constraint channel in this paper, which reduces the benefits of stock market participation. Consequently, with the fixed costs of stock market participation, households choose not to participate. Also, in their model, the house price risk channel crowds out stock holdings, and this effect is larger for households with low financial net worth. Though Cocco (2005) suggests these two important concepts, he only shows the empirical evidence on the crowding-out effect as a whole, not by component. In addition, he considers only homeowners without the endogenous choice of housing tenure, which is important for understanding the size of the crowding-out effect.

On the other hand, Yao and Zhang (2005) make housing tenure choice endogenous in their life-cycle model so that households in the model can choose between renting and owning. They compare renters and homeowners, and obtain results similar to those of Cocco (2005). They also show how the low correlation between housing return and stock return generates the diversification effect, so that homeowners have a higher stock ratio over financial assets than renters.

Whereas Yao and Zhang (2005) explain the joint mechanism of housing tenure choice and stock investment choice, their model cannot explain the stock market participation puzzle. Their model predicts that renters should participate in the stock market more aggressively than homeowners because expected labor income is a close substitute for safe bonds. However, the data show that homeowners participate in the stock market more and hold more stocks than renters in general. Vestman (2019) explains this puzzle. To make the model compatible with these patterns in the data, he introduces preference heterogeneity with Epstein-Zin preferences and participation cost heterogeneity. He argues that though a crowding-out effect exists in theory, the main forces that shape the joint distribution of the homeownership rate and stock market participation rate in the data are the preference heterogeneity and heterogeneous stock market participation costs. High-saving-type households save much throughout their lifetime, which naturally gives them incentives to participate in the stock market and to become homeowners, while low-saving-type households save less, which leads them to remain renters and not participate in the stock market with their limited savings.

My paper is closest in spirit to these two papers, Yao and Zhang (2005) and Vestman

(2019). As a new contribution, I add another housing tenure type—jeonse,—and provide the actual portfolio choice data pattern from household-level panel survey data, and especially for jeonse tenants. As a result, I newly contribute to the literature by studying the liquidity constraint channel and the house price risk channel separately. In addition, I study the heterogeneous effects from the liquidity constraint channel and house price risk channel with respect to household characteristics, such as age and net wealth-to-income ratio, in the data.

2.3 A Unique Korean Housing Tenure Type: Jeonse

In this section, I explain the contract structure of jeonse[5] and how I decompose the crowding-out effect into the liquidity constraint channel and the house price risk channel. Note that I do not focus on why the jeonse contract emerged in South Korea (Kim 2013), the general equilibrium effect of jeonse contracts (Shin and Kim 2013), or how the jeonse deposit size is determined (Jing et al. 2022). I instead study the portfolio choice of households given a jeonse contract as one of the possible housing tenure choices. Consequently, I only focus on how a jeonse contract is processed, and what it means for households, not the aggregate economy.

When households make jeonse contracts, potential jeonse tenant and homeowner decide the size of the jeonse deposit and the contract period. At the beginning of the contract, the jeonse tenant gives a jeonse deposit to the landlord. After that, the jeonse tenant lives in the house for a period predetermined by the contract. During the period, the jeonse tenant does not have to pay any rent or they pays little rent compared with a conventional rent contract. After the contract period ends, the landlord must return exactly the same amount of money to the jeonse tenant, and the jeonse tenant must leave the house. Jeonse can be understood as a contract that has characteristics of both conventional rent and home-ownership.

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[5] In other papers, this is referred to as *chonsei* or *chonsae*. I use "jeonse" throuhgout this paper.

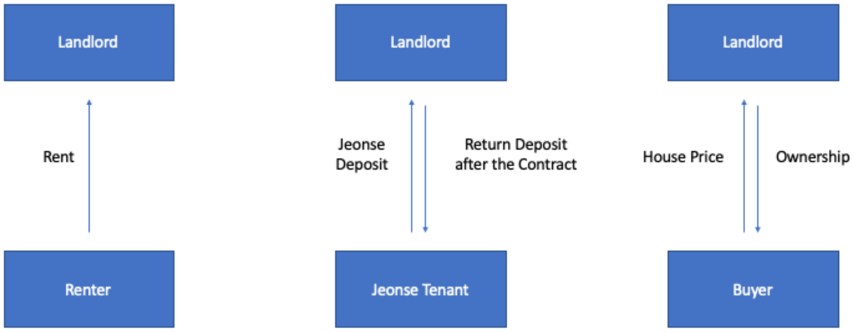

Figure 2.3.1: Housing Tenure Contracts

The unique structure of the jeonse contract represented in Figure 2.3.1 allows me to identify the liquidity constraint channel separate from the house price risk channel. First, jeonse tenants face the large liquidity constraint channel when they make a jeonse contract. The national average jeonse deposit size from 2012 to 2019 was about 66.7% of the house price, according to the Korea Appraisal Board. In addition, there is a mortgage market for jeonse tenants similar to that of home purchasers in Korea. Consequently, if we think in terms of down payment, the jeonse contract also requires a huge amount of down payment, like a housing purchase contract does. Assuming that households transition from a rent contract to jeonse contract, we can easily imagine that they should experience a substantial liquidity constraint channel.[6]

Second, jeonse tenants are not exposed to the house price risk channel. Since they are guaranteed to receive, at the end of the contract, the same amount of deposit they paid at the beginning of the contract, they do not have to worry about the house price risk channel. Even though they are exposed to the rent fluctuation risk as shown in Sinai and Souleles (2005), we can still say that they are exposed to the same rent risk

---

[6] If we assume that the house price is $1,000,000 and the jeonse deposit ratio is 65%, households need to come up with $650,000. If the mortgage down payment ratio is 20% for any mortgage product, home buyer's mortgage down payment will be $200,000 while the jeonse tenant's mortgage down payment is $130,000. It shows that it takes substantial amount of money to initiate the jeonse contract even though households use the mortgage.

a renter is exposed because they have to renew the contract, which is usually every 2 years. I naturally conclude that households that transition from rent to a jeonse contract experience the liquidity constraint channel only and not the house price risk channel. [7]

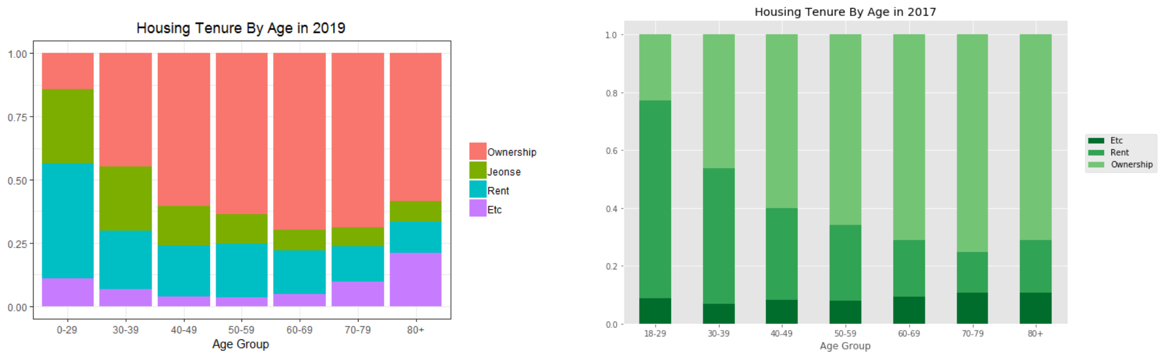

Figure 2.3.2: Housing Tenure Distribution in South Korea (Left) and the U.S. (Right)

Figure 2.3.2 is the life-cycle pattern of housing tenure choice in Korea and the United States. The data are from the 2017 Survey of Consumer Finance (hereafter SCF) and the 2019 Korean Survey of Household Finances and Living Conditions (hereafter SHFLC). We can see that the jeonse contract does account for a significant portion of housing tenure types in Korea. Also, many young households in Korea start as renters while saving money for a jeonse deposit down payment. After they save enough amount of money for a jeonse deposit down payment, they transition to a jeonse contract while saving more money. After that, most households transition to homeownership. In particular, this life-cycle pattern implies that the crowding-out effect of housing on stock holdings will be more pronounced among young households that have small savings and seek to purchase a house using a mortgage.

---

[7] Default by landlords can be one potential risk to jeonse tenants. However, according to statistics from the Korea Housing and Urban Guarantee Cooperation (hereafter HUG), the number of landlord default cases in 2016 they worked on was 23, while the number was 258 in 2018. Though there has been a rapid increase in cases recently, it is very still low compared with the total number of jeonse contracts; the monthly average of the number of jeonse contracts is roughly 100,000 nationally. In addition, HUG and Seoul Guarantee Insurance (SGI) provide good insurance products for jeonse contracts, which leads me to assume that households are not concerned about landlord default when they make a jeonse contract.

2.4 Model

To understand the mechanism behind the joint life-cycle decision on housing tenure choice, stock market participation, and the implied crowding-out effect, based on Vestman (2019), Yao and Zhang (2005), and Cocco (2005), I present a quantitative life-cycle model in which households endogenously choose whether to rent, make a jeonse contract, or purchase a house. In addition, households decide how much to consume, save, and invest in risky assets. The labor income process, risky asset return process, and housing return process are exogenous in this model, which renders it a partial equilibrium model.

2.4.1 Demographics and Risks

Households start their lives at 30 and die for sure at 100. In the model, one period (a) corresponds to 2 years, which is a conventional rent and jeonse contract periods. Consequently, households will solve a 35-period problem that corresponds to 70 years. At every period, they face the mortality risk, which causes them to die in the next period with probability π_a. Accordingly, $1-\pi_a$ means the probability that the household survives and continuously solves the household problem in the next period $a+1$ conditional on the households surviving until age a.

2.4.2 Labor Income Process

Following Yao and Zhang (2005), the labor income process has an age-dependent deterministic growth rate of $[g_a]_{a=1}^{a=35}$. In addition, its growth rate is under an identically and independently distributed Gaussian shock, denoted as ν_{a+1}. I also include two other shocks, ϵ^o_{a+1} and n^o_{a+1}, which are perfectly correlated WITH ϵ_{a+1} and n_{a+1}. These are for generating correlations between labor income growth, stock return, and housing return, which is a structure also used by Vestman (2019). In the following formula, in which Y_{a+1} is the labor income (or can be interpreted as the non-capital income) level, we have a full characterization of the labor income process.

$$log(Y_{a+1}) - log(Y_a) = g_{a+1} + \nu_{a+1} + \epsilon^o_{a+1} + n^o_{a+1}, \text{ for } a = 0, 1, ..., 34 \tag{2.1}$$

Unlike the specification in Cocco (2005), this process allows only transitory shock to the growth rate of labor income.e., A permanent shock to labor income level. Lastly, I assume that households retire at age 64, which is the most common retirement age in Korea. Once the household retires, they only receive λ portion of the labor income they received right before retirement, and thereafter receive the same amount as a retirement pension until their death.

$$Y_{17} = \lambda Y_{16} \tag{2.2}$$

$$Y_{a+1} = Y_a, \quad a \geq 17 \tag{2.3}$$

2.4.3 Stock Returns

Stock returns are assumed to follow a normal distribution with constant risk premium μ. Specifically, R_{a+1} is the gross stock return households will experience at age $a+1$. R_f is the gross risk-free rate, and μ is the log risk premium. Stock return innovation ϵ_{a+1} follows i.i.d. normal distribution with mean zero. Note that ϵ_{a+1} is perfectly correlated with ϵ^o_{a+1} in the labor income growth rate process, which will generate correlation between labor income growth and stock returns. The following formula fully characterizes the stock return process in the model.

$$log(R_{a+1}) - log(R_f) = \mu + \epsilon_{a+1} \tag{2.4}$$

2.4.4 Housing Returns

Housing returns are assumed to be similar to stock returns. However, as in the labor income process, to assume a correlation between the stock return and house price growth rate, I include additional term ϵ^H_{a+1}, which is perfectly correlated with ϵ_{a+1}. Specifically, P^H_{a+1} is the unit house price that households face at age $a+1$, μ_H is the mean housing return, and housing return shock n_{a+1} follows i.i.d. mean zero normal distribution. So the following characterizes the housing return process:

$$log(P^H_{a+1}) - log(P^H_a) = \mu_H + n_{a+1} + \epsilon^H_{a+1} \tag{2.5}$$

2.4.5 Bequest Motive

Whenever households die, it is assumed that their descendants spend their remaining asset and households get utility from their descendants' utility. This is a common feature that appears in most life-cycle models to match the saving behaviors of old households. X_{a+1} represents the asset left to the descendants, α_f represents the annuity factor, and $\alpha_f X_{a+1}$ accordingly represents the money descendants receive every period for T_b periods. Consequently, α_f is a function of T_b given interest rate R_f. I assume that the bequeathed wealth will always be invested 50-50 in risky and risk-free assets. Then, every period, this money is optimally used by descendants, who have the same Cobb-Douglas utility functions over consumption and housing. Consequently, the utility households receive from bequeathing is the following. This approach is similar to that of Yao and Zhang (2005).

$$\sum_{k=1}^{T} \beta^k (\alpha_f X_{a+1}(1-\omega))^{1-\omega} (\frac{\alpha_f X_{a+1}\omega}{\tau P^H_a})^{\omega} \tag{2.6}$$

2.4.6 Preference

Given the above specifications, I define the household's finite horizon problem formally. Households have Cobb-Douglas preference over a non-durable consumption good C_a and durable housing good H_a where ω denotes the expenditure share for the housing good. Households have CRRA utility function over the combined consumption.

2.4.7 First-stage Problem

At the beginning of each age period, households solve the first-stage problem regarding the housing tenure choice. Depending on whether households purchased the house in the previous period or not (also whether they received a moving shock or not), households solve either the owner's problem or the non-owner's problem.

2.4.7.1 The Owner's Problem

For the owner, state variables are cash-in-hand X_a, which is the sum of net wealth and contemporaneous labor income (or can also be understood as non-capital income); the labor income Y_a; the quantity of housing purchased in previous period H_{a-1}; and the unit price of housing good P_a^H. In addition, I assume that households have information about the probabilistic structures of stock and housing return processes and labor income shock processes. Also, households know the deterministic future life-cycle profile of the labor income growth rate. Owners who chose to buy a house in the previous period and did not get the exogenous moving shock solve the following problem:

$$\widehat{V_a}(X_a, H_{a-1}, Y_a, P_a^H) = \max(\bar{V}_a(X_a, Y_a, P_a^H), V_a^s(X_a, H_{a-1}, Y_a, P_a^H)) \tag{2.7}$$

Here, they can sell the house and move back to the non-owner's problem, or they can solve the stayer's problem by deciding to stay. Here, $\widehat{V_a}$ denotes the optimal utility households can achieve as an owner at age a. Similarly, $\bar{V}_a$ represents the optimal utility of a non-owner, and V_a^s is the optimal utility that households can achieve by staying in the previously purchased house. By choosing the maximum value between these two value functions, households effectively decide which housing tenure to choose.

2.4.7.2 The Non-owner's Problem

Non-owners who chose to rent or to enter a jeonse contract and moving owners who chose to sell solve the following problem.

$$\bar{V}_a(X_a, Y_a, P_a^H) = \max(V_a^r(X_a, Y_a, P_a^H), V_a^j(X_a, Y_a, P_a^H), V_a^b(X_a, Y_a, P_a^H)) \tag{2.8}$$

Here, $V_a^r(X_a, Y_a, P_a^H)$ means the optimal value households can achieve under the constraint whereby households must rent. $V_a^j(X_a, Y_a, P_a^H)$ and $V_a^b(X_a, Y_a, P_a^H)$ represent the counterparts for jeonse contract and purchasing. Again, by choosing the maximum value among these three value functions, households effectively decide which housing tenure to choose.

2.4.8 Second-stage Problem

After households solve the first-stage problem, depending on their housing tenure choice (rent, jeonse, purchase, stay), they solve the second-stage problem in which they choose the optimal level of consumption, housing value, saving, and risky asset share. The problems solved by households with different housing tenure types are described below.

2.4.8.1 The Renter's Problem

Households that decide to rent a house solve the following problem:

$$\begin{aligned} V_a^r(X_a, Y_a, P_a^H) = & \max_{C_a, H_a, A_a, \alpha_a} \frac{(C_a^{1-\omega} H_a^{\omega})^{1-\sigma}}{1-\sigma} + \beta E_a[(1-\pi_a)\bar{V}_{a+1} + \pi_a \alpha_3 (\frac{X_{a+1}}{(P_a^H)^{\omega}})^{1-\sigma}] \\ s.t \qquad & X_a \geq A_a + C_a + \tau P_a^H H_a + 1[\alpha_a > 0]\gamma Y_a \\ & X_{a+1} = A_a R_f + \alpha_a A_a (R_{a+1} - R_f) + Y_{a+1} \\ & \alpha_a \in [0,1], \ A_a \geq 0, \ C_a \geq 0, \ H_a \geq 0 \end{aligned}$$

C_a represents non-durable consumption, H_a represents the quality of house to live in, A_a represents the amount of savings, and α_a represents the share of financial savings invested in risky financial assets. Since this is the problem solved by households that decide to rent for this period, they are expected to solve the non-owner's problem and to get $\bar{V}_{a+1}$ in the next period. τ is the rent-to-price ratio.

One thing to note here is the stock market participation cost γ. A one-time stock market participation cost has been used in many papers, such as by Haliassos and Michaelides (2003) and Gomes and Michaelides (2005), to explain the fact that many households do not participate in the stock market. However, a one-time stock market participation cost often fails to explain the intermittent stock market participation studied by Fagereng et al. (2017) and Brandsaas (2018). Thus, I use a per-period stock market participation cost specification.

Lastly, I use a stock market participation cost proportional on income Y_a. Once households invest in the stock market, they often spend time on investing by checking brokerage accounts or finding new information, which supports the proportional participation cost I used here with opportunity cost interpretation. These types of participation costs can be found in numerous papers, such as by Alan (2006), Ball (2009), and Gomes and Michaelides (2008).

2.4.8.2 The Jeonse Tenant's Problem

Households that decide to make a jeonse contract solve the following problem:

$$\begin{aligned} V_a^j(X_a, Y_a, P_a^H) = & \max_{C_a, A_a, H_a, \alpha_a} \frac{(C_a^{1-\omega} H_a^{\omega})^{1-\sigma}}{1-\sigma} + \beta E_a[(1-\pi_a)\bar{V}_{a+1} + \pi_a \alpha_3 (\frac{X_{a+1}}{(P_t^H)^{\omega}})^{1-\sigma}] \\ s.t. \qquad & X_a \geq A_a + C_a + (\delta_J + \phi_J)\bar{J} P_a^H H_a + 1[\alpha_a > 0]\gamma Y_a \\ & X_{a+1} = A_a R_f + \alpha_a A_a (R_{a+1} - R_f) + Y_{a+1} + P_a^H H_a \bar{J}(1-(1-\delta_J)R_M) \\ & \alpha_a \in [0,1],\ A_a \geq 0,\ C_a \geq 0,\ H_a \geq 0,\ X_a \geq \delta_J \bar{J} P_a^H \underline{H} \end{aligned}$$

Note that the value function form is the same as that of a renter, except for the budget constraint. From the budget constraint, we can see that households have to pay for housing service in a different way. $\bar{J}$ represents the ratio of jeonse deposit to house price, and δ^J denotes the down-payment ratio for using a jeonse mortgage. Lastly, ϕ_J is the transaction cost for a jeonse contract. So, unlike renters, they pay a substantial amount of money to the landlord. I add an additional constraint whereby cash-in-hand X_a should be larger than the down payment for a jeonse deposit for minimum quality housing $\underline{H}$. Consequently, we have $X_a \geq \delta_J \bar{J} P_a^H \underline{H}$.[8] Even for the lowest quality of housing, the average jeonse deposit is the size of a multiple of the average worker's annual income, which is why many households cannot choose jeonse.

Another thing to note is that, in the law of motion of net wealth, households receive back the exact same amount of jeonse deposit they paid in the previous period, which means there is no house price risk for jeonse tenants. Here, the mortgage structure is continuous refinancing. To make model tractable, I assume that after one period, households pay interest rate R_M, receive the down-payment they paid, and decide to refinance or not depending on their next-period housing tenure choice.

2.4.8.3 The Buyer's Problem

Households that decide to buy a house solve the following problem:

$$
\begin{aligned}
V_a^b(X_a, Y_a, P_a^H) = \max_{C_a, A_a, H_a, \alpha_a} \; & \frac{(C_a^{1-\omega} H_a^{\omega})^{(1-\sigma)}}{1-\sigma} + \beta E_a[(1-\pi_a)(\xi \bar{V}_{a+1} + (1-\xi)\hat{V}_{a+1}) + \pi_a \alpha_3 (\frac{X_{a+1}}{(P_a^H)^{\omega}})^{1-\sigma}] \\
s.t \qquad & X_a \geq A_a + C_a + (\chi + \delta + \phi_b) P_a^H H_a + 1[\alpha_a > 0]\gamma Y_a \\
& X_{a+1} = A_a R_f + \alpha_a A_a (R_{a+1} - R_f) + Y_{a+1} + P_a^H H_a (R_{a+1}^H (1-\phi) - (1-\delta) R_M) \\
& \alpha_a \in [0,1], \; A_a \geq 0, \; C_a \geq 0, \; H_a \geq 0, \; X_a \geq \delta P_a^H \underline{H}
\end{aligned}
$$

Note that now households expect two types of future value functions in the next period. If they do not receive a moving shock, they are expected to solve the owner's problem

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[8] In the normalized model, I impose $\frac{X}{Y} \geq 1.064$ based on the median household income and the median jeonse deposit for an apartment in 2015.

$\widehat{V}_a$ in the next period. On the other hand, if they receive a moving shock, they solve the non-owner's problem $\bar{V}_a$. As an owner, households should pay the maintenance cost χ. In addition, households should buy houses through a mortgage to obtain a housing service, where δ is the down-payment ratio and ϕ is a transaction cost. Here, household wealth in the next period depends on the house price realization in the next period, R^H_{a+1}, which can be interpreted as a house price risk. I add a down-payment constraint similar to that in the jeonse tenant's problem.[9]

One last thing to note is that households actually pay the selling cost ϕ in the next period regardless of whether they get a moving shock and decide to sell. This is for tractability of the model. If households decide to stay in the house they purchased previously in the next period, they will be compensated for this cost.

2.4.8.4 The Stayer's Problem

If households decide to stay in the house they purchased before, they take H_{a-1} into account as an additional state variable and solve the following problem:

$$\begin{aligned}
V^s_a(X_a, Y_a, P^H_a, H_{a-1}) = \max_{C_a, A_a, \alpha_a} \frac{(C_a^{1-\omega} H_{a-1}^{\omega})^{(1-\sigma)}}{1-\sigma} &+ \beta E_a[(1-\pi_a)(\xi \bar{V}_{a+1} + (1-\xi)\hat{V}_{a+1}) + \pi_a \alpha_3 (\frac{X_{a+1}}{(P^H_a)^{\omega}})^{1-\sigma}] \\
s.t \qquad X_a &\geq A_a + C_a + (\chi + \delta - \phi) P^H_a H_{a-1} + 1[\alpha_a > 0]\gamma Y_a \\
X_{a+1} &= A_a R_a + \alpha_a A_a (R_{a+1} - R_f) + Y_{a+1} + P^H_a H_{a-1}(R^H_{a+1}(1-\phi) - (1-\delta) R_M) \\
\alpha_a &\in [0,1],\ A_a \geq 0,\ C_a \geq 0
\end{aligned}$$

Notice that the value function structure is the as that in the buyer's problem; the only difference is that households get compensated for selling cost ϕ. In addition, they do not have to pay the buying cost ϕ_b. This captures the benefit of staying in the same house, which comes from being exempt from adjustment costs.

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[9] In the normalized model, I impose $\frac{X}{Y} \geq 1.7304$ based on the median household income and the median apartment price in 2015.

2.4.9 Solution Method

Since this model is a finite-horizon problem, we can solve it through backward induction. At the last period, since households surely die, they solve an optimization problem with a trade-off between bequest and consumption only, which is a simple one-period problem. After solving the last-period value functions, we move backward and solve the problem of one period before the last period, given these last-period value functions. I use a grid method and standard linear interpolation for next-period value functions. Shocks are discretized via Gaussian quadrature. In addition, before actually solving the problem, to reduce the number of state variables I normalize the value function with $\frac{X_a}{(P_a^H)^\omega}$ and choice variables with X_a so that the policy variables will be $c_a = C_a/X_a$, $a_a = A_a/X_a$, $h_a = (P_a^H H_a/X_a)$, and $\alpha_a = \alpha_a$ following Yao and Zhang (2005).

2.5 Calibration

For most of the parameters, I externally calibrate by using the data counterpart of the corresponding periods. For example, for π, I use the 2020 Life Table from Statistics Korea. Regarding household preference parameters, including discount factor β, concavity of the utility function σ, housing expenditure ratio ω, bequest motives T_b, and stock market participation cost γ, I follow the parameter values used by Gomes and Michaelides (2005); Yao and Zhang (2005); Vissing-Jorgensen (2002); and Gomes and Michaelides (2008).

For other housing tenure-relevant parameters such as τ and $\bar{J}$, I use the sample average of periods from 2012 to 2018 with aggregate time-series data from the Korea Real Estate Board. For δ and δ_J, using the Survey of Household Finances and Living Conditions (SHFLC), which is another survey that contains detailed information on households' mortgage debt, I collect households that actually transitioned from rent to jeonse or homeownership through mortgage, and calculate the weighted average of their initial loan-to-value ratios according to the survey weight. Lastly, for ϕ_J, χ, ϕ_b, and ϕ, I use the acquisition tax rate, brokerage fee for each housing tenure, and the 2015 wealth tax law.

For progressive taxes, I use the tax rate for the house price for the bin containing the largest number of houses' market values in the data.

Moving to asset returns, for R_f I use the rate for the average 2-year saving deposit rate across banks from 2012 to 2018 and for μ, μ_h, σ_ϵ, and σ_h, I use the KOSPI index and national housing price index statistics from Korea Real Estate Board for the period from 2004 to 2018 in my calculations, since these concerns households' expectations, and the longer periods capture the property of exogenous price processes more realistically.

Calibrated Parameters 1		**Value**	**Source**
Discount Rate	(β)	0.96^2	Gomes and Michaelides (2005)
CRRA Parameter	(σ)	5	Gomes and Michaelides (2005)
Housing Expenditure	(ω)	0.2	Yao and Zhang (2005)
Bequest Period	(T_b)	20/2	Yao and Zhang (2005)
Participation Cost	(γ)	2*0.0057	Vissing-Jorgensen (2002) & Gomes and Michaelides (2008)
Calibrated Parameters 2		**Value**	**Source**
Rent to House Price Ratio	(τ)	2*0.035	Korea Real Estate Board (2012-2018).
Jeonse Deposit to House Price Ratio	$(\bar{J})$	0.645	Korea Real Estate Board (2012-2018)
Down Payment Ratio for Jeonse	(δ_J)	0.416	SHFLC (2012-2018)
Down Payment Ratio for Home Purchase	(δ)	0.482	SHFLC (2012-2018)
Jeonse Contract Cost	(ϕ_J)	0.003	Brokerage Fee (Jeonse) (2015)
House Purchase Cost	(ϕ_b)	0.0165	Acquisition Tax + Brokerage Fee (Purchase/Sell) (2015)
Selling Cost	(ϕ)	0.004	Brokerage Fee (Purchase/Sell) (2015)
Maintenance Cost	(χ)	2*0.003	Wealth Tax (2015)
Calibrated Parameters 3		**Value**	**Source**
Gross Risk Free Rate	(R_f)	1.023^2	Bank of Korea ECOS (2012-2018)
Gross Mortgage Rate	(R_M)	1.047^2.	Bank of Korea ECOS (2012-2018)
Expected Log Risk Premium	(μ)	2*0.012	Bank of Korea ECOS (2004-2018)
Expected Log Housing Return	(μ_h)	2*0.011	Korea Real Estate Board (2004-2018)
Standard Deviation of Labor Income Shock.	(σ_y)	2*0.045	Ahn et al. (2021)
Standard Deviation of Stock Return Shock	(σ_ϵ)	2*0.104	Bank of Korea ECOS (2004-2018)
Standard Deviation of Housing Return Shock	(σ_h)	2*0.013	Korea Real Estate Board (2004-2018)
Correlation between Housing and Stock Return	(ρ_{hs})	0.00	Bank of Korea ECOS / Korea Real Estate Board (2012-2018)
Correlation between Labor Income and Stock Return	(ρ_{ys})	0.00	KLIPS / Bank of Korea ECOS(2012-2018)
Correlation between Housing Return and Labor Income	(ρ_{hy})	0.00	KLIPS / Korea Real Estate Board (2012-2018)
Moving Shock	(ξ)	2*0.04	KLIPS

Table 2.5.1: Calibrated Parameters

Regarding the life-cycle labor income profile, I regress the logged non-capital income (which will be defined in more detail in the empirical analysis section) on *Age* dummy variables for each year of data set. Then, I calculate the average of estimates across years. Finally, I fit the fifth-order polynomial of *Age* on the average estimates of *Age* dummy variables estimated from the initial regressions. From this generated life-cycle labor income profile, I calculate the non-capital income growth rate life-cycle profile ($[\hat{g}_a]_{a=1}^{a=35}$). For the labor income shock, I calculate the average (2009-2016) of the estimated variance of permanent income level shock in Ahn et al. (2021), which uses Korea Labor Income Panel Studies (KLIPS) and which I also use in the empirical analysis. As I only have transitory shocks to the growth rate, which can be interpreted as permanent shocks to the income level in my model, I use this variance of permanent income shocks only. By taking the square roots of it, I calculate the standard deviation of the labor income shock. To account for the fact that I do not have a transitory income-level shock in my model, when I estimate the life-cycle income profile I include all types of income other than capital income. This includes any transfers from family members, government agencies, or social welfare programs. This definition of income allows me to view this income process as containing all of households' endogenous responses to the transitory shocks to income level. Consequently, using this definition of income rather than conventional labor income for the model allows me to have no transitory income level shock in the model. For the covariance structure among exogenous processes, I use the procedure used by Vestman (2019) and Cocco (2005) with minor modifications[10]. For both methods, it turns out that correlations among stock returns, housing returns and labor income shocks are not statistically significant at all. This might be because I use only 11 years of observations. However, this statistical non-significance was also observed in several papers, such as by Fagereng et al. (2017) and Brandsaas (2018), and thus I set correlations to zero. Lastly, for the exogenous moving probability (ξ), I calculate the portion of homeowners who moved out of their original house for every year, and I calculate the average of such probability, which gives me 0.044. For the sample selection process I use for the above calibration procedures, I explain further in the empirical analysis section later when I use the same sample for these calibrations and the empirical analysis.

2.6 Optimal Policies

In this section, I present households' optimal policies for the first-stage problem and the second-stage problem to explain how the model works and what it says about the crowding-out effect.

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[10] More details are in the Appendix

2.6.1 Optimal Policies for The First-stage Problem

First, I analyze the non-owner's problem in which households choose a tenure type —rent, jeonse, or homeownership. The left subplot in Figure 2.6.1 shows the optimal housing tenure policy for the non-owner's problem. It is remarkable that these optimal policies can generate the housing tenure pattern in Figure 2.3.2 if I assume young households that start with a low cash-in-hand-to-income ratio (hereafter $\frac{X}{Y}$) and move to higher $\frac{X}{Y}$ through their net wealth accumulation. We can see that as households have a higher $\frac{X}{Y}$, their optimal tenure choices move from rent to homeownership. The intuition is the following. If we compare jeonse and renting, because jeonse is cheaper than renting in terms of the cost of unit housing service,[11] it is better to choose jeonse. However, when households have very low savings compared with future labor income, it is better to rent because jeonse forces households to save a substantial portion of their assets in the form of a jeonse deposit, which hampers the consumption-smoothing problem. With low accumulated wealth compared with upcoming future income, becoming a jeonse tenant will force households to oversave and sacrifice high marginal utility for the current period. In addition, the fact that households need to have enough net wealth for the down payment prevents households with low $\frac{X}{Y}$ from becoming jeonse tenants or homeowners.

On the other hand, if households have very large assets compared with future labor income, which means high $\frac{X}{Y}$, using most of their assets for the jeonse deposit, which corresponds to a risk-free asset with housing service as dividends, renders their asset position too safe. Given the positive expected return on housing, once households accumulate enough wealth, purchasing a house is better than living on a jeonse contract. Also, households prefer to buy a house because once they move in, unless they move out, they do not have to pay the moving costs they have to pay every period if they choose

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[11] If a household rents a house, they have to pay $\tau P_a^H H$, which is $0.07 \times P_a^H H$. On the other hand, if a household chooses jeonse contract, they have to pay, including the opportunity costs, $\phi_J \bar{J} P_a^H H + (1 - \delta_J) \bar{J} P_a^H H (R_M - 1/R_f) + \delta_J \bar{J} P_a^H H (R_f - 1/R_f)$, which is $0.0484 P_a^H H$. Consequently, jeonse is cheaper in unit housing level.

to use jeonse. Moving costs proportional to housing prices becomes nonnegligible as households buy more expensive houses. These optimal policies can generate a pattern similar to the distribution of housing tenures in the actual data depicted in Figure 2.3.2. In addition, it quantitatively matches the sample mean of the $\frac{Net\ Wealth}{Income}$ ratio for each tenure of the actual household survey data presented in Table 2.7.1. One period in the model corresponds to 2 years. In addition, cash-in-hand X in the model corresponds to the sum of net wealth and contemporaneous labor income. Consequently, $\frac{X}{Y}$ in the model corresponds to $\frac{1}{2} \times \frac{Net\ Wealth}{Income} + 1$ in the data. Based on this relationship, my model predicts that households with $\frac{X}{Y}$ between 1 and 1.5 choose renting, which means, in the data, the $\frac{Net\ Wealth}{Income}$ of the renter should be between 0 and 1 while the actual sample mean of renters' $\frac{Net\ Wealth}{Income}$ is 1.47, which is very close to the model's prediction. The model also predicts the $\frac{Net\ Wealth}{Income}$ of a jeonse tenant should be between 1 and 7, where the sample mean of the $\frac{Net\ Wealth}{Income}$ of jeonse tenant is 5.83, and the model predicts that the $\frac{Net\ Wealth}{Income}$ of homeowners should be larger than 7, where the sample mean of $\frac{Net\ Wealth}{Income}$ of homeowners is 16.82. One thing to note is that in the data, there are still many renters and jeonse tenants whose $\frac{Net\ Wealth}{Income}$ is very high, which is out of my model's predictions. Since households live in different areas with different housing markets that have different rent-to-price ratio τ or different jeonse deposit size $\bar{J}$, it is natural that we have some misprediction here. I believe that there are some exogenous forces which affect tenure choices, but are not in my model, such as homeownership tax considerations or uncertainty about moving.

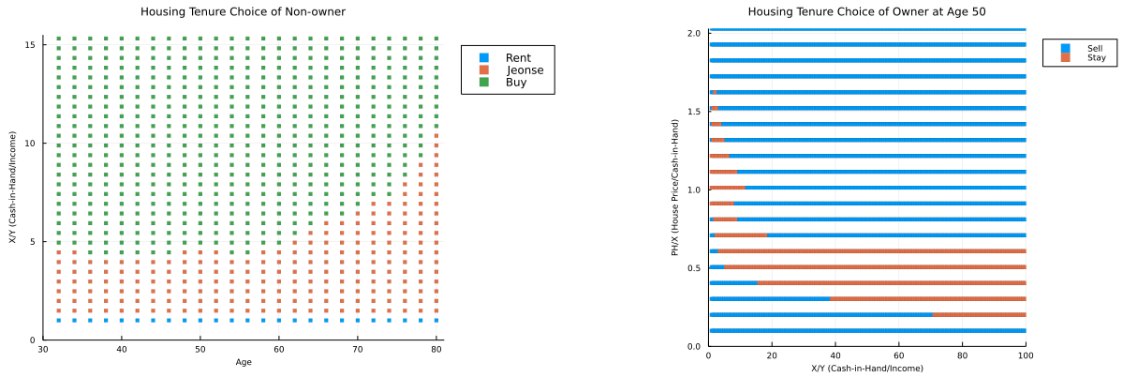


Figure 2.6.1: Optimal Housing Tenure Policy

The right subplot of Figure 2.6.1 also shows the first-stage optimal policy for the owner's problem. This decision concerns about whether they will move to a new house or stay. As we can see in the figure, the optimal policy is defined as a threshold rule. For the specific value of $\frac{X}{Y}$, there is an optimal level of housing consumption $\frac{P^H H}{X}$, and even though the current housing consumption level exhibits a minor deviation from the optimal level, households do not adjust their housing consumption to avoid moving costs. However, once they deviate too much from their optimal housing consumption level, they sell their houses. This pattern is also observed in Grossman and Laroque (1990) and Yao and Zhang (2005), which means that my model also captures the crowding-out effects discussed in both papers.

2.6.2 Optimal Policies for the Second-stage Problem

The second-stage problem is defined for each tenure type. Thanks to the normalization, at each age, I can depict optimal policies as ratios over cash-in-hand as consumption share $\frac{C}{X}$ and housing expenditure share $(\frac{\tau P^H H}{X}, \frac{\delta_J \bar{J} P^H H}{X}, \frac{\delta P^H H}{X})$ for renters, jeonse tenants, and homeowners, respectively. In this subsection, rather than considering the consumption behavior, I will directly jump into portfolio choices.

To understand the model's implications for portfolio choices correctly, carefully defining the model's portfolio choice variables is crucial. First, I define net worth in the following ways. For renters, A_a is equal to their net worth W_a^r, since they have no any other asset. On the other hand, for jeonse tenants, I define the sum of $\delta_J \bar{J} P^H H_a$ and A_a as their net worth W_a^J, since the downpayment for the jeonse deposit can also be understood as an asset. Lastly, I define the sum of A_a and $\delta P^H H_a$ as net worth W_a^b for homeowners in a similar vein. I consider A_a to correspond to a financial asset (or it can be interpreted as an asset other than a housing-related asset.), and $\alpha_a A_a$ to correspond to a risky financial asset (or it can be understood as a risky asset other than a housing-related asset.)

Then, with the above definitions, I can define three portfolio choice variables for each tenure: (1) the ratio of financial assets over net worth $\frac{A_a}{NW_a}$, (2) the ratio of risky financial assets over financial assets $\frac{\alpha_a A_a}{A_a} = \alpha_a$, and (3) the ratio of risky financial assets over net worth $\frac{\alpha_a A_a}{NW_a}$.

$\frac{A_a}{NW_a}$ shows how net worth is distributed over financial assets versus housing assets. Housing serves not only as a consumption but also as an asset in this model. As we will see, housing assets substitute financial asset out, which is the *substitution effect*. As households invest more in housing asset, $\frac{A_a}{NW_a}$ will be lower, and it means that households are left with smaller portion of net worth for financial asset. Next, $\frac{\alpha_a A_a}{A_a} = \alpha_a$ is a risky financial asset portfolio weight among financial assets. This measures how much of the risk is assumed by households in their financial assets. Yao and Zhang (2005) show, in their model, that while homeowners at the trigger bound of owning versus renting have a lower of proportion equity in net worth compared with renters, homeowners actually hold a higher proportion of equity in their financial assets compared with renters. They argue that this is because housing return and stock return have low correlation, which provides a portfolio diversification benefit for homeowners if they hold both housing and stocks; this is called a *diversification effect.* This measure allows us to better understand how the diversification effect works in each tenure. In my context, this can be understood as part of the house price risk channel, which shows the stochastic nature of the return on the housing asset. Lastly, $\frac{\alpha_a A_a}{NW_a}$ shows how total the crowding-out effect is. By comparing this measure across housing tenures, we clearly see how the total crowding-out effect works.

Under an ideal identification condition, different housing tenures should be forcefully imposed on otherwise identical households to see the true causal effect of housing on portfolio choices. In addition, those crowding-out effects should depend on parameters $(\Phi_{OW}, \Phi_J, \tau)$ that define the characteristics of tenures such as the wealth tax, adjustment cost, and rent-to-price ratio. In addition, the characteristics of households and asset return processes (Z), such as correlations across returns on assets, stock market participation costs, and households' belief on asset return processes, also affect the crowding-out effect size, as in Equation 2.9 and Equation 2.10.

$$E(PF|\frac{X}{Y}, Age, Renter(\tau), Z) - E(PF|\frac{X}{Y}, Age, Homeowner(\Phi_{OW}), Z) \tag{2.9}$$

$$E(PF|\frac{X}{Y}, Age, Renter(\tau), Z) - E(PF|\frac{X}{Y}, Age, Jeonse(\Phi_J), Z) \tag{2.10}$$

$$PF \in [\frac{A_a}{NW_a}, \frac{\alpha_a A_a}{A_a}, \frac{\alpha_a A_a}{NW_a}]$$

My model provides theoretical predictions on these crowding-out effects, because I can forcefully impose different housing tenures on identical households by comparing the optimal policies for the second-stage problems of different housing tenures. Note that in the actual model, only one housing tenure is optimally chosen for each combination of $\frac{X}{Y}$ and Age. Thus this is a hypothetical exercise that differs from the model simulation. However, on the other hand, as we have some households in the data who do not follow the optimal housing tenure policies in the model and who are likely affected by other exogenous tenure shifters, this practice should provide a good lens for interpreting the data. Below, I present figures that represent optimal portfolio choice, and the resulting crowding-out effects. To understand the model's implications for the crowding-out effect intuitively, I present the optimal portfolio choices and the resulting crowding-out effects (1) across $\frac{X}{Y}$ at the age of 50 and (2) across ages at $\frac{X}{Y}$ equals 10, which represent the cross-sectional pattern best.

First, I present the optimal portfolio choices across $\frac{X}{Y}$ for each tenure at the age of 50. In Figure 2.6.2, the top row shows the size of each measure and the bottom row shows the difference between each measure of for the jeonse tenant and homeowner with that for the renter. First, in (a), we clearly see the substitution effect happening with respect to each housing tenure. Because jeonse tenants and homeowners save not only in financial assets (A_a) but also in housing assets ($\delta_J \bar{J} P^H H_a$) or ($\delta P^H H$), the portion of financial assets in their total net worth is much lower. This substitution effect is strongest for households with the lowest $\frac{X}{Y}$. As households get less liquidity constrained, which means higher $\frac{X}{Y}$, this substitution effect decreases as noted in (d), but does not go to zero.

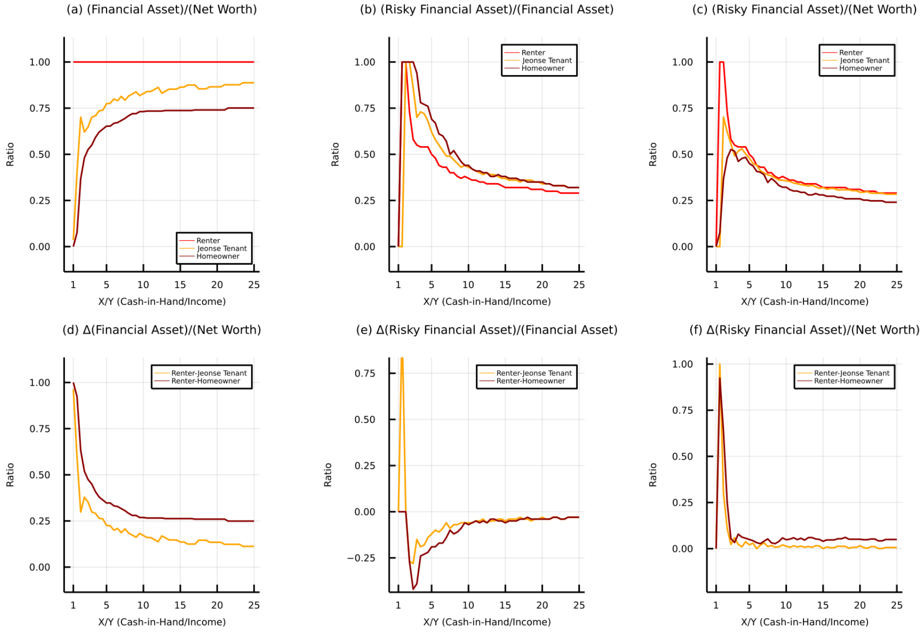


Figure 2.6.2: Optimal Portfolio Choices for All Tenures over $(\frac{X}{Y})$ Cross-section

For jeonse tenants, even though households have high $\frac{X}{Y}$, 13% of their total net worth is still in the form of the jeonse deposit while, for homeowners, 25% of their total net worth is in the form of housing assets. This may stem from the fact that housing assets are a good investment, given the housing return stochastic process with high return and low standard deviation. In addition, the difference is because these housing tenures force households to save much of their wealth in the form of housing-related assets to consume housing services. This substitution effect can be understood as coming from the liquidity constraint channel of the housing crowding-out effect. It decreases as households get less liquidity constrained, which means higher $\frac{X}{Y}$.

Moving to (b), we see that the $\frac{\alpha_a A_a}{A_a} = \alpha_a$ measure is higher for jeonse tenants and homeowners than renters, which is called the diversification effect by Yao and Zhang (2005). Since renters have all of their assets in the form of financial assets, investing all of them in a risky financial asset is too risky. However, since jeonse tenants and homeowners also have housing assets, they may take more risks in their financial portfolios. In particular, the jeonse deposit corresponds to the risk free asset where the dividend is housing service. Consequently, it is natural that jeonse tenants have higher $\frac{\alpha_a A_a}{A_a} = \alpha_a$

than renters. In addition, since I assume no correlations across housing return and stock return, investing in housing also provides a diversification benefit from investing in stocks. Again, as households go to higher $\frac{X}{Y}$, this diversification effect also gets smaller, as depicted in (e). As the ratio of financial assets over net worth goes up, they have less need to have a high portion of equity in their financial assets.

In the end, households also adjust the margin of their stock proportion over total net worth not only through $\frac{\alpha_a A_a}{A_a} = \alpha_a$ but also through $\frac{A_a}{NW_a}$. In the end, we should check $\frac{\alpha_a A_a}{NW_a}$ to see the total crowding-out effect. Lastly, shifting to the total effect on $\frac{\alpha_a A_a}{NW_a}$ in (c), we see that the crowding-out effect clearly exists for both jeonse tenants and homeowners. The two effects in (a) and (b) are combined and generate this pattern. One notable observation is that the crowding-out effect is higher for households with low $\frac{X}{Y}$. As households get higher $\frac{X}{Y}$, which means less liquidity constrained, most of the effect goes away. The other notable observation is that while the crowding-out effect from jeonse completely goes away with high $\frac{X}{Y}$, which is 0.006, the crowding-out effect for homeowners remains even with the high $\frac{X}{Y}$, which is estimated as 0.0497. It seems that the liquidity constraint channel disappears once households are no longer liquidity constrained, while the house price risk channel remains. In the case of jeonse tenants, even though the financial assets are crowded out by the jeonse deposit, by adjusting $\frac{\alpha_a A_a}{A_a} = \alpha_a$, they achieve the optimal risk exposure.

Moving to the age cross-section, I present the optimal portfolio choices of all housing tenures with $\frac{X}{Y}$ equal to 10 across all ages. Other than the case of extremely low $\frac{X}{Y}$, I find similar patterns for any $\frac{X}{Y}$. In Figure 2.6.3, in (a) and (d), I find that the ratio of financial assets over net worth goes down as households get older, for both jeonse renters and homeowners. This stems from the fact that housing is not only a kind of asset but also a kind of consumption. Following consumption-smoothing motives, households consume more and save less as they get closer to the end of their lifetime. Interestingly, in (b) and (e), we can see that α gets higher as they get older for both jeonse tenants and homeowners. Since they have lower financial assets, to achieve the optimal

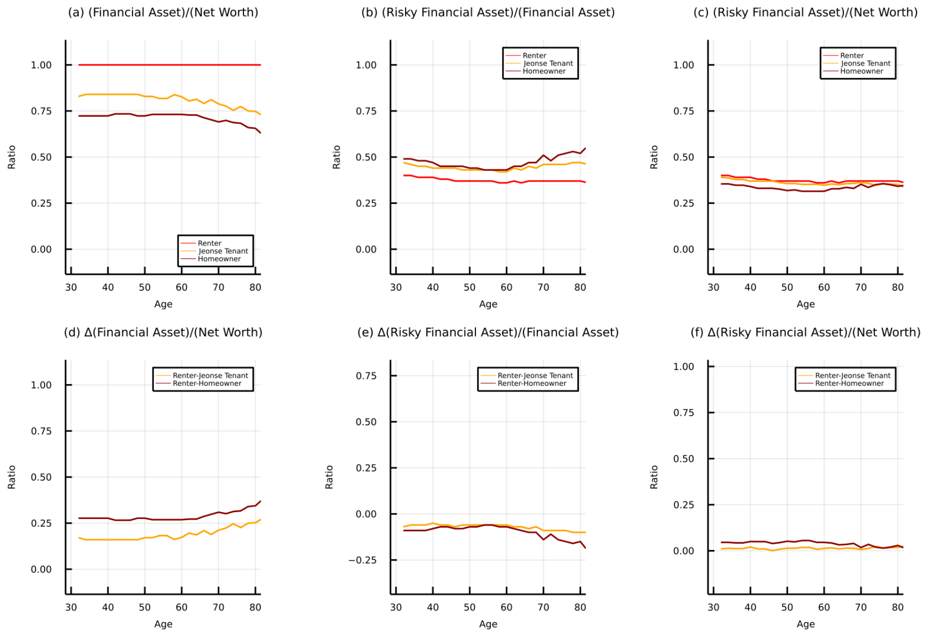
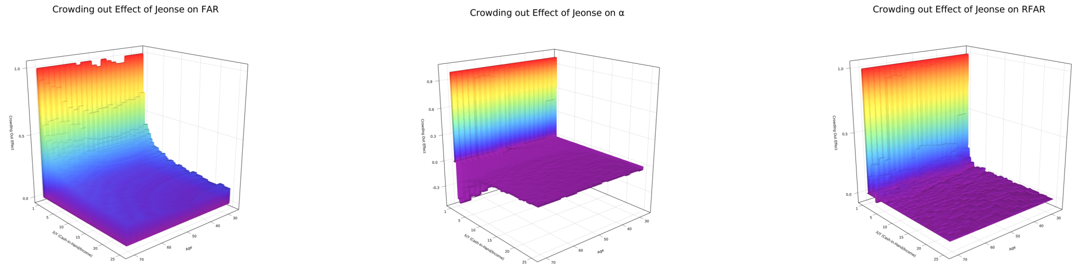


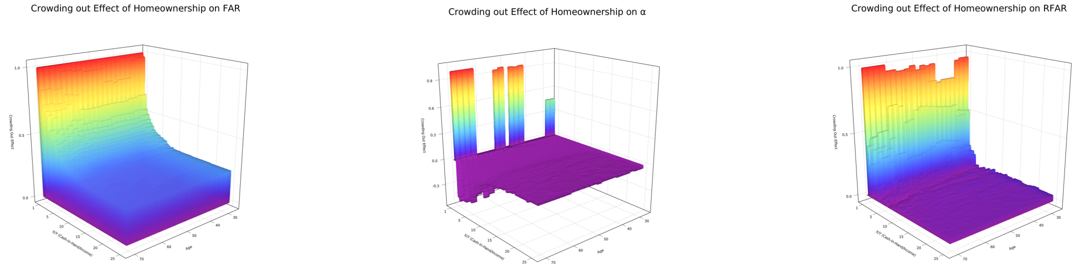
Figure 2.6.3: Optimal Portfolio Choices for All Tenures over (Age) Cross-section

equity exposure level, they try to increase their risky asset ratio of their financial assets. Finally, in (c) and (f), we see that the total crowding-out effect differs for jeonse tenants and homeowners. For jeonse tenants, given the relatively high $\frac{X}{Y}$, there is no liquidity constraint channel, which generates zero crowding-out effect. However, homeowners exhibit a sustained crowding-out effect, which goes away only when they are older than 70. This again demonstrates the nature of crowding-out effect. The house price risk channel persists even though households are not liquidity constrained.

Figure 2.6.4 shows the crowding-out effects for all ages and $\frac{X}{Y}$. We can see that the overall patterns that we saw in Figure 2.6.2 and Figure 2.6.3 again appear across Age and $\frac{X}{Y}$. The crowding-out effect from jeonse fades away, while the crowding-out effect from homeownership persists. We see some exotic optimal policies in Figure 2.6.4.(e) with low $\frac{X}{Y}$, especially for homeowners and jeonse renters. However, keep in mind that when $\frac{X}{Y}$ is low, because they only have a very small portion of A, either having a very high α or very low α do not make much difference in terms of total portfolio choices $\frac{\alpha_a A_a}{NW_a}$.



(a) Jeonse on $\frac{A_a}{NW_a}$ (b) Jeonse on α_a (c) Jeonse on $\frac{\alpha_a A_a}{NW_a}$



(d) Homeowner on $\frac{A_a}{NW_a}$ (e) Homeowner on α_a (f) Homeowner on $\frac{\alpha_a A_a}{NW_a}$

Figure 2.6.4: Crowding-out Effect in the Baseline Calibration

2.6.3 Liquidity Constraint from the Life-cycle versus Housing

In the end, it is important to understand the relationship between the liquidity constraint channel of the crowding-out effect and the nature of the incomplete market for households' life-cycle, which is well-established in early literature. The fact that households have to smooth their consumption and achieve the optimal portfolio choices while they cannot borrow against their future labor income (*liquidity constraint of the life-cycle*) affects households' portfolio choices. Because they are forced to have most of their lifetime income in the form of illiquid labor income, their portfolio choices are affected.

Housing contracts affect the stock investment behavior by adding the additional liquidity constraint channel of the crowding-out effect of housing on the liquidity constraint of the life-cycle. Being a homeowner or jeonse tenant forces households to save a substantial amount of their asset in the form of illiquid housing to consume a housing service.

This is why young households are affected more by the liquidity constraint channel, given the same $\frac{X}{Y}$, compared with older households. They are already experiencing the liquidity constraint of the life-cycle, and housing exacerbates. Older households, who are relatively free from the liquidity constraint of the life-cycle are get much affected by it.

On the other hand, the house price risk channel is independent of such a mechanism. It directly affects the risk-return trade-off of a household's overall portfolio regardless of households characteristics. Consequently, this channel affects all types of households.

2.6.4 Determinants of the Crowding-out Effect

In this subsection, I show how these crowding-out effects change depending on stock market participation costs γ and the correlation structure between the housing returns and stock returns, ρ_{hs}.

These two comparative statics analyses have important meanings. For γ, it is related to the liquidity constraint channel. As households have to pay γY participation costs, in the model, if households do not have enough financial assets A, they have no incentive to participate in the stock market, since they cannot get much from participating in the stock market compared with the participation cost. This is especially the case for the households who have large portion of their assets as housing assets. Through this, the crowding-out effect can be affected nonlinearly via two channels with the stock market participation cost. First, purchasing a house or making a jeonse contract leads households to hold a large portion of their wealth in the form of housing assets, which decreases A as we saw above. Given the decreased A, higher stock market participation costs prevent homeowners and jeonse tenants from participating in the stock market, which exacerbates the crowding-out effect defined in Equation 2.9 and Equation 2.10. Second, too high participation costs eliminates all participation, even by the renter who is not affected by the substitution effect, which causes the crowding-out effect to be zero. These comparative statics can show us how this intuition works. In addition, assuming with higher stock market participation costs for Korean households compared with US households seems reasonable based on historical experiences and the different levels of development of financial markets in Korea and the US.

On the other hand, for ρ_{hs}, this parameter affects the house price risk channel: The negative correlation between housing return and stock return effectively decreases the additional risk from housing when households have both stocks and housing, due to the diversification effect observed above and also that of Yao and Zhang (2005). While my baseline calibration assumes no correlation, I assume high positive correlation in these comparative statics to see how the crowding-out effect behaves. Consequently, these two comparative statics analyses will show how we should think about the crowding-out effect present in the data in the empirical analysis section.

2.6.4.1 High Correlation between Stock Return and Housing Return

In this subsection, I present the optimal portfolio choices of households with higher correlation between stock return and housing return processes. While I set correlation ρ_{hs} as zero in the baseline case, here I set the correlation as 0.3. Figure 2.6.5 shows the optimal portfolio choices at the age of 50 across $\frac{X}{Y}$. Though it is very similar to Figure 2.6.2, it has some notable differences. As we see in (e), the α_a of homeowners is similar (and even lower with high $\frac{X}{Y}$) to that of jeonse tenants while homeowners' α_a was much higher in the baseline case. Consequently, the resulting crowding-out effect in (f) is much stronger and more prominent, and can be understood as a decreased benefit of diversification.

Moving to the optimal portfolio choices of households across ages, we again see similar patterns qualitatively; the only difference is that the magnitude of the crowding-out effect from homeownership becomes larger. Graphs for all $\frac{X}{Y}$ and ages are in the Appendix.

2.6.4.2 High Stock Market Participation Costs

In this subsection, I analyze the case with high stock market participation cost (γ). This change in particular can cause qualitative change in optimal portfolio choices due to the nonlinear effect discussed above. Whereas I set γ as 0.0057 in the baseline case, here I

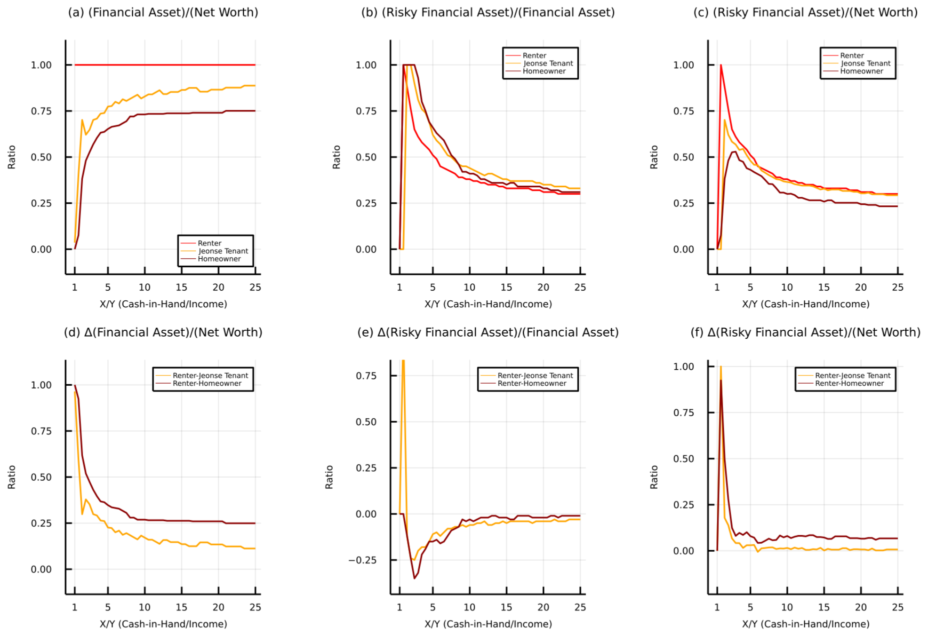


Figure 2.6.5: Optimal Portfolio Choices for All Tenures over $\frac{X}{Y}$ Cross-section with High ρ_{hs}

set it as 0.05.

In Figure 2.6.7, we see that the crowding-out effect pattern is strikingly different: The behavior of $\frac{A_a}{NW_a}$ is very similar to that of the baseline case. However, the α_a pattern is now very different. Due to high stock market participation costs, only renters who have $\frac{X}{Y}$ higher than 10.5 participate in the stock market. With the decreased A due to housing tenure, if that household is a jeonse tenant or homeowner, they participate in the stock market only with $\frac{X}{Y}$ higher than 14. Consequently, it eliminates the crowding-out effect for households with $\frac{X}{Y}$ lower than 10.5 and suddenly increases the crowding-out effect for households with $\frac{X}{Y}$ between 10.5 and 14. Once a household has $\frac{X}{Y}$ more than 14, the crowding-out effect again drops and converges to zero, as we saw in the baseline cases.

Such nonlinearity is strikingly represented in Figure 2.6.8. Since this is the optimal policy for households with $\frac{X}{Y}$ equal to 10 at different ages, the figure shows zero crowding-out effect across any Age. It is natural to imagine that households should have stock market participation costs very different from each other, based on their different peer groups, or education levels. Consequently, it should be difficult to capture any strong pattern

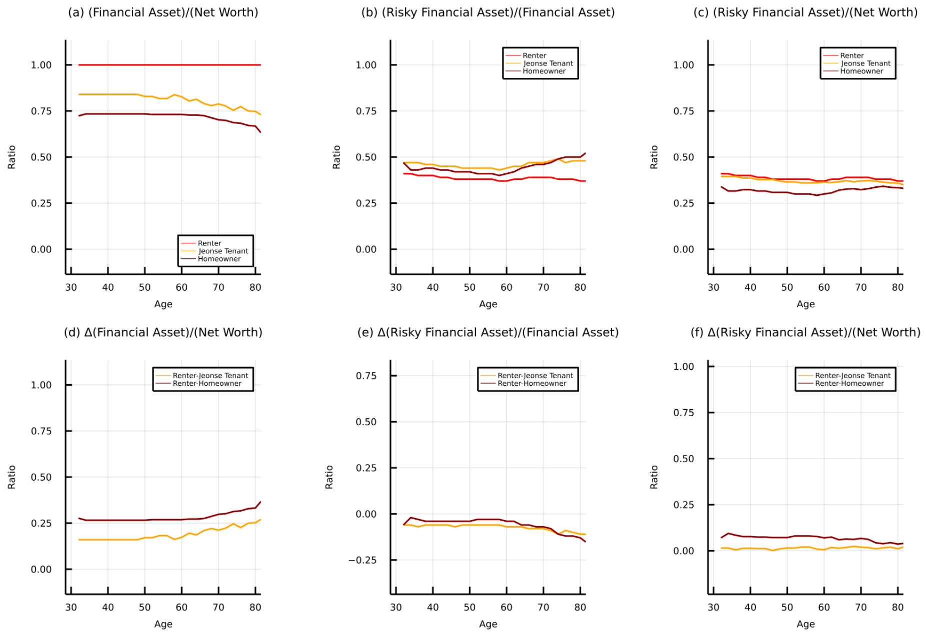


Figure 2.6.6: Optimal Portfolio Choices for All Tenures over (Age) Cross-section with High ρ_{hs}

of such an effect by exploiting panel data. In the next section, will strive to capture the crowding-out effect patterns from household survey panel data.

2.7 Empirical Analysis

To study whether these patterns of the crowding-out effect are present in the data, I examine how renters, jeonse tenants, and homeowners make portfolio choices using household panel data from the Korea Labor and Income Panel Study (hereafter KLIPS.) KLIPS started in 1998 with 5,000 households as the initial household samples. All new households generated from the initial household sample are also tracked. As of 2009, 1,721 households had been added to the sample, and with the addition of more households in 2018, currently 12,134 households are being tracked. This household panel survey sample was constructed to represent the whole Korean population. Every year, between April and September, households in the sample are surveyed. The data contain detailed information on households' demographics, income, expenditures, assets, and debts. I standardized all variables as real variables at 2020 price level using the consumer

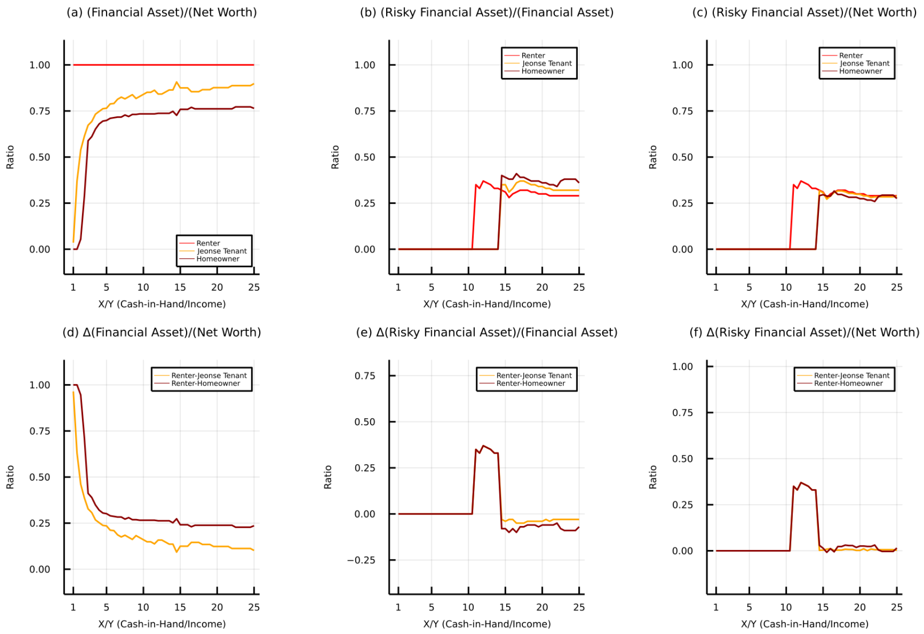


Figure 2.6.7: Optimal Portfolio Choices for All Tenures over $\frac{X}{Y}$ Cross-section with High γ

price index.

2.7.1 Descriptive Statistics

To study the portfolio choices of households properly, deriving the proper definitions of portfolio variables and balance sheet variables is important. I define households' net wealth, financial assets, risky financial assets, liabilities, and households' non-capital income as follows. Net wealth (hereafter W) is defined as the sum of financial assets (herefater FA) and real assets (hereafter RA) minus any type of liabilities (hereafter LB). Defining FA requires additional consideration, especially when we consider the jeonse deposit. This can be interpreted as a risk-free financial asset, which is a kind of collateralized lending with housing services as dividends. On the other hand, the jeonse deposit can be interpreted as a housing-related asset, in the sense that it crowds out any other type of financial assets. I define FA as including bank deposits, mutual funds, stocks, bonds, saving insurances, and private lending but not jeonse deposit or rent deposit. This is to facilitate comparison of its crowding-out effect with that of the model. Of these financial assets, I consider the sum of stocks, bonds, and mutual

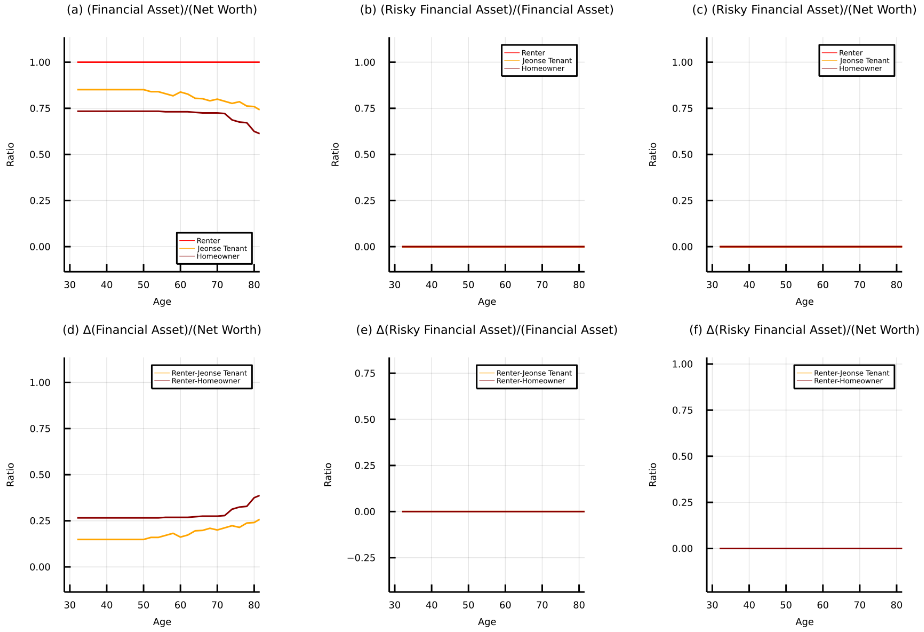


Figure 2.6.8: Optimal Portfolio Choices for All Tenures over (Age) Cross-section with High γ

funds as risky financial assets (hereafter RFA). RA include real estate assets including the house lived in, cars, land, and any other type of real assets. LB includes any type of borrowing from the bank (including mortgages) and private borrowing from individuals. Jeonse deposits and rent deposits are also included in LB if responding households are landlords. Lastly, non-capital income (hereafter Y) includes labor income, pensions, social insurance, and other family transfer income. I include all types of income other than income from housing or financial investments to incorporate households' ability to cope with idiosyncratic labor income shock, which is not present in my model.

Based on these assets and liabilities variables, I define portfolio choice variables as follows. The financial asset ratio (hereafter FAR) is defined as $\frac{FA}{W}$, while the risky financial asset ratio (hereafter $RFAR$) is defined as $\frac{RFA}{W}$. Also, I define the risky financial asset ratio over financial assets (hereafter $Alpha$) as $\frac{RFA}{FA}$. When I study the above variables only for households who ever participated in the stock market, I put $c-$ in front of these variables to represent "conditional" (e.g., $c - RFAR$.) As a participation dummy, I define stock market participation (hereafter SMP) as $1[Risky\ Fin\ Asset > 0]$. Lastly, the net wealth-to-income ratio will be denoted by $(\frac{W}{Y})$ following the above definitions as a variable corresponding to the model's most important state variable $\frac{X_{model}}{Y_{model}}$. Note that X_{model} in the model is cash-in-hand, which is a sum of net wealth and contemporaneous labor income. In addition, one period in the model is 2 years. Consequently, the following relationship holds: $\frac{X_{model}}{Y_{model}} = \frac{W_{data}+2Y_{data}}{2Y_{data}}$. Note that FAR corresponds to $\frac{A_a}{NW_a}$, $Alpha$ corresponds to $\frac{\alpha_a A_a}{A_a} = \alpha_a$, and $RFAR$ corresponds to $\frac{\alpha_a A_a}{NW_a}$ in the model. By using each variable, I will compare model predictions with the data pattern.

	Renters	**Jeonse Tenants**	**Homeowner**
Fraction of households	0.129	0.228	0.584
Age	45.93	43.59	54.66
Net Wealth (W)	3455.43	13066.38	28364.04
Real Assets (RA)	1903.60	5129.64	29411.29
Financial Assets (FA)	828.52	2143.89	2922.23
Risky Financial Asset (RFA)	137.43	354.83	364.80
Liabilities (LB)	987.38	2816.77	4381.23
Non-capital Income (Y)	3083.27	4303.13	4512.95
Financial Asset Ratio (FAR)	0.2962	0.1897	0.1003
Risky Financial Asset Ratio ($RFAR$)	0.0087	0.0154	0.0096
Risky Financial Asset Ratio over Financial Assets ($Alpha$)	0.0181	0.0595	0.0444
Conditional Risky Financial Asset Ratio ($c - RFAR$)	0.2688	0.1207	0.1083
Conditional Risky Financial Asset Ratio over Financial Assets ($c - Alpha$)	0.5549	0.4654	0.4960
Stock Market Participation (SMP)	0.0326	0.1279	0.0894
Net Wealth over Income Ratio ($\frac{W}{Y}$)	1.4705	5.8382	16.8268
House Price	0	0	23483.21
Jeonse Deposit	0	8310.23	0
Rent Deposit	1538.40	0	0

Table 2.7.1: Summary Statistics

Table 2.7.1 reports summary statistics for the variables of interest. It reveals stark differences across housing tenures. While owners are usually older than renters and jeonse tenants, they also have more net wealth W, more income Y, and higher $\frac{W}{Y}$ ratio, as predicted by my model. Keep in mind that one period in the model is 2 years, which means that the model's $\frac{X_{model}}{Y_{model}}$ corresponds to $\frac{W_{data}+2Y_{data}}{2Y_{data}} = \frac{1}{2}\frac{W_{data}}{Y_{data}} + 1$ in the data. If we compare each tenure's sample mean $\frac{W}{Y}$ by dividing by 2 and add 1 with $\frac{X_{model}}{Y_{model}}$ in the model's optimal housing tenure policy in Figure 2.6.1, we find that the model matches remarkably well each tenure's $\frac{W_{data}}{Y_{data}}$ as I discussed in the modeling section. Another interesting point is that South Korea exhibits a very low stock market participation rate compared with major developed countries. This may stem from the fact that the Korean stock market is valued as low with a high risk premium due to its geopolitical risks and high dependence on exports. In addition, several financial crises, including the East Asia Crisis in 1997, may have led many households to believe that the stock market is too risky to participate in. The stock market participation rate presented here is the direct participation rate and does not take indirect participation through pensions fund into account. Lastly, while renters show very low stock market participation, jeonse tenants and homeowners participate more in the stock market. On the other hand, renters show higher FAR, $c - RFAR$, and $c - Alpha$ compared with others and lower $RFAR$ and $Alpha$ compared with jeonse tenants and homeowners. While FAR and $c - RFAR$ are similar to the predictions from model with higher level of stock market participation costs, $Alpha$ seems to follow the predictions made by the model with the high positive correlation between housing return and stock return.

2.7.2 Sample Selection

To avoid the abnormalities of the Great Recession and the COVID-19 crisis, I use survey data only survey years from 2009 to 2019. In addition, to validate the accuracy of responses, I collect only households who ever responded more than 4 times, because several households respond only 1 or 2 times, with missing responses for many questions. Also, I removed households with negative net wealth and households with yearly non-capital income Y less than 1,200,000 Korean won, which is equivalent to \$1,057.45 at the 2010 exchange rate. Households with too low Y show too high $\frac{W}{Y}$, and some unrealistic portfolio weights that are larger than 100%. I also removed the bottom 1% and top 1% of households in terms of $\frac{W}{Y}$ to remove any abnormal data patterns from outliers. Lastly, I removed renters and jeonse tenants whose value of other real estate assets is twice as large as their jeonse or rent deposit. If they have other large housing asset, and only temporarily use jeonse or rent contracts for their housing needs, I decided not to consider them as jeonse tenant or renters.

2.7.3 Housing Tenure and Portfolio Choice

There is substantial variation across years, especially for the stock market participation rate. To more clearly see the relationship between housing tenure and households' portfolio choices, while controlling for region and year fixed effects, I run the following regression in which dependent variable PF_{it} can be FAR, $Alpha$, $c - Alpha$, $RFAR$, $c - RFAR$, or SMP.

$$PF_{it} = \beta_J Jeonse_{it} + \beta_O Owner_{it} + RegionTime_{it} + \epsilon_{it} \tag{2.11}$$

Figure 2.7.1 shows the estimated parameters and confidence intervals of β_J and β_O.[12] It clearly summarizes the relationship between housing tenure status and households' portfolio choices, while controlling for year and region fixed effects. We can clearly see the substitution effect in FAR. Jeonse tenants show a -21% lower FAR compared with renters, while homeowners show a -29% lower FAR. Jeonse and homeownership seem to predict positive relationships with $Alpha$ and to have some small negative effects on $c - Alpha$. Moving to $RFAR$, it is negatively correlated with jeonse and homeownership, while being a jeonse tenant predicts 20% lower $RFAS$ conditional on participation and homeownership predicts 26% lower $RFAS$ conditional on participation. Though I do not include other control variables, these patterns seem to be fairly consistent with the model's predictions. Interestingly, jeonse tenant status and homeownership seem to have crowding-out effects on the intensive margin but not on the extensive margin, which shows actually positive relationships. Jeonse and ownership are positively correlated with stock market participation, where being a jeonse tenant predicts 2.13% higher stock market participation and homeownership predicts 1.31% higher stock market participation. These results are similar to those of Vestman (2019) for the extensive margin. The regression in Vestman (2019) uses moving to homeownership as a treatment in DID set-up with household fixed effect, and thus it is slightly different from the regression specification here. However, the two regressions are similar in the sense that they do not

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[12] Standard errors are clustered at region-time level.

control for the household's wealth or income, and show the positive relationship between stock market participation and homeownership (also jeonse tenant status.) Though this positive relationship likely stems from the endogeneity caused by confounders, including $\frac{W}{Y}$, it still describes the overall data patterns well.

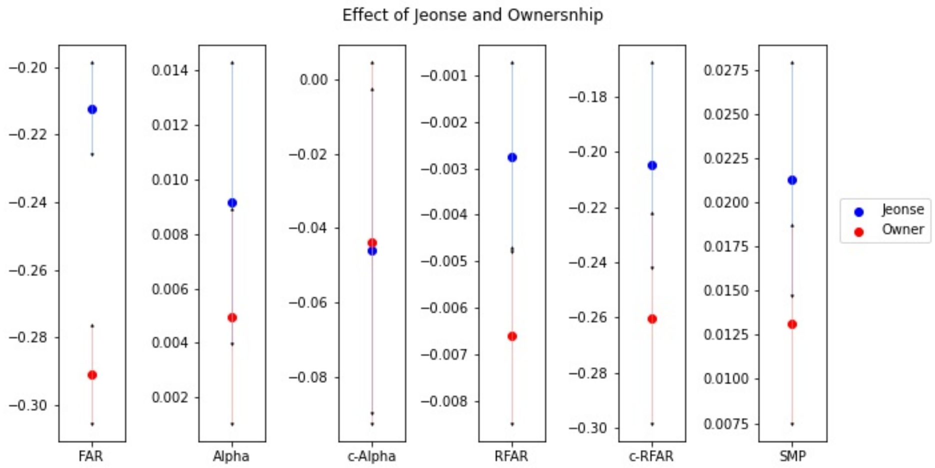

Figure 2.7.1: Housing Tenure and Portfolio Choice

2.7.4 The Crowding-out Effect Across $\frac{W}{Y}$

In this subsection, with full control for household characteristics, I capture the crowding-out effect pattern of each tenure type across $\frac{W}{Y}$ in more detail. I will state the definitions of crowding-out effects to estimate again in terms of the variables defined in this empirical section. Because the housing tenure variables are highly correlated with $\frac{W}{Y}$ and Age variables, which also substantially affect portfolio choice variables—which is predicted by my model—controlling for $\frac{W_{data}}{Y_{data}}$ and Age_{data} in the regression is important. This is equivalent to controlling for $\frac{X_{model}}{Y_{model}}$ and Age_{model} in the model.

$$E(PF|\frac{W}{Y}, Age, Renter(\tau), Z) - E(PF|\frac{W}{Y}, Age, Homeowner(\Phi), Z) \tag{2.12}$$

$$E(PF|\frac{W}{Y}, Age, Renter(\tau), Z) - E(PF|\frac{W}{Y}, Age, Jeonse(\Phi_J), Z) \tag{2.13}$$

$$PF \in (FAR, RFAR, c-RFAR, SMP, Alpha, c-Alpha)$$

Also, there are two ways we can view the effect of housing tenure. We can either use dummy variables for jeonse tenure and homeownership, as Brandsaas (2018) does, or we can use $\frac{Jeonse\ Deposit}{Net\ Wealth}$ ($\frac{JD}{W}$) and $\frac{House\ Price}{Net\ Wealth}$ ($\frac{HP}{W}$), as Cocco (2005) and Yao and Zhang (2005) do. To facilitate comparison across the research, I perform both of the specifications below.

$$PF_{it} = \beta U_{it} + \sum_{Q=1}^{5} \gamma_{1Q} Jeonse_{it} [\frac{W}{Y}]_{it}^{Q} + \sum_{Q=1}^{5} \sigma_{1Q} Owner_{it} [\frac{W}{Y}]_{it}^{Q} + \epsilon_{it} \tag{2.14}$$

$$PF_{it} = \beta U_{it} + \sum_{Q=1}^{5} \gamma_{2Q} \frac{JD}{W}_{it} [\frac{W}{Y}]_{it}^{Q} + \sum_{Q=1}^{5} \sigma_{2Q} \frac{HP}{W}_{it} [\frac{W}{Y}]_{it}^{Q} + \epsilon_{it} \tag{2.15}$$

$$PF_{it} \in (FAR_{it}, RFAR_{it}, c - RFAR_{it}, SMP_{it}, Alpha_{it}, c - Alpha_{it})$$

I include the interaction terms with housing-related variables and $[\frac{W}{Y}]^{Q}$, which is a dummy variable for being in each $\frac{W}{Y}$ quantile group. I divide all households into 5 groups, depending on their quantile group of $\frac{W}{Y}$. This is in order to see whether there is a heterogeneous crowding-out effect that depends on households' wealth-to-income ratio, as predicted by the model. U_{it} includes $Log(\frac{W}{Y})$, education level, $Log(Age)$, number of members in the household, year fixed effects, and household fixed effects. These variables are all controlled for by Cocco (2005) and Yao and Zhang (2005). What I do not control for here is whether the household is operating their own business or not and the amount of mortgage debt, as I have no corresponding information.

These regressions effectively exploit two within-household variations of portfolio choices. The first variation is the variation in portfolio changes that occurs when the household changes their housing tenures, and the second variation is the variation that occurs when the household experiences changes in their wealth-to-income ratio. If an individual changes their housing tenure from renting to jeonse, if something occurs in their portfolio choices, that will be captured by my regression. At the same time, even when households stay in same housing tenure,—let's say jeonse—, if they experience changes in their wealth-to-income ratio, and if their portfolio choices also change, the variation will be captured by the regression.

These regressions may be subject to endogeneity concerns, since housing tenure choice and portfolio choice can be simultaneously affected by numerous confounders such as the household's risk preference, the household's belief about future income, and their current income or wealth. I strive to control for such factors using individual fixed effects and detailed household demographics and balance sheet information.

As another concern, Beaubrun-Diant and Maury (2016) argue that there are strong simultaneity and cross-causality effects between homeownership and stock market participation. Here I do not try to control for such confounding relationships, because I have no proper instrumental variables. I proceed under the assumptions that all the confounding effects are controlled by controlling Age and $\frac{W}{Y}$. Also I assume that all dynamics can be controlled for by their wealth variables and age variables. At the least, the empirical analysis below can be interpreted as summarizing the correlations that represents how the data compare with the model's predictions.

Table 2.7.2 reports the results for the specification in equation 2.14. I find that $Log(Age)$ has a negative relationship with all portfolio choice variables. This is consistent with the finding of Brandsaas (2018) for stock market participation. In addition, the $Number\ of\ Members$ has a negative sign as, as is also the case for Brandsaas (2018). As an important state variable, $Log(\frac{W}{Y})$ is estimated to have positive effects on most portfolio choice variables other than FAR, which is again consistent with the concave relationship implied by the model and the results in Brandsaas (2018). In particular, it shows that high $Log(\frac{W}{Y})$ implies higher SMP. A model with a certain level of participation cost predicts such a relationship.

Shifting to the crowding-out effects of interest, I find consistent crowding-out effects of housing from homeowners (σ_{1Q}) on FAR, $RFAR$, $c - RFAR$, and SMP, in contrast the crowding-out effects of jeonse tenure (γ_{1Q}) seem to have an effect only on FAR and $RFAR$.

First, for FAR, we see jeonse tenure and homeownership have strong negative effects on

	FAR	$Alpha$	$c-Alpha$	$RFAR$	$c-RFAR$	SMP
$Education1$	0.4108***	0.1922	-0.3144	0.0584***	-0.0117	0.3951***
	(3.0984)	(1.4493)	(-0.5233)	(2.5818)	(-0.2262)	(4.0079)
$Education2$	0.4078***	0.1939	-0.3071	0.0572***	-0.0093	0.3940***
	(3.1888)	(1.5323)	(-0.5415)	(2.6802)	(-0.1871)	(4.1747)
$Education3$	0.3982***	0.1668	-0.2720	0.0596***	-0.0017	0.3593***
	(3.1936)	(1.3711)	(-0.5122)	(2.7721)	(-0.0339)	(3.7797)
$Number\ of\ Members$	-0.0117***	-0.0032*	-0.0022	-0.0015**	-0.0031	-0.0060**
	(-3.7816)	(-1.6782)	(-0.3820)	(-2.3245)	(-0.9111)	(-2.5073)
$Log(Age)$	0.0177	-0.0371	0.0864	-0.0100*	0.0096	-0.0797***
	(0.5345)	(-1.1400)	(0.6200)	(-1.8180)	(0.7726)	(-3.2685)
$Log(\frac{W}{Y})$	-0.0185***	0.0055**	0.0030	0.0017	0.0057	0.0086***
	(-2.9040)	(2.5559)	(0.4490)	(1.3073)	(0.9271)	(3.7985)
$Owner \times [\frac{W}{Y}]_1^Q$	-0.2985***	-0.0024	-0.0027	-0.0096***	-0.0056	-0.0189***
	(-17.186)	(-0.4052)	(-0.0958)	(-3.9377)	(-0.3953)	(-2.9461)
$Owner \times [\frac{W}{Y}]_2^Q$	-0.3197***	-0.0058	-0.0302*	-0.0110***	-0.0256*	-0.0190***
	(-24.125)	(-1.0591)	(-1.8988)	(-3.6546)	(-1.8158)	(-2.8609)
$Owner \times [\frac{W}{Y}]_3^Q$	-0.3126***	-0.0116*	-0.0257	-0.0140***	-0.0296*	-0.0257***
	(-22.348)	(-1.9127)	(-1.4591)	(-3.7786)	(-1.6826)	(-3.5689)
$Owner \times [\frac{W}{Y}]_4^Q$	-0.3119***	-0.0189***	-0.0272	-0.0153***	-0.0334	-0.0345***
	(-20.579)	(-2.8703)	(-1.5783)	(-3.6464)	(-1.6340)	(-4.4235)
$Owner \times [\frac{W}{Y}]_5^Q$	-0.3041***	-0.0160**	-0.0195	-0.0155***	-0.0343	-0.0327***
	(-16.463)	(-2.0542)	(-0.9226)	(-3.1197)	(-1.3945)	(-3.5877)
$Jeonse \times [\frac{W}{Y}]_1^Q$	-0.1976***	0.0024	0.0070	-0.0027	0.0011	-0.0052
	(-14.213)	(0.4458)	(0.3510)	(-1.1066)	(0.0899)	(-0.9058)
$Jeonse \times [\frac{W}{Y}]_2^Q$	-0.2331***	-0.0004	0.0088	-0.0088***	-0.0155	-0.0022
	(-20.325)	(-0.0698)	(0.5059)	(-2.8967)	(-0.8874)	(-0.2986)
$Jeonse \times [\frac{W}{Y}]_3^Q$	-0.2210***	-0.0023	-0.0127	-0.0089**	-0.0213	-0.0041
	(-17.139)	(-0.3647)	(-0.6592)	(-2.3762)	(-1.0297)	(-0.4704)
$Jeonse \times [\frac{W}{Y}]_4^Q$	-0.2054***	-0.0054	-0.0042	-0.0087*	-0.0222	-0.0113
	(-13.062)	(-0.6107)	(-0.2031)	(-1.8975)	(-1.1578)	(-1.0366)
$Jeonse \times [\frac{W}{Y}]_5^Q$	-0.1759***	0.0105	0.0223	-0.0039	-0.0184	-0.0006
	(-8.5335)	(0.8658)	(0.7312)	(-0.6904)	(-0.7676)	(-0.0468)
No. Observations	60220	43478	4462	60220	6642	60220
R-squared	0.0869	0.0019	0.0049	0.0049	0.0181	0.0026
P-value (F-stat)	0.0000	0.0000	0.2442	0.0000	0.0000	0.0000
Effects	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE

Table 2.7.2: Regression Specification 1 - $\frac{W}{Y}$ Cross-section

FAR, which is also predicted by the model as the substitution effect. Interestingly, the effect of jeonse is much smaller than that of homeownership. In addition, crowding-out effect from jeonse (γ_{1Q}) decreases as households move into higher $\frac{W}{Y}$ quantile groups, while the crowding-out effect from homeownership (σ_{1Q}) somewhat decreases or persists, which is also predicted by my model. This should stem from the fact that homeownership not only requires larger down payment (more of the liquidity constraint channel) but also incurs the house price risk channel.

Second, moving to $Alpha$, we see that the coefficients on jeonse (γ_{1Q}) are not significant. The model predicted higher $Alpha$ for jeonse tenants compared with the renters, and it seems the regression does not capture that channel fully. For the effect of homeownership on $Alpha$, we see that in the model, this heavily depends on the correlation structure between housing returns and stock returns. Because households in our data set should have different houses in different locations (which means different correlation structures between the housing returns and stock returns they face), it is natural that we cannot capture strong patterns of diversification effects. However, it seems that it implies, on average, high correlation between housing return and stock return based on my model's predictions, so they are negatively estimated. In total, the crowding-out effect on α is heavily affected by individual stock market participation costs and correlation structures between its housing price process and stock return process, and thus it is natural that the effect is not captured in this regression. It would require more detailed data to clearly see the effect on α such as the detailed locations of households.

Most importantly, we see the total crowding-out effect from the regressions on $RFAR$ and $c - RFAR$. The most interesting pattern is that, in the regression for $RFAR$, the crowding-out effect from homeownership (σ_{1Q}) increases as $\frac{W}{Y}$ increases, while the crowding-out effect from jeonse (γ_{1Q}) decreases and becomes insignificant as $\frac{W}{Y}$ increases. In the case of the crowding-out effect from homeownership on $RFAR$, if households have $\frac{W}{Y}$ corresponding to the lowest 20th percentile group of $\frac{W}{Y}$, which is from 0.156 to 1.497 in our sample, the crowding-out effect is -0.96%. On the other hand, if households have $\frac{W}{Y}$ corresponding to the highest 20th percentile group of $\frac{W}{Y}$, which is from 8.51 to 90.923, homeownership is estimated to crowd out the $RFAR$ by -1.55%, which is much larger than the effect on the lowest 20th percentile group. Quantitatively, this is a little different from the model's prediction for this effect for the age of 50 households with high $\frac{X}{Y}$, which was about 4%. I believe that the crowding-out effect for households in the lowest quantile of $\frac{W}{Y}$ is eliminated due to the stock market participation cost, as we saw in Figure 2.6.7, while the latter sustained crowding-out effect is as the model predicted due to the house price risk channel. Considering the sample mean of $RFAR$ for renters in the 2010 survey, which is 0.87%, its size is economically significant.

On the other hand, for the crowding-out effect stemming from jeonse , we find that the crowding-out effect for households with $\frac{W}{Y}$ in the 40th to 60th quantiles is estimated to be -0.89%, while that of households with $\frac{W}{Y}$ in the 80th to 100th quantile is estimated as having no significant effect. This is also as predicted by the model. A higher $\frac{W}{Y}$ effectively eliminates the liquidity constraint channel, which causes the crowding-out effect of jeonse to be zero. One interesting feature is that the jeonse crowding-out effect for the lowest $\frac{W}{Y}$ quantile is estimated to be insignificant, as in the case of homeownership. As I elaborated on above, a high stock market participation cost can effectively eliminates much of the crowding-out effect for households with low $\frac{W}{Y}$, since even renters do not participate in stock market. For $c - RFAR$, though we lose all significance due to the small number of observations, we see the same patterns for signs and the sizes of estimates.

Lastly, for stock market participation, we see that homeownership crowds out stock market participation, while jeonse has no significant effect. In Figure 2.6.7, we saw that with some level of stock market participation costs, homeowners and jeonse tenants participate in the stock market only with higher $\frac{X_{model}}{Y_{model}}$ compared with renters, due to the low level of financial assets A_{model} in hand. The Regressions seem to also capture those effects.

Table 2.7.3 reports results for the specification in equation 2.15. It shows patterns similar to those we found in specification 1. Both homeownership and jeonse tenure show substantial crowding-out effects on FAR but have less significant effects on $Alpha$ and $c - Alpha$. We also see the increasing crowding-out effect on $RFAR$ and $c - RFAR$ with higher $\frac{W}{Y}$ from homeownership and decreasing crowding-out effects on $RFAR$ and $c - RFAR$ with higher $\frac{W}{Y}$ from jeonse. Lastly, I find that the crowding-out effect on SMP stems not only from homeownership but also from jeonse, which is different from specification 1. Comparing the result with Yao and Zhang (2005) and Cocco (2005), we see similar patterns in general, especially for the stronger significance of the effect on $RFAR$ than that on $Alpha$. Overall, we find evidence of a crowding-out effect of housing among for Korean households, as the literature has shown in other countries. Though the endogeneity concerns could not be fully resolved, the data

	FAR	$Alpha$	$c - Alpha$	$RFAR$	$c - RFAR$	SMP
$Education1$	0.4304***	0.2009	-0.3116	0.0612***	-0.0165	0.3958***
	(3.2779)	(1.5181)	(-0.5214)	(2.7202)	(-0.3420)	(4.0361)
$Education2$	0.4201***	0.2022	-0.3006	0.0596***	-0.0137	0.3941***
	(3.3060)	(1.6013)	(-0.5332)	(2.8075)	(-0.2953)	(4.1978)
$Education3$	0.3984***	0.1750	-0.2646	0.0615***	-0.0060	0.3595***
	(3.2378)	(1.4430)	(-0.5017)	(2.8790)	(-0.1293)	(3.8050)
$Number\ of\ Members$	-0.0230***	-0.0035*	-0.0033	-0.0020***	-0.0042	-0.0066***
	(-6.8950)	(-1.8594)	(-0.5901)	(-3.0063)	(-1.1100)	(-2.7607)
$Log(Age)$	-0.0188	-0.0394	0.0849	-0.0117**	0.0088	-0.0800***
	(-0.5759)	(-1.2116)	(0.6121)	(-2.1243)	(0.7578)	(-3.2991)
$Log(\frac{W}{Y})$	-0.0222***	0.0050***	0.0026	0.0008	0.0017	0.0087***
	(-3.5647)	(3.2060)	(0.4851)	(1.1596)	(0.5428)	(5.0337)
$\frac{HP}{W} \times [\frac{W}{Y}]^Q_1$	0.0111	0.0007	-0.0020	2.659e-05	0.0007	-0.0021**
	(0.8192)	(0.6328)	(-1.0912)	(0.0517)	(0.6870)	(-2.0933)
$\frac{HP}{W} \times [\frac{W}{Y}]^Q_2$	-0.0780***	-0.0011	-0.0106	-0.0015	-0.0041***	-0.0114***
	(-8.7990)	(-0.3175)	(-1.3860)	(-0.7941)	(-3.3328)	(-3.5347)
$\frac{HP}{W} \times [\frac{W}{Y}]^Q_3$	-0.1078***	-0.0086**	-0.0138	-0.0053***	-0.0064***	-0.0217***
	(-11.645)	(-2.4887)	(-1.6341)	(-4.5195)	(-2.6324)	(-6.1812)
$\frac{HP}{W} \times [\frac{W}{Y}]^Q_4$	-0.1308***	-0.0186***	-0.0221***	-0.0071***	-0.0091**	-0.0338***
	(-11.574)	(-4.9443)	(-2.6817)	(-5.6611)	(-2.4979)	(-7.9756)
$\frac{HP}{W} \times [\frac{W}{Y}]^Q_5$	-0.1406***	-0.0163***	-0.0185	-0.0078***	-0.0110*	-0.0349***
	(-7.4822)	(-3.4173)	(-1.5651)	(-4.8216)	(-1.8187)	(-6.3566)
$\frac{JD}{W} \times [\frac{W}{Y}]^Q_1$	0.0135	-0.0003	0.0024	0.0015	0.0033	-0.0022
	(1.0227)	(-0.1716)	(0.5271)	(1.1829)	(0.9680)	(-1.1666)
$\frac{JD}{W} \times [\frac{W}{Y}]^Q_2$	-0.0933***	-0.0033	0.0130	-0.0050***	-0.0065	-0.0084*
	(-5.0732)	(-0.7844)	(0.7186)	(-3.2054)	(-0.8450)	(-1.6516)
$\frac{JD}{W} \times [\frac{W}{Y}]^Q_3$	-0.1132***	-0.0074	-0.0158	-0.0065***	-0.0123	-0.0128*
	(-8.6323)	(-1.3638)	(-1.0341)	(-3.1673)	(-1.2569)	(-1.6947)
$\frac{JD}{W} \times [\frac{W}{Y}]^Q_4$	-0.1187***	-0.0085	0.0041	-0.0058**	-0.0079	-0.0201**
	(-8.3772)	(-0.9658)	(0.1806)	(-2.2915)	(-1.1760)	(-2.2984)
$\frac{JD}{W} \times [\frac{W}{Y}]^Q_5$	-0.1122***	0.0048	0.0299	-0.0051	-0.0110	-0.0146
	(-5.9606)	(0.4257)	(1.0277)	(-1.6076)	(-0.9158)	(-1.3909)
No. Observations	60220	43478	4462	60220	6642	60220
R-squared	0.0649	0.0022	0.0057	0.0044	0.0113	0.0037
P-value (F-stat)	0.0000	0.0000	0.1265	0.0000	0.0000	0.0000
Effects	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE

Table 2.7.3: Regression Specification 2 - $\frac{W}{Y}$ Cross-section

pattern seems fairly consistent with the structural model's prediction. In particular, the presence of the crowding-out effect of jeonse on FAR, the stronger crowding-out effect of homeownership compared with that of jeonse on FAR, and the increasing pattern of the housing crowding-out effect of homeowners on $RFAR$ with higher $\frac{W}{Y}$ and opposite patterns for jeonse tenants yields better understanding of how each channel of the crowding-out effect works.

2.7.5 The Crowding-out Effect Across *Age*

In this subsection, I examine how the crowding-out effect changes across age groups. While other controls are same, I use the following regression formulas to reveal the pattern of crowding-out effects.

$$PF_{it} = \beta U_{it} + \sum_{Q=1}^{5} \gamma_{1Q} Jeonse_{it}[Age]_{it}^{Q} + \sum_{Q=1}^{5} \sigma_{1Q} Owner_{it}[Age]_{it}^{Q} + \epsilon_{it} \tag{2.16}$$

$$PF_{it} = \beta U_{it} + \sum_{Q=1}^{5} \gamma_{2Q} \frac{JD}{W}_{it}[Age]_{it}^{Q} + \sum_{Q=1}^{5} \sigma_{2Q} \frac{HP}{W}_{it}[Age]_{it}^{Q} + \epsilon_{it} \tag{2.17}$$

$$PF_{it} \in (FAR_{it}, RFAR_{it}, c - RFAR_{it}, SMP_{it}, Alpha_{it}, c - Alpha_{it})$$

Overall, the estimates of control variables are similar, which allows me to directly jump into crowding-out effect estimates across age group. First, regressions on FAR show that the crowding-out effect on FAR is fairly similar across ages groups for both homeownership and jeonse, which is not as the model predicts; the model predicted that older households are expected to show a lower crowding-out effect on FAR. For $Alpha$, jeonse tenants and homeowners should show higher values than renters based on the models predictions, which means that positive estimates get bigger for the higher age groups. However, again we cannot find any significant effect on α. This seems coming from the heterogeneous correlation structure likely faced by different households. For $RFAR$, we can see that the crowding-out effects are estimated as decreasing as households get older, which seems to be consistent with the model's predictions for both homeowners and jeonse tenants. In particular, the crowding-out effect of jeonse completely goes away when households get old enough, while the crowding-out effect of homeownership persists even though households get older with decreasing sizes. Similar to the previous regressions, homeownership and jeonse tenure seem to prevent households from participating in the stock market, though it is difficult to find any specific patterns across ages.

Table 2.7.5 also shows similar patterns. Interestingly, some of the crowding-out effects for $Alpha$ and $c - Alpha$ are estimated as positive, which seems consistent with the model. Since the crowding-out effect on FAR gets larger as they get older, households increase their α_a in the model. This specification gives some support for the model's prediction. However, again, the effect on α should be difficult to measure since it depends largely

	FAR	$Alpha$	$c-Alpha$	$RFAR$	$c-RFAR$	SMP
$Education1$	0.4432***	0.1408	-0.4287	0.0670**	-0.0509	0.3231***
	(2.9588)	(1.0767)	(-0.7426)	(2.5595)	(-0.6904)	(3.2528)
$Education2$	0.4320***	0.1474	-0.4154	0.0665***	-0.0487	0.3277***
	(2.9553)	(1.1840)	(-0.7662)	(2.6630)	(-0.6843)	(3.4457)
$Education3$	0.4212***	0.1204	-0.3801	0.0691***	-0.0404	0.2922***
	(2.9355)	(1.0040)	(-0.7505)	(2.7411)	(-0.5616)	(3.0446)
$Number\ of\ Members$	-0.0133***	-0.0029	-0.0028	-0.0013**	-0.0037	-0.0055**
	(-4.2100)	(-1.5470)	(-0.5344)	(-1.9805)	(-1.0347)	(-2.3045)
$Log(Age)$	0.0121	-0.0245	0.1137	-0.0126*	0.0197	-0.0621**
	(0.3159)	(-0.7651)	(0.8539)	(-1.9444)	(1.0051)	(-2.5281)
$Log(\frac{W}{Y})$	-0.0173***	0.0025*	0.0038	0.0003	0.0016	0.0054***
	(-4.1099)	(1.7420)	(0.7239)	(0.3870)	(0.4773)	(3.5948)
$Owner \times [AGE]_1^Q$	-0.3149***	0.0026	0.0355	-0.0125***	-0.0121	-0.0066
	(-25.078)	(0.3917)	(0.8595)	(-4.2543)	(-1.4094)	(-0.7719)
$Owner \times [AGE]_2^Q$	-0.3108***	-0.0125*	-0.0208	-0.0120***	-0.0213*	-0.0269***
	(-24.003)	(-1.8953)	(-1.0639)	(-3.7498)	(-1.9539)	(-3.4756)
$Owner \times [AGE]_3^Q$	-0.2948***	-0.0228***	-0.0264	-0.0116***	-0.0214	-0.0407***
	(-18.582)	(-3.7023)	(-1.5565)	(-3.7965)	(-1.5322)	(-5.6589)
$Owner \times [AGE]_4^Q$	-0.3069***	-0.0195***	-0.0347*	-0.0105***	-0.0284	-0.0384***
	(-16.055)	(-3.1568)	(-1.9517)	(-3.1843)	(-1.5633)	(-5.4960)
$Owner \times [AGE]_5^Q$	-0.3388***	-0.0004	-0.0131	-0.0062*	-0.0226	-0.0142*
	(-15.431)	(-0.0534)	(-0.6062)	(-1.8795)	(-1.1729)	(-1.9331)
$Jeonse \times [AGE]_1^Q$	-0.2334***	0.0065	0.0853	-0.0059*	-0.0005	0.0096
	(-18.248)	(1.0323)	(1.4716)	(-1.8633)	(-0.0428)	(1.1561)
$Jeonse \times [AGE]_2^Q$	-0.2083***	0.0033	-0.0102	-0.0048*	-0.0053	-0.0013
	(-14.313)	(0.4992)	(-0.4808)	(-1.7708)	(-0.5577)	(-0.1496)
$Jeonse \times [AGE]_3^Q$	-0.1944***	-0.0086	0.0031	-0.0066*	-0.0092	-0.0189**
	(-13.091)	(-1.2396)	(0.2108)	(-1.9258)	(-0.6194)	(-2.1538)
$Jeonse \times [AGE]_4^Q$	-0.1810***	-0.0087	-0.0037	-0.0078	-0.0193	-0.0203**
	(-8.4354)	(-1.1493)	(-0.2227)	(-1.4683)	(-0.8083)	(-1.9876)
$Jeonse \times [AGE]_5^Q$	-0.2013***	0.0098	0.0155	-0.0024	-0.0119	-0.0029
	(-8.8016)	(1.1824)	(0.5587)	(-0.7901)	(-0.7186)	(-0.4514)
No. Observations	60220	43478	4462	60220	6642	60220
R-squared	0.0871	0.0028	0.0086	0.0043	0.0137	0.0036
P-value (F-stat)	0.0000	0.0000	0.0058	0.0000	0.0000	0.0000
Effects	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE

Table 2.7.4: Regression Specification 1 - Age Cross-section

on individual housing characteristics. We can see a decreasing pattern of the crowding-out effect from homeownership on *RFAR* but no significant effect from jeonse tenure on *RFAR* among the oldest households. Again, this corroborates my argument regarding the nature of the liquidity constraint channel. In the end, as households get older, they are free from the incomplete-market nature of their life-cycle.

2.8 Conclusion

In this study, by using a calibrated life-cycle model with endogenous housing tenure choice and stock market participation, I show how the crowding-out effect from jeonse, which only occurs with the liquidity constraint channel, differs from the crowding-out

	FAR	$Alpha$	$c - Alpha$	$RFAR$	$c - RFAR$	SMP
$Education1$	0.4632***	0.2121	-0.4356	0.0706***	-0.0578	0.4149***
	(3.2523)	(1.6095)	(-0.7283)	(2.9310)	(-1.0164)	(4.1932)
$Education2$	0.4358***	0.2146*	-0.4245	0.0690***	-0.0542	0.4146***
	(3.1548)	(1.7094)	(-0.7533)	(3.0330)	(-1.0004)	(4.3815)
$Education3$	0.4130***	0.1877	-0.3879	0.0710***	-0.0471	0.3798***
	(3.0708)	(1.5537)	(-0.7352)	(3.0950)	(-0.8720)	(3.9846)
$Number\ of\ Members$	-0.0271***	-0.0034*	-0.0038	-0.0019***	-0.0043	-0.0067***
	(-7.5246)	(-1.7942)	(-0.7149)	(-2.7832)	(-1.1397)	(-2.7856)
$Log(Age)$	-0.0284	-0.0433	0.1141	-0.0146**	0.0179	-0.0866***
	(-0.7981)	(-1.3412)	(0.8256)	(-2.4693)	(1.3092)	(-3.5407)
$Log(\frac{W}{Y})$	-0.0516***	0.0014	0.0012	-0.0009*	-0.0005	0.0020
	(-12.654)	(1.0996)	(0.2945)	(-1.8518)	(-0.2732)	(1.4654)
$\frac{PH}{W} \times [AGE]_1^Q$	-0.0338***	0.0018	0.0146	-0.0020**	0.0067**	-0.0042
	(-4.9659)	(0.6677)	(0.7602)	(-2.2276)	(2.3416)	(-1.3406)
$\frac{PH}{W} \times [AGE]_2^Q$	-0.0131**	-0.0027	-0.0028	-0.0013***	-0.0001	-0.0072***
	(-2.0845)	(-1.5287)	(-1.1315)	(-3.2479)	(-0.2988)	(-3.5249)
$\frac{PH}{W} \times [AGE]_3^Q$	0.0290	-0.0026*	0.0003	-0.0003	0.0015	-0.0055***
	(1.1486)	(-1.6885)	(0.0935)	(-0.7128)	(0.8111)	(-3.2125)
$\frac{PH}{W} \times [AGE]_4^Q$	-0.0146	0.0006	-0.0135	0.0016	-0.0030*	-0.0053*
	(-1.3474)	(0.1466)	(-1.4445)	(0.7758)	(-1.6961)	(-1.9364)
$\frac{PH}{W} \times [AGE]_5^Q$	-0.0737***	0.0113***	-0.0097	0.0019*	-0.0019	0.0063**
	(-6.5479)	(2.6803)	(-0.8122)	(1.6493)	(-1.0963)	(2.3761)
$\frac{JD}{W} \times [AGE]_1^Q$	-0.0162	-0.0015	0.0741	9.658e-05	0.0011	-0.0027
	(-1.3451)	(-0.6139)	(1.1153)	(0.0427)	(0.3560)	(-0.7815)
$\frac{JD}{W} \times [AGE]_2^Q$	0.0192	0.0027	0.0095	0.0017	0.0070	0.0020
	(1.4248)	(0.9871)	(0.4858)	(1.1370)	(1.0747)	(0.5065)
$\frac{JD}{W} \times [AGE]_3^Q$	0.0002	0.0001	0.0146	0.0019	0.0109	-0.0041
	(0.0162)	(0.0287)	(1.1980)	(0.5748)	(0.9040)	(-0.9143)
$\frac{JD}{W} \times [AGE]_4^Q$	0.0619	-3.736e-05	0.0026	3.614e-05	0.0022	-0.0055
	(1.1850)	(-0.0113)	(0.2816)	(0.0185)	(0.2921)	(-1.4856)
$\frac{JD}{W} \times [AGE]_5^Q$	-0.0143	0.0033	-0.0004	0.0004	-0.0002	0.0015
	(-1.4444)	(1.2145)	(-0.2214)	(1.1040)	(-0.4967)	(1.1865)
No. Observations	60220	43478	4462	60220	6642	60220
R-squared	0.0454	0.0013	0.0063	0.0022	0.0095	0.0022
P-value (F-stat)	0.0000	0.0000	0.0722	0.0000	0.0000	0.0000
Effects	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE	HH/Year FE

Table 2.7.5: Regression Specification 2 - Age Cross-section

effect from ownership, which incurs both the liquidity constraint channel and house price risk channel.

The model tells us that the crowding-out effect from jeonse (the liquidity constraint channel) affects only young and low wealth (or liquidity-constrained) households, but does not affect not liquidity-constrained or old households. However, the crowding-out effect coming from the homeownership (the liquidity constraint channel + house price risk channel) affects all types of households, and the crowding-out effect persists even though households accumulate much more wealth. If households get older, the crowding-out effect gets smaller but never goes to zero.

We see that stock market participation cost and the covariance structure between stock return and housing return can nonlinearly affect the size and nature of the crowding-out effect of housing. In particular, these dramatically affect the risky financial asset ratio over financial asset non-linearly. This causes us to expect that in regression, it should be difficult to observe such channels.

Regressions from KLIPS household panel data show that the crowding-out effect of jeonse gets smaller as households have a higher net wealth-to-income ratio, while the crowding-out effect of homeownership does not decrease (or even increase in some cases) even though households have a higher net wealth-to-income ratio. In addition, as households get older, the crowding-out effect from jeonse disappears while the crowding-out effect from homeownership persists, though it decreases quantitatively. This empirical pattern confirms the different natures of the crowding-out effect from the liquidity constraint channel and the house price risk channel, as predicted by the model.

Future work may reveal clearer identification of each channel using other novel instrumental variables and suggest a more accurate quantitative nature of crowding-out effects. More detailed data on a granular level may also more clearly show us the crowding-out effect of the risky financial asset over financial asset ratio.

APPENDIX

2.A Life-Cycle Non-Capital Income Profile

Through following procedure, I calculate the life-cycle labor income profile. First, I use the almost the same sample from KLIPS which I use for fixed effect regressions in the paper. One difference is that I additionally include households who are renters or *Jeonse* tenants and have other real estate assets twice higher than their *Jeonse* deposit or rent deposit. These households were removed from the empirical analysis as they do not represent the renters and *Jeonse* tenants properly, I include them here as I want more information to consistently estimate the life-cycle profile of labor income.

With this sample, I regress the logged non-capital income (Y) on age dummy variables for each year (2009-2019). Then, I averaged out all the estimates across the years. Finally, I regress the averaged estimates on age from 30 to 64 dummy variables on the fifth order age polynomial, while averaging out the estimates on ages after 64 for estimating retirement income. Then, I calculate the fitted values which are represented below in Figure 2.A.1.

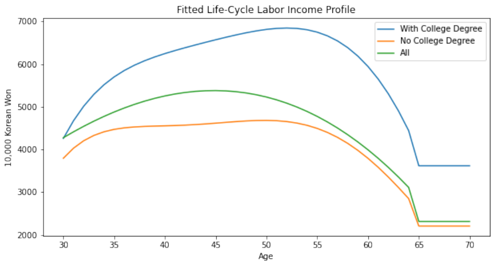

Figure 2.A.1: Calibrated Life-Cycle Income

Here, by averaging out, I controlled each year's fixed effect. In addition, I assume that households' individual characteristics are averaged out. With following calibrated labor income profile, I calculate the growth rate $[g_i]_{i=1}^{i=35}$ (log difference), and use them to solve the model in the main paper.

2.B Calibration for Exogenous Processes

2.B.1 First Moments

For housing return process and stock return process, I use national stock index and national housing price index from KOSPI and Korea Real Estate Board. I calculate the log of yearly mean return for them, and I calculate the μ, μ_h, σ_ϵ, and σ_h.

2.B.2 Correlations across Return Processes

To calculate out the correlation between labor income process, stock return process, and housing return process, we need each component's aggregate shocks. For housing return and stock return, following Vestman (2019), I use aggregate indices for both, and calculate the log of yearly mean return. For the labor income process, following Vestman (2019), I calculate the following component.

$$resid1_{it+1} = log(Y_{it+1}) - log(Y_{it}) + g_{it+1} \tag{2.18}$$

$$AggLab1_t = \frac{\sum_{i=1}^{i=N_I} resid1_{it} * SW_{it}}{\sum_{i=1}^{i=N_I} SW_{it}} \tag{2.19}$$

Here, $AggLab1$ represent the aggregate shock as idiosyncratic shocks goes away by averaging out for each year. As the second method, similar to that of Cocco (2005), I regress following regression.

$$\begin{aligned} log(Y_{it}) =& \alpha_i + \gamma_t \beta_1 Age + \beta_2 Age^2 + \beta_3 Age^3 + \beta_4 Age^4 + \beta_5 Age^5 \\ &+ \beta_6 Education + \beta_7 NumOfMember + \epsilon_{it} \end{aligned} \tag{2.20}$$

After that, by calculating the fitted value $log(\hat{Y}_{it})$, I calculate following residuals.

$$resid2_{it+1} = log(Y_{it+1}) - log(Y_{it}) + log(\hat{Y}_{it+1}) - log(\hat{Y}_{it}) \tag{2.21}$$

$$AggLab2_t = \frac{\sum_{i=1}^{i=N_I} resid2_{it} * SW_{it}}{\sum_{i=1}^{i=N_I} SW_{it}} \tag{2.22}$$

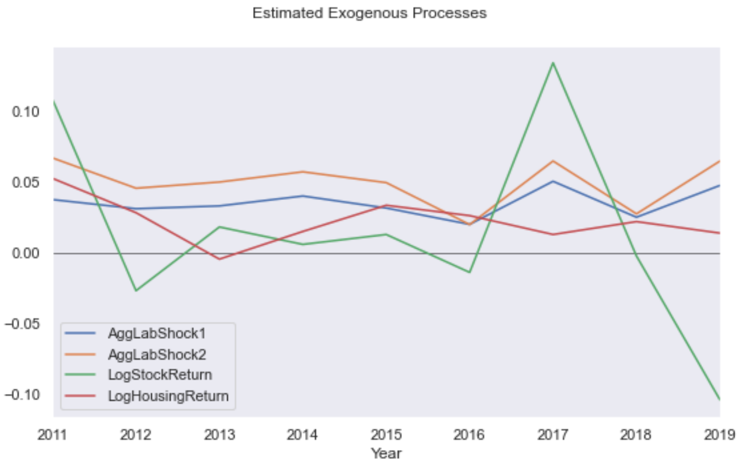

Figure 2.B.1: Estimated Exogenous Processes

Then, I calculate the weighted mean according to the survey weight (SW_{it}) for each year. Following Figure 2.B.1 is the plot for $AggLab1$, $AggLab2$, $log(R)$, and $log(R^H)$.

It is interesting that $AggLab1$ and $AggLab2$ share very similar trajectories throughout the years. If I calculate the Pearson correlations between these processes, none of them are statistically significant as noted in Table 2.B.1.

	AggLab1 & Stock	AggLab1 & Housing	AggLab2 & Stock	AggLab2 & Housing	Stock & Housing
Correlation	0.114546	-0.222892	0.179976	0.021417	0.22599
P-Value	0.752693	0.535934	0.618808	0.953171	0.53013

Table 2.B.1: Exogenous Process Correlation Structures

Consequently, I set all the correlations as zero as in Fagereng et al. (2017) and Brandsaas (2018).

2.C Downpayment Constraint for the Normalized Model

According to Korea Real Estate Board, the median price of all types of apartments in 2015 is estimated as 25,194.5, while the median *Jeonse* deposit size of all types of apartments in 2015 is estimated as 17,953.4. [13] On the other hand, median household yearly income with 3 household members after tax is 3507.5. As one period is 2 years in the model, it corresponds to 7,015. With calibrated downpayment ratio for *Jeonse* and purchase in the main paper (0.416, 0.482), we can calculate as following for *Jeonse* tenant.

$$X_a \geq \delta_J \bar{J} P^H \underline{H} \tag{2.23}$$

$$\frac{X_a}{Y_a} \geq \frac{\delta_J \bar{J} P^H \underline{H}}{Y_a} \tag{2.24}$$

$$\frac{X_a}{Y_a} \geq 0.416 * 17,953.4/7,015 = 1.064 \tag{2.25}$$

Also, with the same method, for home purchaser, we calculate following.

$$X_a \geq \delta P^H \underline{H} \tag{2.26}$$

$$\frac{X_a}{Y_a} \geq \frac{\delta P^H \underline{H}}{Y_a} \tag{2.27}$$

$$\frac{X_a}{Y_a} \geq 0.482 * 25,194.5/7,015 = 1.7304 \tag{2.28}$$

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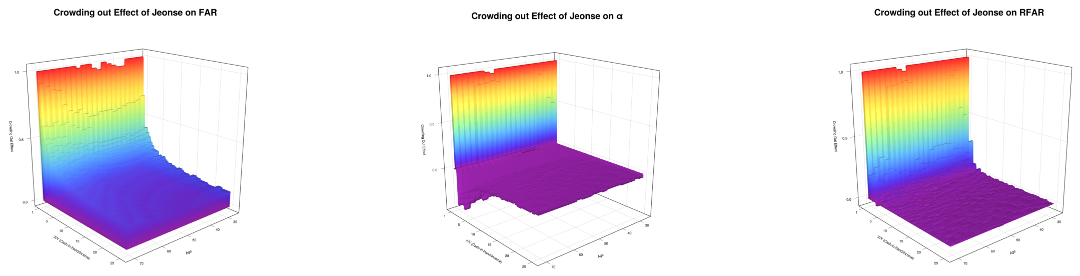
[13] Here, 1 means 10,000 Korean Won which is $8.52 in 2015 average exchange rate.

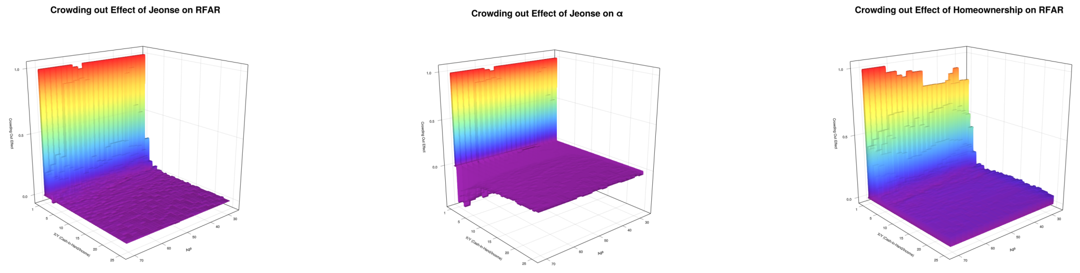
2.D Crowding Out Effect Graphs

2.D.1 High Correlation between Stock Return and Housing Return

Here I use the baseline calibration with only ρ_{hs} set as 0.3 which is higher than that of original value.



(a) *Jeonse* on $\frac{A_a}{NW_a}$ (b) *Jeonse* on α_a (c) *Jeonse* on $\frac{\alpha_a A_a}{NW_a}$

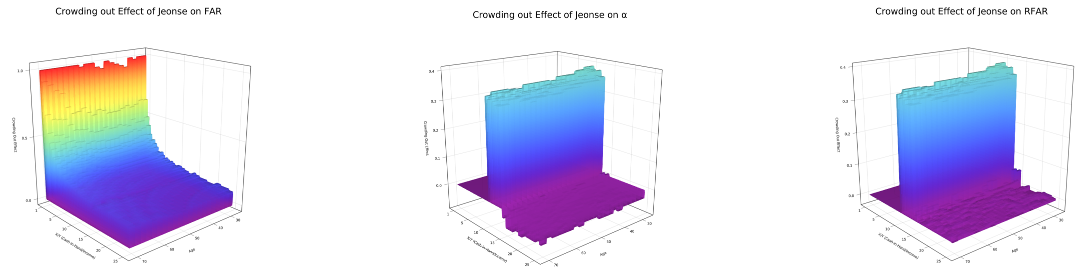


(d) Homeowner on $\frac{A_a}{NW_a}$ (e) Homeowner on α_a (f) Homeowner on $\frac{\alpha_a A_a}{NW_a}$

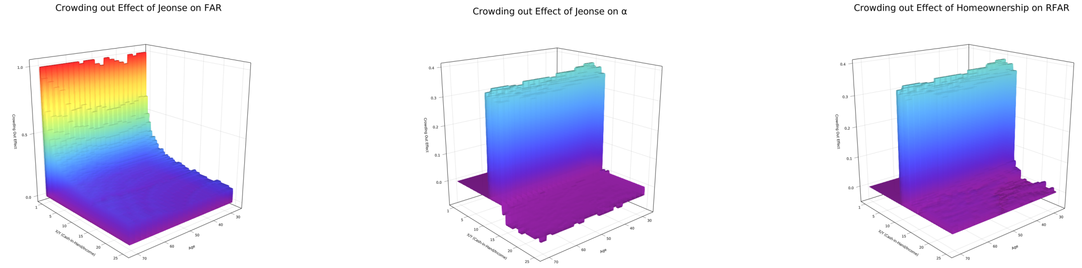
Figure 2.D.1: Crowding out Effect With $\rho_{hs} = 0.3$

2.D.2 High Stock Market Pariticpation Costs

Here I use the baseline calibration with only γ set as 0.05 which is higher than that of original value.



(a) *Jeonse* on $\frac{A_a}{NW_a}$ (b) *Jeonse* on α_a (c) *Jeonse* on $\frac{\alpha_a A_a}{NW_a}$



(d) Homeowner on $\frac{A_a}{NW_a}$ (e) Homeowner on α_a (f) Homeowner on $\frac{\alpha_a A_a}{NW_a}$

Figure 2.D.2: Crowding out Effect With $\gamma = 0.05$

CHAPTER 3

Building Housing: The Allocative Efficiency of Creating New Cities Versus Expanding Existing Cities

3.1 Introduction

Recent skyrocketing house prices in the superstar cities such as Los Angeles and New York have been decorating the newspapers. At the same time, unlike before, labor incomes of those productive cities have been much higher than those of other cities, showing no patterns of convergence as noted by Ganong and Shoag (2017). Many economists believe that this pattern implies the misallocation of labors due to frictions caused by the housing market. Though Los Angeles and New York have higher labor productivities, enticing workers to move there, high house prices prevent those workers from moving. Recent research has estimated that the lost productivity in the US due to this misallocation is huge (Herkenhoff et al., 2018; Hsieh and Moretti, 2019).

Flip side of the coin named misallocation is a regional decline.[1] As productive cities absorb economic resources, cities with low productivities lose most of their resources. People leave low productivity cities and city gets abandonded. This implies that the more reallocation means more regional decline. In the European Union (EU), Iammarino et al. (2019) showed that high income regions had population growth around 10%

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[1] Regional decline can be a form of a decline not only in terms of absolute or relative living standards but also in terms of absolute or relative population (Breinlich et al. 2014). The literature has proposed a broad range of explanations for regional decline: it could be a result of geographical sorting (Diamond 2016; Kaplan and Schulhofer-Wohl 2017), lack of local competition (Alder et al. 2014) or misallocation (Hsieh and Moretti 2019), which partially stems from rising housing prices in higher-income regions (Ganong and Shoag 2017.)

from 2000 to 2014, attracting individuals from low-income regions, which lost 2% of the population. Regional decline cannot be understood purely as a healthy resource reallocation. Breinlich et al. (2014) points out the potential externalities that might happen as a result of the regional decline. Infrastructure and social overhead capital in the declining regions will be less well utilized, and the local tax base will erode. In addition, the influx of new people into growing cities requires additional, expensive, infrastructure. Most importantly, declining regions are likely to become low-trust, high-crime regions. These regional decline issues also effect political stability, as shown in the Brexit Referendum.

Studying this coin named as "misallocation" in the head and "regional decline" in the tail, researchers have emphasized the role of land use policies. Glaeser (2014) shows how the 1960 property rights revolution led to a less elastic housing supply resulting in skyrocketing house prices. In addition, Herkenhoff et al. (2018) (hereafter HOP) argue that California and New York are much more tightly regulated than Texas, and they interpret such land-use regulations as main drivers of the misallocation. While academic discussion is in progress, these issues have also been prominent in political discourse. For example, the Biden Administrations Housing Supply Action Plan states Exclusionary land use and zoning policies constrain land use, artificially inflate prices, perpetuate historical patterns of segregation, keep workers in lower productivity regions, and limit economic growth.[2] On the ther hand, in 2019, the former UK prime minister Boris Johnson and Conservative Party articulated a policy agenda called “Levelling up”, which aims to “reduce the imbalances, primarily economic, between areas.” This type of intervention, in the UK or elsewhere, combines various land policies. [3]

We provide a comprehensive analysis on these issues by analyzing South Korea through the lens of the model from HOP. We analyze the effects of different types of land use

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[2] The White House (2022, May 16). President Biden Announces New Actions to Ease the Burden of Housing Costs [Press release]. Retrieved from https://www.whitehouse.gov/briefing-room/statements-releases/2022/05/16/president-biden-announces-new-actions-to-ease-the-burden-of-housing-costs/

[3] *Levelling Up the United Kingdom*, Leveling up White Paper, CP 604, HM Government, Feb 2022. https://www.gov.uk/government/publications/levelling-up-the-united-kingdom

policies on the economy's allocative efficiency. Throughout the paper, we use a broader definition of allocative efficiency. On top of efficient resource allocations in terms of the marginal cost and marginal benefit, we use "allocative efficiency" as a concept that also incorporates potential externalities from regional decline. Our analysis goes beyond aggregate productivity changes, following our broader definition, to account for regional decline in South Korea.

Our paper is different in several aspects compared to the previous research. Our first innovation comes from the scope of land-use policies we cover. The South Korea government has implemented different types of land-use policies. First, it implements conventional land use policies on how land can be used for construction such as floor area ratio, building coverage ratio, and height restrictions. It is usually the legal restriction on what types of buildings can be built on or legal restriction on physical shape of the building.[4] The South Korean government has dealt with excessive migration to the Seoul Metroplitan Area (SMA) by relaxing these policies in the SMA. (*Expanding Existing Cities*) From now on, we call a group of such land use policies as "Land-Use Restriction." The South Korean government has also implemented unique land use policies we categorize as "Active Land Supply", following the terminology of "active labor market policies (ALMPs)". Here, by the word "Land Supply", we mean the supply of the usable land which has a well-equipped infrastructure such as roads, irrigation system, and electricity grid system. In a land without any infrastructure, it is hard to encourage any economic activity. We do not consider land without any infrastructure a production factor. We only consider usable land with enough infrastructure where the economic activity can readily happen as a production factor. Starting in the 1980s, South Korean government implemented several New Town Projects (NTP) near SMA. Via these projects, they converted land near SMA without any well-equipped infrastructure into land on which a city can be built. This infrastructure initiative included a new zoning system to provide appropriate infrastructure. Such New Town Projects can be understood as kinds of the

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[4] In South Korea, local land-use restrictions are determined by regional authorities, while there are uniform legal boundaries in place, resulting in considerable variation across regions.

active land supply policies. (*Building New Cities*.) For instance, the 2nd NTP in early 2000s provided 139.0km^2 of usable land and 666,000 housing units nearby SMA.

South Korea's diverse land policies give us a reasonable case study for examining how different types of land policy affects regional economies. We study the effects of these two different types of land-use policies by using a structural model in HOP. We first estimate the overall level of land-use restrictions over time and across regions. We then perform a cost-benefit analysis of the 2nd NTP, and check how the active land-supply policy affected allocative efficiency in regional economics. To that end, we incorporate detailed administrative data from the 2nd NTP. Though many studies have examined the role of land use restrictions, this is the first paper that studies the implications of active land supply policies on allocative efficiency and regional economies.

Our second innovation is clearer identification on the effect of land use policies on regional resource allocations. South Korea is geographically small and its sub-regions are very homogeneous compared to other large economies, such as the US and the EU. South Korea's small size means it has low trading costs and low migration costs. All of the sub-regions in Korea share the same legal and cultural backgrounds. These two characteristics allow us to clearly observe the effects of land policies that are heterogeneously applied to the regions.

South Korea has experienced dramatic resource reallocation across regions. In 1970, only 34% of the total population lived in SMA. However, now its share is over 50%. House prices in SMA and the rest of South Korea have also rapidly diverged, implying that rural South Koreans have experienced a decline in their relative quality of life.

By using the region level data of South Korea from 2002 to 2019, we estimate the regional productivities, amenities, and land-use restriction levels by using the structural model. We find that the model-implied regional land price distributions matches the data quite well, and the model-inferred land-use restrictions are highly correlated with the observed legal regulations such as floor area ratio and building coverage ratio. Our calibration results indicate that Seoul has the highest TFP but is the least restrictive in terms of land-use restriction. We interpret this result as the South Korean government's choice to stabilize the Seoul Metropolitan housing market. In contrast, our estimates suggest that rural areas have heavy land-use restrictions compared to SMA.

We leverage the model and calibration results to analyze the impact of land-use restriction adjustments and active land supply on regional output, population distribution, housing prices distribution, and aggregate productivity. Through a set of counterfactual experiments, we examine the effect of changing land-use restrictions in the SMA while keeping the national usable land stock fixed. This mimics a policy suggestion from the public arena calling for stringent regulation in the SMA to alleviate regional decline. Our findings indicate that tightening land-use restrictions in the SMA by 15% could lead to a significant increase of population in rural regions, but at the cost of a universal increase in housing prices and a 1.4% decrease in aggregate output.

The second set of experiments focuses on the impact of actual land supply on economic outcomes. To establish a benchmark, we evaluate the 2nd New Town Project of South Korea, a significant land supply initiative in the SMA. Our findings show that the policy increased aggregate output by 0.4%. Given its cost of 4.05% of GDP at the time of implementation, we conclude that the NTP was a net positive for the economy based on a back-of-the-envelope calculation. The relaxed land-use restrictions in the SMA and New Towns also led to lower housing prices across all regions by attracting more people to these areas. However, our analysis suggests that the economic outcomes could have been better if the NTP had been implemented in non-SMA areas. In the "worst" case scenario, where all the NTP land was taken from the SMA and uniformly redistributed to Rural regions, the aggregate output would still have been 0.1% higher than the SMA baseline, and population concentration in the SMA would have been reduced and housing prices would have been lower across all regions. It is important to note that these results are based on a basic neoclassical model that does not account for agglomeration or skill heterogeneity, and should therefore be viewed as a baseline analysis and a call for further comprehensive analysis.

Our paper proceeds in following way. Section 2 places our paper within the literature and outlines its contribution. Section 3 provides an overview of the regional economies in South Korea, including a discussion of the ongoing debates surrounding land-use policy. Section 4 presents our model, and calibrates it using Korean data to estimate region-specific parameters of productivity, amenities, and land-use restrictions. We validate our model in this section using observed land prices and land-use restrictions. Section 5 conducts a set of land-policy experiments. Section 6 concludes, discussing the limitations of our analysis and potential directions for future research.

3.2 Literature Review

This paper is related to several veins of spatial-macro general equilibrium analysis. First, It falls within the realm of spatial policy literature that focuses on the effect of land-use regulation. The main focus of most research in this field is on understanding the impact of land-use restrictions on aggregate productivity. Land-use restrictions are viewed as a cause of slower growth via spatial misallocation with declined regional mobility, as demonstrated by Glaeser (2014), Furman (2015), and Hsieh and Moretti (2019). In this paper, we not only study the effect of conventional land-use restriction policies but also analyze the effect of active land supply policies on aggregate productivity through the lens of a structural model. While most related papers assume that the government determines how land can be used while its supply is constant (Herkenhoff et al., 2018; Hsieh and Moretti, 2019), we consider increases in land stock due to active land-supply policies by the government. Land stock refers to land with appropriate infrastructure suitable for regular economic activities. While these policies may be similar to relaxing land-use restrictions in theory, the active land supply policies are considered an independent alternative in the public arena. Also, such policies can be better measured via their costs, area supplied, and location. To the best of our knowledge, there is no prior research that has used a structural model to analyze the impact of active land supply policy. We use our framework to evaluate the efficacy of South Korea's 2nd New Town Project, adding a new dimension to the land policy literature. The results of our study have implications for other countries that are using land policy to address regional decline, such as the UK.

Another challenge in the literature is measurement of land-use restrictions over time across regions. There have been several attempts to construct a systematic metric from regulation-related survey, beginning with the work of Gyourko et al. (2008), which was recently followed by Gyourko et al. (2021). Another approach is modeling an economic framework that maps more generic economic variables to a metric of land-use restriction. In recent work, HOP develop a spatial general equilibrium model to construct a time series estimate of residential land-use regulations for US states. Babalievsky et al. (2023) identify land-use restrictions on commercial properties from tax information, utilizing the near-universe of U.S. commercial property tax records. This paper adds an international dimension to the existing literature by providing the first estimates of land-use restrictions in South Korea. We validate the reliability of the model-based approach by leveraging South Korean data on observed land prices and land-use restrictions, such as floor area ratio or building coverage ratio.

The effects of land policies are studied for various outcomes other than aggregate productivity as well. Lindsay (2022) study the effect of land-use restrictions on welfare of households in different age and education groups in the US. Colas and Morehouse (2022) studies the relationship between land-use restrictions and environmental costs, arguing that relaxing land-use restriction in environmentally friendly cities will reduce carbon emissions. Moreover, Dachis and Thivierge (2018) studies the effect of land-use restriction on construction costs in Canada, while Cun and Pesaran (2021) studies the impacts of land-use restriction on internal migration, wages, and housing price to analyze spatial spillover effects. Our paper connects land policies to the regional decline literature by examining the relationship between land policies and the distribution of population and housing prices across regions. We view land policy not only as a possible contributor to population concentration and high housing prices, but also as a potential solution to these issues.

Regional decline has been a prevalent problem in many countries and a topic of significant interest in academic literature. Recently, in the US, the rise of super-star cities drastically contrasted with the fall of the rust-belt has prompted many researchers to study the determinants of regional growth and regional decline as noted in Desmet and Rossi-Hansberg (2014), Ganong and Shoag (2017), and Moretti (2013). While economists tend to interpret this process as a market driven reallocation, the public demand policy interventions to protect, or revive, regions with declining economies. Instead of taking a stance on regional decline as either a natural process or a problem in need of resolution, our study tries to analyze allocative efficiency in a broader sense, considering both aggregate productivity and potential externalities caused by land use policies.

3.3 Regional Economies in South Korea

South Korea has gone through significant resource reallocations, with the majority of economic resources moving to the countrys capital, Seoul, and its surrounding areas. In order to comprehend this process and allocative efficiency in South Korea, it is crucial to overview its economic geography. This section begins by outlining the administrative divisions of the country.

3.3.1 Administrative Divisions

South Korea is comprised of seven Metropolitan Cities, eight Provinces (-do), and two special regions (Sejong and Jeju Special Self-Governing Province) in the highest geographical hierarchy as in Figure 3.3.1. Metropolitan Cities are legally independent entities, as they are not part of the Provinces. Designating certain regions as "Metropolitan Cities" is a political process. While there is a law defining requirements for each geographical unit, politics usually preceded laws.

Still, this administrative division provides a useful overview of the economic geography of South Korea. All seven Metropolitan Cities have a population of over 1 million and were once the major cities in their respective Provinces. Despite their legal independence, Metropolitan Cities are often still seen as representative of the Province they are located in. As a result, we classify Metropolitan Cities as urban areas with high population density and consider Provinces to encompass the remaining rural areas.

There are two special regions, Sejong and Jeju Special Self-Governing Provinces. These regions are considered separate and independent due to their specialized functions as a government and public administration cluster (like Washington D.C.) or large islands, rather than economic factors. Considering this, we exclude Sejong and Jeju from our analysis of regional decline.

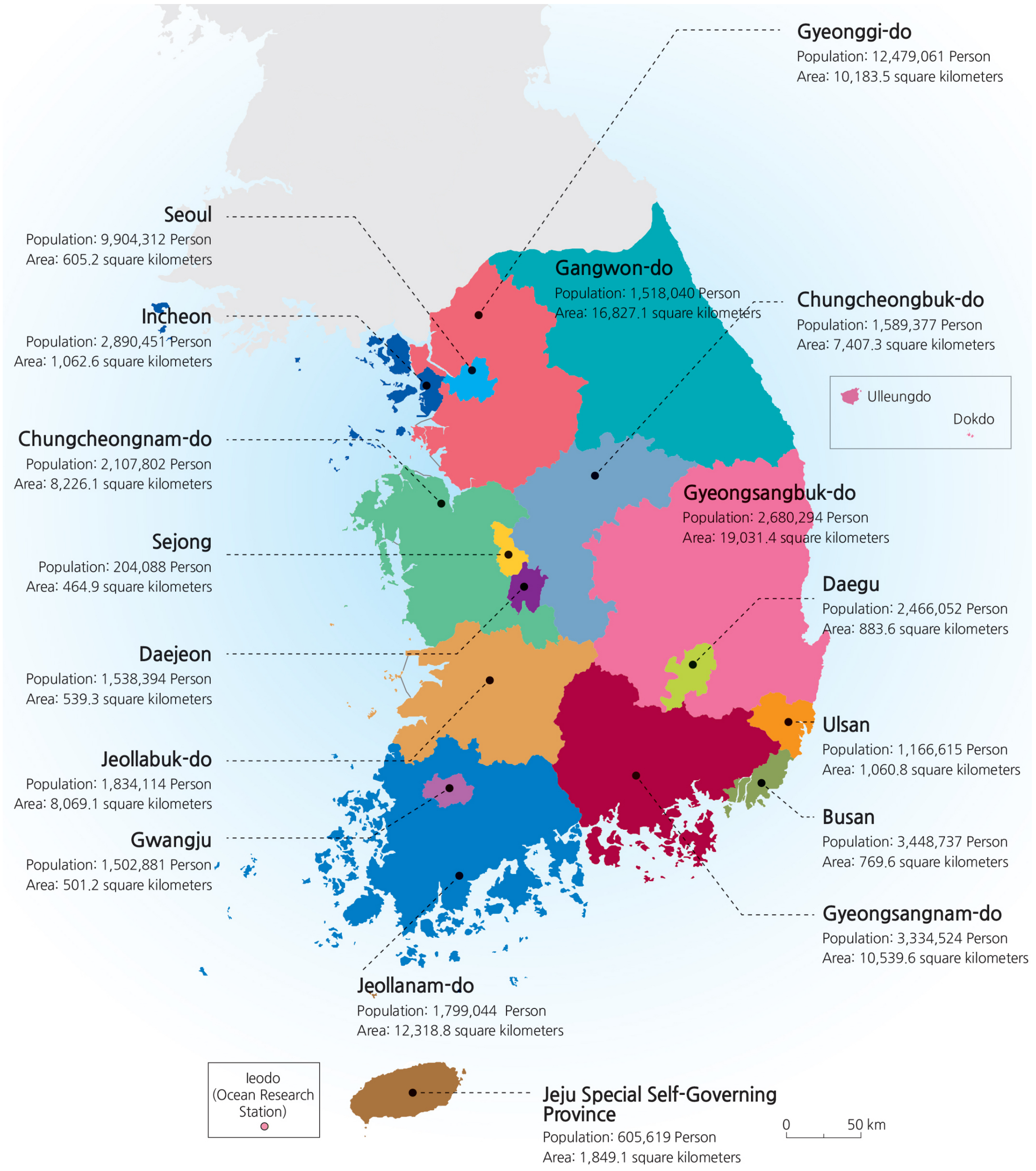


Figure 3.3.1: Administrative Division in South Korea (KNGII) (2017)

3.3.2 Population Distribution

We start with showing how the regional population distribution has evolved in South Korea over time. Table 3.3.1 shows the population in each administrative region in 2020.

Table 3.3.1: The Regional Population Distribution

Category	Region Name	Population Millions	%
A. Administrative Divisions			
Metropolitan City	Seoul	9.5	(18.4)
	Incheon	2.9	(5.7)
	Busan	3.4	(6.5)
	Daegu	2.4	(4.6)
	Gwangju	1.4	(2.8)
	Daejeon	1.5	(2.8)
	Ulsan	1.1	(2.2)
Province (-do)	Gyeonggi-do	13.6	(26.3)
	Gangwon-do	1.5	(3.0)
	Chungcheongbuk-do	1.6	(3.1)
	Chungcheongnam-do	2.1	(4.1)
	Jeollabuk-do	1.8	(3.5)
	Jeollanam-do	1.8	(3.5)
	Gyeongsangbuk-do	2.6	(5.1)
	Gyeongsangnam-do	3.3	(6.4)
Special Self Governing City	Sejong	0.4	(0.7)
Special Self Governing Province	Jeju	0.7	(1.3)
Total		51.6	(100.0)
B. Upper-level Divisions in the Analysis			
Seoul Metropolitan Area (SMA)	Seoul, Incheon, Gyeonggi-do	26.0	(50.4)
Metro	Busan, Daegu, Gwangju, Daejeon, Ulsan	9.8	(18.9)
Rural	All Provinces except Gyeonggi-do	14.8	(28.7)
Excluded	Sejong, Jeju	1.0	(2.0)

Seoul Metropolitan City and Gyeonggi Province, which is near Seoul, have the largest populations. Because Incheon Metropolitan City is close to Seoul Metropolitan City, we group these three regions as Seoul Metropolitan Area (SMA). In 1970, only 34% of the total population lived in Seoul Metropolitan Area. However, now its share is over 50%. On top of the SMA, we use two other regional classifications: Metro and Rural. Each corresponds to a group of Metropolitan cities and Provinces, except the three SMA regions. (Table 3.3.1) The upper-level divisions are analogous to the U.S. Census Regions in that the delineation is for the purposes of statistical analysis and presentation, not for administration.

Figure 3.3.2 shows the regional distribution of energy consumption in residential buildings in 2019 in the finer administrative division levels. Populations are concentrated in Seoul and near Seoul areas (Gyeonggi and Incheon) where the residential building energy consumption is significantly concentrated. On the other hand, in most of the Province areas, the energy consumption from residential building in each division is low, which means that the population is spread over larger regions. Most of the regions with high energy consumption coincide with the Metropolitan Cities' locations.

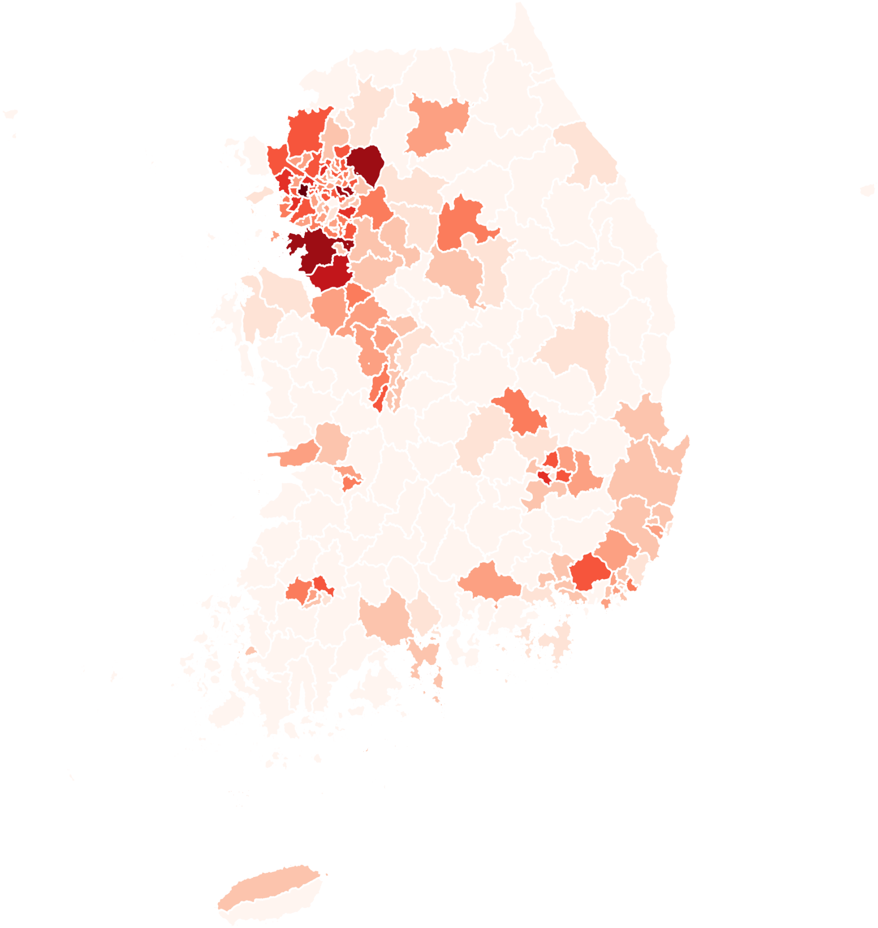


Figure 3.3.2: Residential Energy Consumption in South Korea

Now we present time trends in population distribution. Starting from 1970, Seoul Metropolitan Area and other Metropolitan Cities showed a dramatic increase in the population level, while the Provinces lost their populations. However, starting from 2000, even other Metropolitan Cities populations stopped increasing while Seoul Metropolitan Area kept absorbing the population. This population influx into SMA was driven by young people, which increased the relative average age of other region to Seoul Metropolitan Area. The fact that most Provinces are losing their populations and getting older has become a national concern because of potential negative externalities such as political instability and dramatic decrease of quality of life for residents.

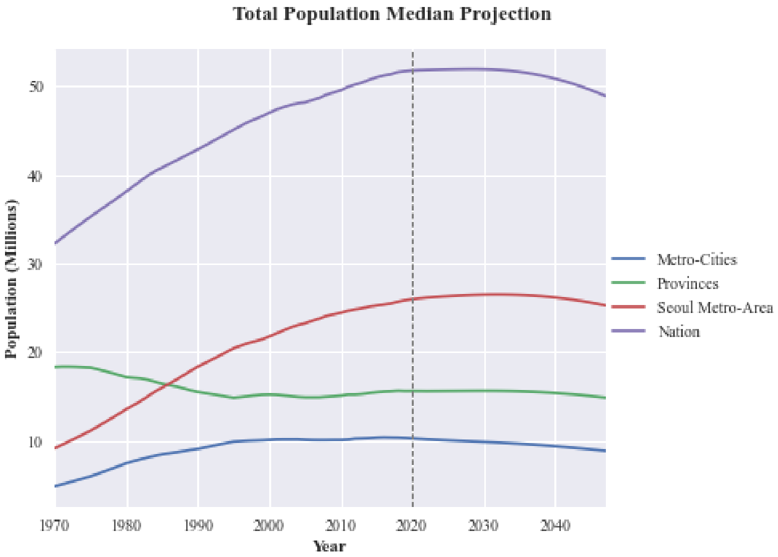


Figure 3.3.3: Population Distribution

3.3.3 Regional GDP

Migration from non-SMA to SMA has exacerbated the difference between SMA and other regions. Figure 3.3.4 shows how this pattern has evolved. Most regions have seen their GDP per capita fall relative to Seoul. Even in the Ulsan Metropolitan City, which is filled with exporting factories, GDP per capita has fallen relative to Seoul. This pattern implies that Seoul's economic significance in South Korea is getting larger, which may come from the agglomeration effect.

3.3.4 Housing Price Distribution

What naturally follows is house price divergence. Given the limited land, as more population concentrates in Seoul Metropolitan Area while other regions' economies do not grow as much as Seoul, housing prices in Seoul have increased relative to other

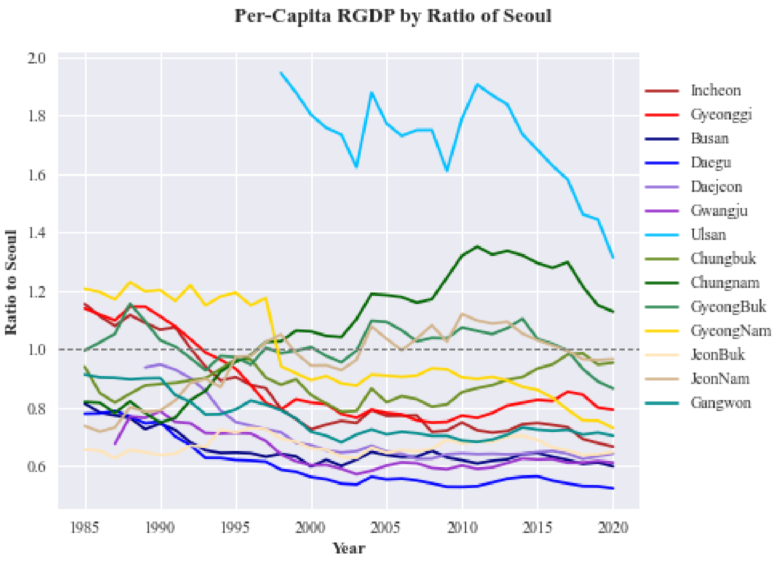


Figure 3.3.4: Relative real GDP per capita

regions. In addition, although we cannot see the house price growth in Gyeonggi Province, in some of the subregions in Gyeonggi Province house prices are comparable to Seoul Metropolitan City. Figure 3.3.5 shows how housing prices have evolved over time. All regions show falling house prices relative to Seoul. On average, all regions' house prices relative to Seoul have been halved from 1986 to 2019. This change in house prices has made it considerably harder for workers to relocate to Seoul.

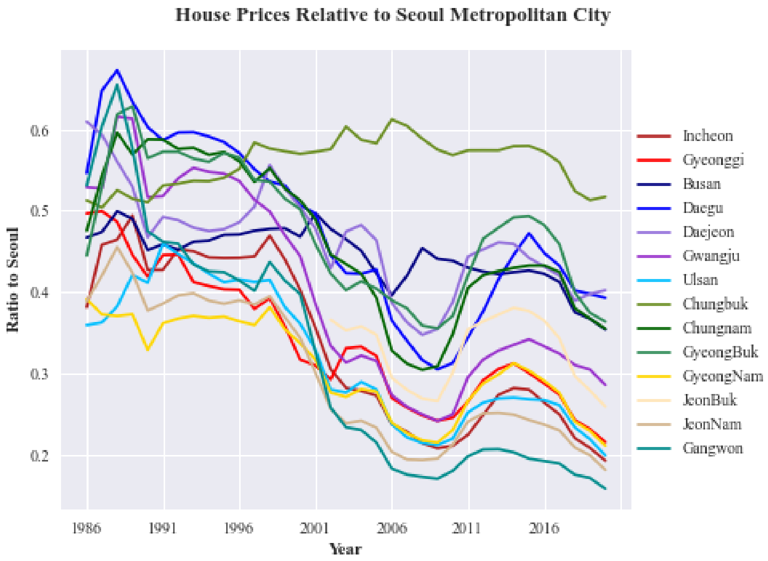


Figure 3.3.5: House Price Distribution

3.3.5 Land Policy and Regional Economies

This increasing concentration of economic resource in Seoul has been discussed as one of the most important problems that South Korea is facing. Many people discussed the potential role of land policies in such transitions. In this subsection, we discuss how these land policies are connected to both resource reallocation and regional decline.

3.3.5.1 Land-Use Restriction

Land-use restrictions are any constraints on how a specific piece of land can be used. Common types of land-use restrictions include floor area ratios, building coverage ratios, and height restrictions. These policies focus on the physical properties of the structures that can be built. Additionally, there may be restrictions on the types of buildings that can be constructed in certain areas. For example, in some regions, factories or garbage incinerators may not be allowed, and in extreme cases, no structures can be built at all.

In the latest presidential election in 2022, the two main candidates pledged to increase the floor area ratio in certain areas of Seoul to 500% by implementing new zoning types, according to Shin (2022). In addition, the elected President Yoon plans to increase the average floor area ratio from 200% to 300% in order to boost the supply of housing units Kim (2022).

These expansionism pledges have generated opposition due to concerns over insufficient infrastructure. The increase in housing unit supply is expected to result in a corresponding increase in population levels in the region, however, the capacity of current infrastructure is limited and unable to keep pace. Experts are also worried about the exacerbation of regional decline as more people are drawn to the Seoul Metropolitan Area, potentially expediting the migration of Rural populations to the city. Our subsequent analysis examines the impact of these land-use restrictions on population distribution, housing price distribution, regional output, and the aggregate output of South Korea.

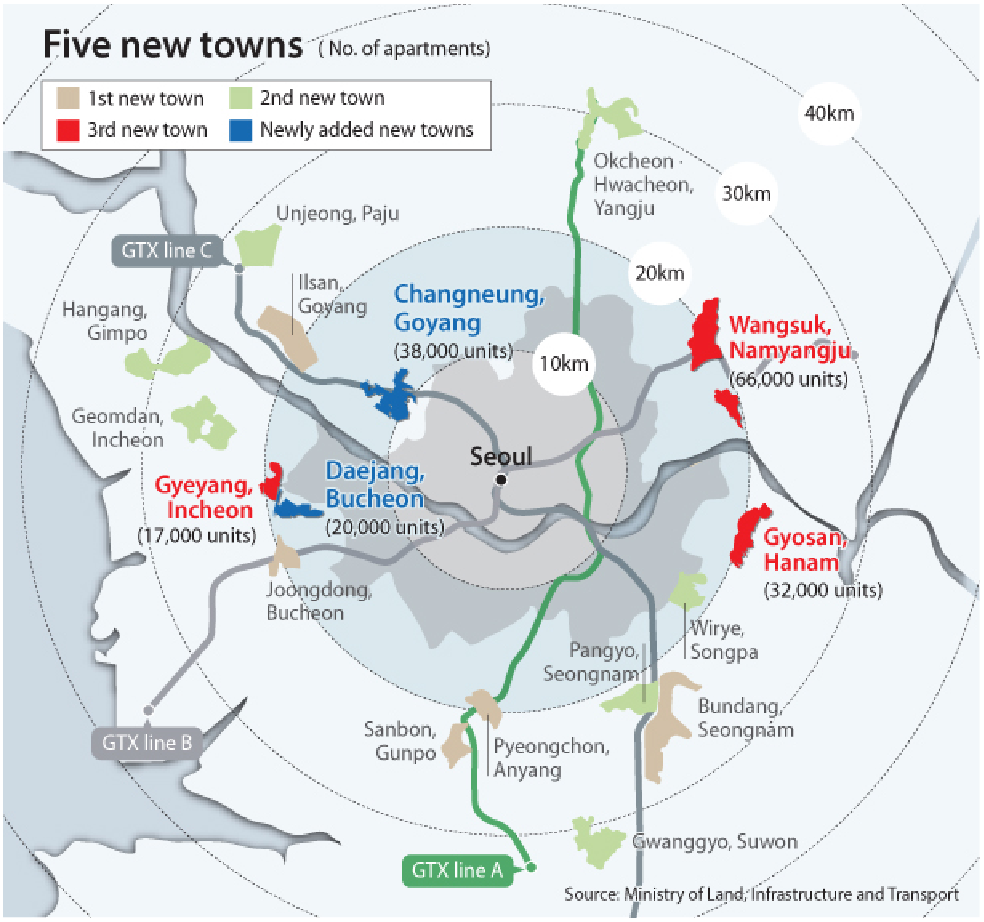
3.3.5.2 Active Land Supply: New Town Project

In the late 1980s, to resolve the sky-rocketing housing prices and lack of housing supply near Seoul Metropolitan City, the South Korean government started to build new towns that are located within a 20 km perimeter around Seoul. This project was named as the “1st New Town Project.” This project consists of building five new towns, Ilsan, Joongdong, Sanbon, Pyeongchon, and Bundang on lands which were rural area. This project supplied 292,000 houses with appropriate infrastructure and transportation systems. Many people consider this ‘1st New Town Project’ successful because it stabilized house prices and solved housing shortage problems. In the 1990s, experiencing another housing market boom, the South Korean government implemented the "2nd New Town Project," which provided 666,000 houses within the 40 km perimeter of Seoul. Most recently, the South Korean government is now planning the "3rd New Town Project" which will provide 178,000 more houses within the 10 km perimeter of Seoul.

This new town project is different from housing supply by private construction companies in the sense that the government plans the whole city with appropriate infrastructure. In other words, the government converts the unused land without any infrastructure into land on which cities can be built. This can be interpreted as active supply of urban lands.

Lands without any infrastructure such as roads, irrigation system and electricity supply will not be used by the private sector for housing nor production. By converting the land into the whole usable city, the government effectively supplies the land factor which can be used either the residential production or goods production. In this sense, the 1st, 2nd, and 3rd New Town Project can be interpreted as the government supplying land near SMA. Figure 3.3.6 shows how those lands were supplied.

On the one hand, proponents of these projects argue that migration to the new towns works as labor supply to the rapidly growing Seoul Metropolitan Area, which bolsters the economic growth of South Korea. On the other hand, many critics argued that these New Town Projects have exacerbated the regional decline by inducing people to



Source: Ministry of Land, Infrastructure and Transport

Figure 3.3.6: The 1st, 2nd, 3rd New Town Projects

move near Seoul Metropolitan Area. In addition, these government driven projects incur tremendous costs. The Second New Town Project cost 22 billion US dollars in 2004 US dollars. This was 4.05% of South Korea GDP in 2004. They argue that this fund could have been used to develop other cities in Provinces or near Non-Seoul Metropolitan Cities, which might have resolved regional decline.

In the later part of our paper, we try to provide the quantitative answer to this debate. By using HOP, we estimate the impact of the 2nd New Town City on regional population distribution, housing price distribution, and aggregate TFP. On top of that, we conduct the cost-benefit analysis of such a project. Lastly, we explore the effects of counterfactual policy building new cities in Provinces or near Non-Seoul Metropolitan Cities.

3.4 Model

In this section, we present our spatial growth model. Our model is based on HOP. Each region has an exogenous stock of land, and this land has two uses, housing production or consumption good production. As a land is a fixed factor at any time, following HOP, we represent the level of land-use restrictions (broadly defined including zoning, height restrictions, etc.) via the share of the land stock that can be utilized. These land-use restrictions are exogenous and time-varying, which we consider as policy variables.

3.4.1 Households

There are J regions, indexed by j. Time is indexed by t. There is one representative household that owns all the capital and stock of lands. In addition, they allocate workers under the constraint that housing should be properly provided to all those workers. The representative household solves the following maximization problem:

$$\max_{k^y_{jt},k^h_{jt},n_{jt},x^h_{jt},x^y_{jt},h_{jt},k_t} \sum_{t=0}^{\infty} \beta^t [u(c_t, n_t) + \sum_{j\in J} a_{jt} n_{jt}] \tag{3.1}$$

$$s.t. \quad c_t + i_t = \sum_{j\in J} p_{jt} h_{jt} = \sum_{j\in J} (w_{jt} n_{jt} + q_{jt} x_{jt} + \pi^y_{jt} + \pi^h_{jt}) + r_t k_t, \tag{3.2}$$

$$i_t = k_{t+1} - (1-\delta) k_t, \tag{3.3}$$

$$k_t = \sum_{j\in J} k_{jt} = \sum_{j\in J} k^y_{jt} + \sum_{j\in J} k^h_{jt}, \tag{3.4}$$

$$n_t = \sum_{j\in J} n_{jt}, \tag{3.5}$$

$$h_{jt} \geq n_{jt} \text{ for any } j, \tag{3.6}$$

$$x_{jt} = x^y_{jt} + x^h_{jt} \text{ for any } j. \tag{3.7}$$

We employ an additive separable utility $u(c_t, n_t) = \ln(c_t) - \frac{1}{1+\frac{1}{\gamma}} (\sum_j n_{jt})^{1+\frac{1}{\gamma}}$. This representative household chooses how many workers to allocate in each region n_{jt}, how many housing to purchase h_{jt} to provide them $n_{jt} = h_{jt}$, how much capital to invest in each region to final good sector and housing sector k^y_{jt}, k^h_{jt}, how much land to rent in each region to

each sector x^y_{jt}, x^h_{jt}, and how much to save for the future production k_t.
From the specification of the problem, we know that consumption goods are traded across regions while housing, land, and labor are traded within each region, which gives the region-specific prices of housing and land, p_{jt}, q_{jt}, and wages w_{jt}.

3.4.2 Consumption Goods Production

In each region j, there is a representative firm producing a consumption good that will be a numeraire in this economy. Each representative firm uses labor n^y_{jt}, land x^y_{jt}, and capital k^y_{jt}. We consider a neoclassical production function $y_{jt} = A_{jt}F(k^y_{jt}, n^y_{jt}, x^y_{jt}) = A_{jt}(k^y_{jt})^{\theta} n^{\chi}_{jt} (\alpha^y_{jt} x^y_{jt})^{(1-\theta-\chi)}$. The land-regulation parameter α^y_{jt} governs the share of rented lands that can be used for consumption good production. Lower α^y_{jt} indicates tighter land-use restriction allowing firms to use very small portion of rented land for production. Consequently, a consumption good producing firm in region j solves:

$$\pi^y_{jt} = \max_{k^y_{jt}, n_{jt}, x^y_{jt}} A_{jt}(k^y_{jt})^{\theta} n^{\chi}_{jt} (\alpha^y_{jt} x^y_{jt})^{(1-\theta-\chi)} - r_t k^y_{jt} - w_t n_{jt} - q_{jt} x^y_{jt}. \tag{3.8}$$

3.4.3 Housing Production

Housing units are produced using capital and land only, while having separate land-use restriction parameter α^h_{jt},

$$\pi^h_{jt} = \max_{k^h_{jt}, x^h_{jt}} \quad p_{jt}(k^h_{jt})^{\zeta} (\alpha^h_{jt} x^h_{jt})^{1-\zeta} - r_t k^h_{jt} - q_{jt} x^h_{jt}. \tag{3.9}$$

3.4.4 Equilibrium

A competitive equilibrium consists of the following. Given the exogenous land stock in each region $[x_j]^J_{j=1}$, total factor productivity $[A_j]^J_{j=1}$, amenities $[a_j]^J_{j=1}$, and the sequence of land-use regulation policies $[\alpha^y_{jt}, \alpha^h_{jt}]^{\infty}_{t=0}$ for each region j, Optimal policy rules: $[n_{jt}, h_{jt}, x^h_{jt}, k^h_{jt}, k^y_{jt}, k_{t+1}, c_t]^\infty_{t=0}$

- Prices: $[w_{jt}, r_t, q_{jt}, p_{jt}]^\infty_t = 0$

which clears every market and solve representative households' optimization problem.

3.4.5 Key Spatial Equilibrium Condition

The economic environment presented above implies several important trade-offs. First,the representative household wants to allocate workers to a region with high productivity A_{jt} or amenity a_{jt}. However, given the fixed land supply, allocating all workers to such a region would not be affordable due to soaring housing prices. The following first-order condition formulates the intuition:

$$w_{jt}u_{c,t} + a_{jt} = -u_{n,jt} - p_{jt}u_{c,t}. \tag{3.10}$$

The left hand side of Equation (3.10) is the benefit of allocating an additional worker to region j. The worker earns w_{jt}, which delivers the marginal utility of $w_{jt}u_{ct}$. Being in j delivers its amenity a_{jt} as well. The right hand side is a sum of the labor disutility and oppotunity cost of forgone consumption due to housing. In the end, Equation (3.10) works as a key spatial equilibrium condition such that a worker cannot merely relocate to chase higher w and a combinations. Given the region specific productivities and amenities, house price and population distribution across regions will be determined following (3.10).

3.4.6 Identification and Data

We follow HOP to estimate the land-use restrictions, amenities, and TFP from the optimal allocation conditions of representative households. We assume symmetric restrictions on land-use $\alpha^h = \alpha^y$, additive amenities, and Cobb-Douglas production function which allows us to come up with identification equations about the land-use restrictions, amenities, and TFP. Those equations effectively connect the data to the parameters of interests

$(\alpha_{jt}, A_{jt}, a_{jt}.)$ We solve for parameters $(\alpha_{jt}, A_{jt}, a_{jt}.)$ that allows the model to perfectly match the actual regional level data on house price, wage, and population distributions. We collected Korean regional level data for the period from 2002 to 2019. Every variable is normalized by the total population of the country. We use the Economically Active Population Survey from Statistics Korea. It has information on population and labor dynamics. We use aggregate population older than 15 from the survey as total population, and use it to normalize every variable. In addition, from the same survey, we collect the number of regional employees for each region in each year for n_{jt}. For y_{jt}, we used the regional level Real GDP from Regional Income Survey by Statistics Korea. For real house prices p_{jt}, we extract the regional all-type average nominal house price in 2015 from Korea Real Estate Board. Then, by using the regional growth rate of nominal house price indices again from Korea Real Estate Board, we construct nominal average housing prices level from 2002 to 2019. After that, by using CPI, we construct the regional real house prices used in p_{jt}. All of these are comparable to the counterparts used in HOP. Regarding the data for land x_{jt} as production inputs, there is a small but important difference between the data that we used here and the data used in HOP. HOP multiplied a share of urban land from the Census with the total available land acreage by state from the USDA-ERS. They calculated x_{jt} by dividing available land acreage by total population in thousands. Though we matched our data in scale as acre per hundred people as in HOP, our land data is the land acrage available for legally building residential and commercial buildings. Since South Korea is a geographically small country, in every region, we have a detailed and precise data regarding the land acres. Because there is a slight difference between the land data definition between HOP (urban land share) and ours (land legally designated for residential and commercial buildings), it is hard to directly compare the numbers from these two papers. However, our data has more direct implications in that our x_{jt} is literally the land that can be used for residential building and commercial activities. In addition, this is also directly related to the land that is supplied by the government in multiple New Town Projects.

3.4.7 Calibration

We use parameter values based on Korean data when there is an available value; otherwise we follow the literature. We set β as 0.9603 to match the average 10-Year Treasury yield between 2002 and 2018. In addition, we set depreciation rate δ as 0.03 which has been used in numerous Korean economy general equilibrium model including Bae (2013) or Song (2014). For the Frisch labor supply elasticity γ, we use 0.96 based on the estimates of Moon and Song (2016).

Moving toward the production function parameters, following HOP, we use 0.05 from Ákos Valentinyi and Herrendorf (2008) for the land income share of final goods production since there is no comparable estimates in South Korea. For the remaining labor income share χ, we use 0.647 while using 0.303 for capital income share θ to match the average labor income share in South Korea from 2002 and 2019.

The most difficult parameter to calibrate is $(1-\xi)$ the land input share in housing production function. South Korea is mountainous and hilly compared to the US. In addition, its total land acreage is much more smaller than the US even relative to the total populations. The preferred housing arrangement is apartment in South Korea, unlike in the United States. This makes us believe that using the U.S. parameter from HOP is not suitable. Instead, we decided to pick the parameter value that best matches the land price data. The model is able to predict regional land prices given the land stock x, housing prices p, and population n. We picked the land share that minimizes the distance between the predicted and observed land prices.[5] We obtained 0.78, which is substantially different from the U.S. counterpart used by HOP, 0.38.

For the target land prices to match, we bring a novel dataset of South Korea. The South Korean government provides the details of every land transaction since 2006. Consequently, we collected all land transactions in every region in 2010. Then, we calculate, for every transaction, the land price per m^2 only for the lands where it is

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[5] See Appendix 3.A for details.

legal to built residential, commercial, or factory buildings.[6] Then, based on those prices per m^2, we calculate the 2010 average land price for every region. We calculate the nominal land price growth rate by using the nominal land price index from Korea Real Estate Board for each region over time. By combining these nominal land prices per m^2 and nominal land price growth rates, we construct the land prices across years for each region. Lastly, we calculate the real house price level per m^2 for every region using CPI. We close this section by reporting the model fit in terms of land prices. Figure 3.4.1 compares the model-predicted and observed land prices. The model matches the land price data pretty well, even without any normalization. The worst prediction is on the southeast of the plot, where the model is underestimating land prices. The four points are from Gyeonggi, the largest Province of the country. We attribute the bad prediction to the Province's significant internal heterogeneity. The northern half is near the Demilitarized Zone (DMZ) and relatively less developed. The southern half is much more developed: it hosts Samsung and SK Hynix, the industry-leading semiconductor firms. It also has Suwon, the largest city hosting more than 1.2 million people.[7]

The comparison is obviously not a validation exercise. However, the model performance should not be underrated as a single parameter $(1-\xi)$ is able to target sixty data points, which cannot be more parsimonious. Moreover, since land price data is available, the comparison can serve for validation if $(1-\xi)$ is given externally.

3.4.8 Model Validation: Predicted vs. Observed Land-use Restrictions

In this subsection, before we proceed to the counterfactual analysis, we validate our model in terms of predictive power. By construction, our model perfectly matches the regional data on house prices, population distribution, and labor productivity like HOP. However, we proceed one more step in terms of model validation. We compare the

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[6] We excluded land on mountains where any types of economic activity is hard to appear or land where it is legally prohibited to build any kinds of building for environmental conservation.

[7] Had disaggregated data, it could have been better predicted, we conjecture.

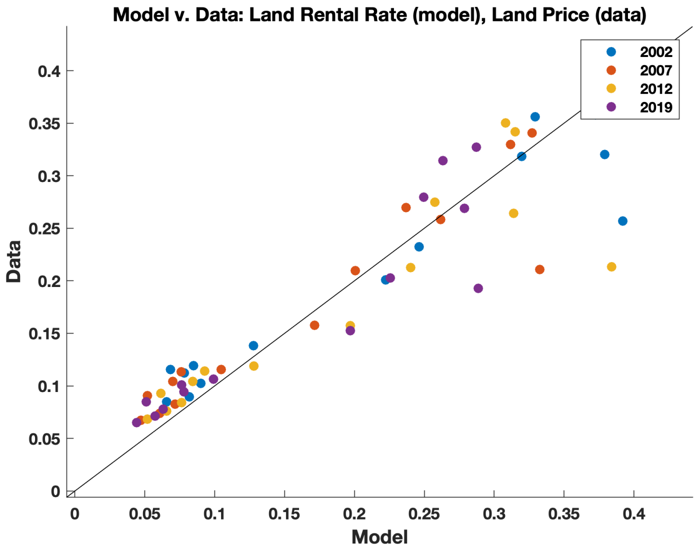

Figure 3.4.1: Model v. Data: Land Prices

model-inferred values of land-use restrictions to empirical analogues. [8] We compare our estimates with actual land-use restriction levels in South Korea by regions using detailed administrative data provided by the South Korean government.

Land-Regulation Predictions Our α is a usable share of urban land. There is no direct real-world counterpart for this measure. Still, popular land measurements such as Floor Area Ratio (FAR) and Building Coverage Ratio (BCR) are in the same spirit because those are fundamentally defined as a ratio with respect to the land area. We obtained area-weighted averages of the ratios at the regional level in 2019, the final steady-state year of the calibration. The model and data measures share the interpretation that any higher values imply lenient restrictions. We normalize both the model and data land-use restrictions to Seoul for ease of comparison.

Figure 3.4.2 shows that the model-inferred restrictions are positively correlated with

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[8] HOP compares the model-inferred TFP, land-use restrictions, amenities, and wages. We are unable to compare TFP and amenities because there are no such regional measures widely accepted in the literature, to our best knowledge. Our empirical analogy of land restrictions, taken directly from legal data, is different from HOP. On the other hand, land prices, the key allocation device, are not evaluated in HOP. While our land price comparison in Figure 3.4.1 is not a validation exercise, it still shows the model's capability. In this sense, our results complement the HOP ones.

both data measures. While the model is underestimating at face value, a simple linear regression shows that the correlations are surprisingly high. Table 3.4.1 reports $R^2 > 0.75$. For the BCR, in particular, the regression coefficient is nearly the unity, which means the model and data measures are nearly the same after adjusting for the constant. The FAR results echo the same message. This gives us confidence regarding the reliability of counterfactual analysis.

Figure 3.4.2: Land-use Restriction: Model v. Data (2019)

Table 3.4.1: Land-use Restriction: Model v. Data (2019)

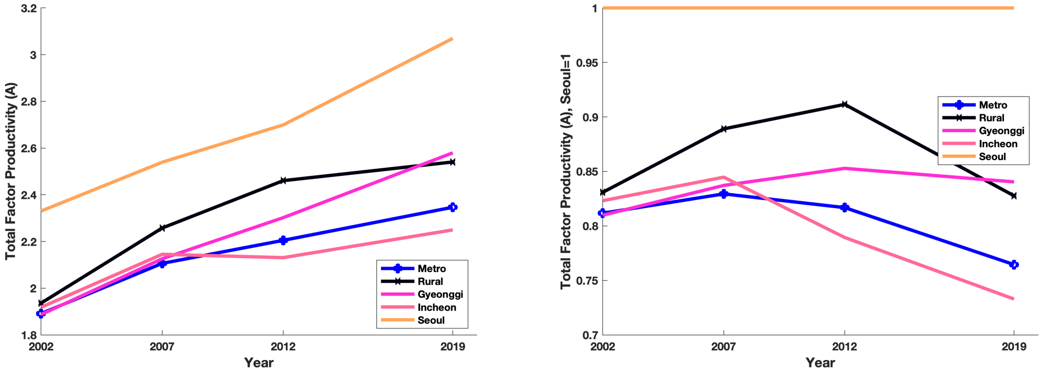
	(1) Building Coverage Ratio	(2) Floor Area Ratio
Model	0.994*** (0.083)	1.253*** (0.185)
Constant	0.148** (0.058)	0.118 (0.105)
N	15	15
R^2	0.831	0.760

All model and data measures are normalized with respect to Seoul.

3.4.9 Model-inferred Parameters

We report the model-inferred TFP, land-use restrictions, and amenities in Figures 3.4.3, 3.4.4, and 3.4.5.

Total Factor Productivities Figure 3.4.3 shows that the Seoul region consistently exhibits the highest productivity across all time periods, with the gap between the least productive region, Incheon, almost 25%. In 2002, the regions were divided into two groups: Seoul and the rest. By 2019, the latter group was further subdivided into Gyeonggi-Rural and Incheon-Metro. This division may be attributed to the significant capital investment made by major exporting firms such as Samsung and SK Hynix in the Gyeonggi and Rural regions. Despite some fluctuations, the overall trend of productivity growth is upward.



(a) Level

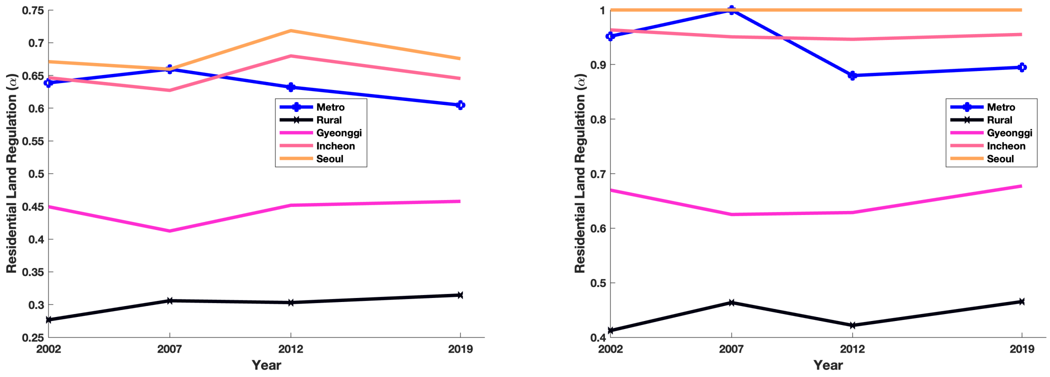
(b) Relative to Seoul

Figure 3.4.3: Total Factor Productivities

Land-Use Restrictions In Figure 3.4.4, the land-use restrictions remain relatively stable over time, both in terms of levels and ranks, with the exception of a slight decline in Metro. Small fluctuations in the Seoul Metropolitan Area coincide with the Great Recession and the government stimulus package. The restriction is relaxed between 2007 and 2012, and reversed since 2012.

It may seem counterintuitive that Seoul, with its hot housing market, has the least restrictive regulations in the country. However, this leniency is precisely because of the high demand for housing in the region. For example, Seoul has the highest floor area ratio and building coverage ratio. A comparison between the actual regulatory figures and the model-inferred restriction parameters can be found in Section 3.4.8. This is the opposite of California with tighter land-use restrictions studied in HOP. In some sense, we can argue that South Korea allowed more people to move into the SMA by relaxing the land-use regulation unlike California. By pushing agglomeration to such a great extent, the country could attain economic prosperity known as the Han River's Miracle, but it came with the cost of regional decline.

This gives us a lesson to the interpretation of our counterfactual experiments later. If such lenient land-use restrictions in Seoul are the consequence of the higher demand from many people while the tighter land-use regulation in rural area is the consequence of lower demand, our counterfactual analysis curbing the SMA land-use restrictions has more realistic implications than the counterfactual relaxing the land-use regulation in rural area, where the restrictions might not be binding.



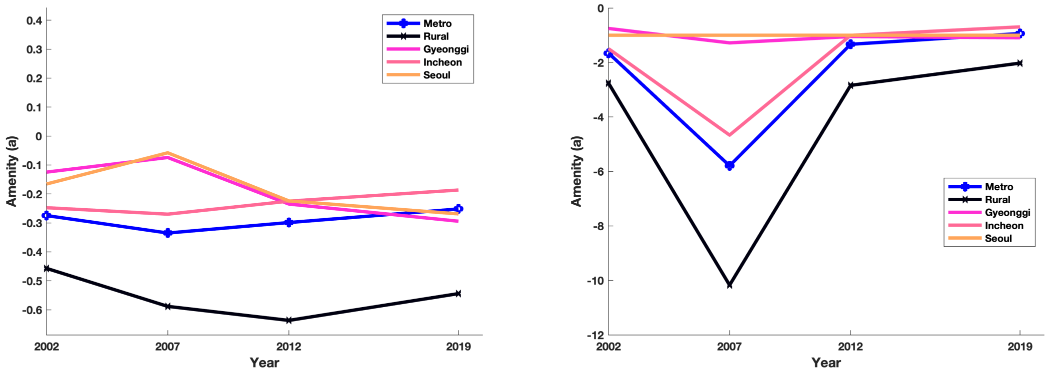
(a) Level

(b) Relative to Seoul

Figure 3.4.4: Land-use Restrictions

Amenities Amenities have converged over time, with the exception of Rural as described in Figure 3.4.5. In 2002, Seoul and Gyeonggi had the highest amenities, but there was a sizable decline by 2019. Incheon and Metro were in the middle-range group of amenities, but grew over twenty years. Rural, however, lagged behind with the lowest levels of amenities. Despite recent growth, the levels of amenities in Rural have not even reached their 2002 level.

The large drops observed in Panel (b) may be misleading. Panel (a) reveals that these drops are primarily driven by the growth of Seoul and Gyeonggi, rather than declines in the other regions. Additionally, the growth observed in 2007 was transitory. The main takeaway from Panel (b) is the convergence of amenities across regions, with Rural regions falling behind.



(a) Level

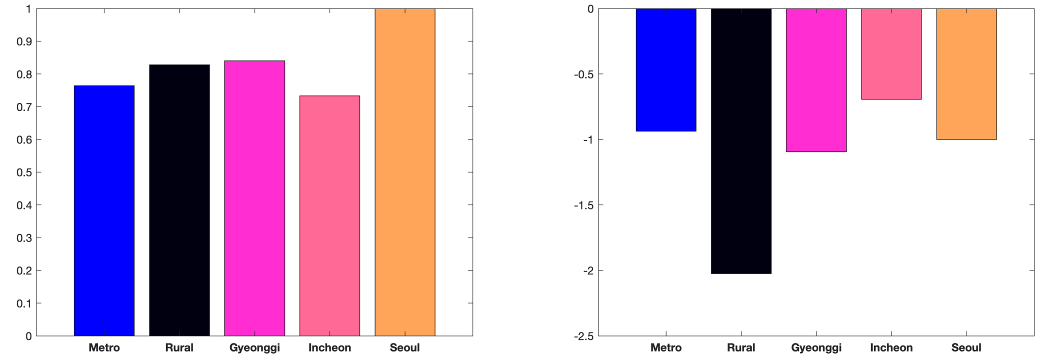
(b) Relative to Seoul

Figure 3.4.5: Amenities

3.5 Counterfactual Experiments

In this section, we experiment with land policies and examine their potentials and limitations at the national and regional economy levels. The first set of experiments adjust land-use restrictions (α_j) and the second set of experiments adjust regional urban land stock (x_j) to emulate historical active land supply policies.

Throughout the analyses, our main outcomes of interest are aggregate and regional output per capita, and population and housing prices distribution across regions.



(a) TFP (Seoul = 1)

Amenities (Seoul = -1)

Figure 3.5.1: 2019 Regional Parameters

3.5.1 Expanding Existing Cities: Land-Use Restriction Experiments

We infer the region-defining fundamentals $(\alpha_{jt}, a_{jt}, A_{jt})$ using the model. The experiments on land-use restrictions manipulate the inferred α_{jt} to simulate a series of counterfactual scenarios that either regulate or deregulate certain regions to alter *usable* urban land stock $\alpha_{jt}x_{jt}$, keeping urban land stock x_{jt} constant. Figure 3.5.1 visualizes the parameters invariant across experiments, (a_{jt}, A_{jt}).

In order to make the experiments comparable, we keep the national stock of usable urban land $\overline{x} = \sum_j \alpha_j x_j$ fixed. For example, if we increase α_{SMA} by 15%, which implies 15% lenient regulation, we proportionally decrease it for all the other regions to balance the national land stock equation. This constraint is to quantify the direction and degree of misallocation due to land use regulation, rather than to add a layer of reality. If deregulating SMA (regulating the others) delivers a higher aggregate output then regulating SMA (deregulating the others), it indicates the former achieves more efficient allocation compared to the latter.

To set the stage, we take the 2019 model steady state and (de)regulate the Seoul Metropolitan Area by 15%. This provides the first quantification of the impact of land-use restrictions in the Korean economy. In other words, we effectively treat the country as a collection of two greater regions, the SMA and the rest of the country, in terms of policy changes.

We then add a simple heterogeneity to the experiment. In contrast to the SMA regulation experiment which deregulates all non-SMA regions uniformly, we deregulate Metro only, keeping Rural the same, then vice versa. Again, the national land stock remains fixed throughout these experiments. The goal of adding the heteogeneity is as follows. By taking regional heterogeneity seriously, it illustrates that the impact of land-use restriction changes on regional decline may starkly vary depending on which regions are more or less regulated.

Table 3.5.1 is a list of the land-use restriction experiments and the corresponding proportional adjustments in $\alpha_{j,2019}$. Table 3.5.2 summarizes the results of these experiments. We discuss the results in the following subsections.

Table 3.5.1: The Land-Use Restriction Experiments: Scale Adjustments in $\alpha_{j,2019}$

	SMA	Metro	Rural
(1) Baseline	1.00	1.00	1.00
(2) Dereg. SMA; Reg. others uniformly	1.15	0.91	0.91
(3) Reg. SMA; Dereg. others uniformly	0.85	1.09	1.09
(4) Reg. SMA; Dereg. Metro; Keep Rural	0.85	1.32	1.00
(5) Reg. SMA; Keep Metro; Dereg. Rural	0.85	1.00	1.13

Table 3.5.2: Land-use Restriction Experiments (Relative to the Baseline)

	(1) Baseline	(2) Dereg. SMA 15% Reg. All others	(3) Reg. SMA 15% Dereg. All others	(4) Reg. SMA 15% Dereg. Metro	(5) Reg. SMA 15% Dereg. Rural
A. Aggregate Measures					
Output	1	1.014	0.986	0.987	0.985
Consumption	1	1.012	0.989	0.990	0.989
Investment	1	1.014	0.986	0.987	0.986
B. Welfare Gains (Percentage Points)					
Total	0	1.638	-1.651	-1.301	-1.794
Contribution of Direct Utility (%)	0	0.598	0.575	0.845	0.494
Contribution of Amenity Access (%)	0	0.402	0.425	0.155	0.506

The aggregate measures are reported as a ratio to the baseline. The welfare gain is defined as a consumption equivalence. It means how many percentage points the per-period consumption should change to achieve the new level of aggregate utility, $100 \times [exp(U_{counterfactual} - U_{baseline}) - 1]$.

3.5.1.1 SMA (de)regulation with uniform treatment of Metro and Rural

Aggregate Output and Welfare Column 2 of Table 3.5.2 shows that the 15% deregulation of SMA increases the aggregate output per capita by 1.4% and welfare by 1.64%p. On the other hand, column 3 of Table 3.5.2 shows that the 15% regulation has the opposite effect. The aggregate output per capita and welfare drops by 1.4% and 1.65%p, respectively.[9] These results indicate that deregulating SMA yields a more efficient allocation than deregulating the other regions. The major driver of the output gain is labor and capital reallocation to higher TFP regions, the SMA. It also contributes to the welfare changes by letting workers access to amenities, especially for those who move from Rural to the other regions. The amenity access driven changes account for about 40% of the total welfare changes.

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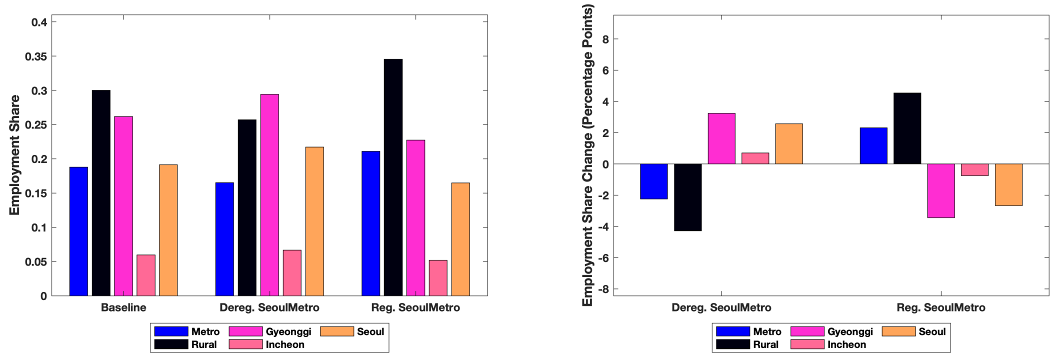
[9] The two experiments mirror each other. The 0.01%p difference between the welfare gain and loss stems from the concavity of the utility function.

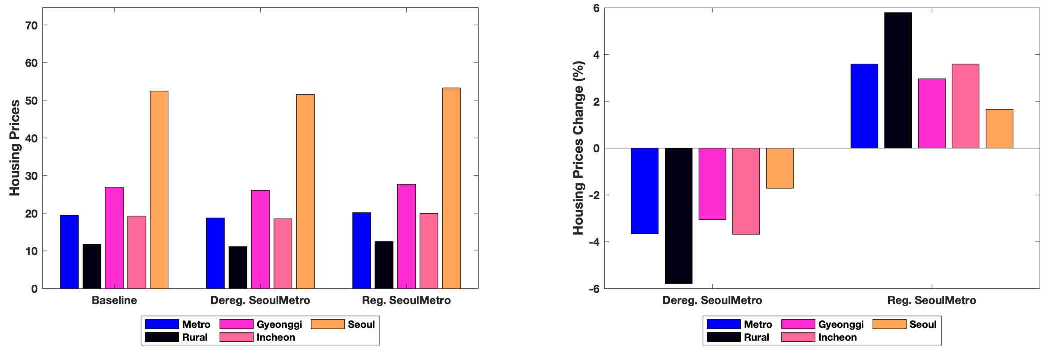
Employment Shares, Housing Prices and Regional Output Figure 3.5.2 shows that the regulation and deregulation experiments (2 and 3) deliver mirrored results for employment, housing prices, and regional output per capita. The deregulation-driven reallocation increases the SMA's employment shares by about 6%p in total. (Panel b) Gyeonggi and Seoul gain about 2.5%p while Incheon, which has the lowest TFP, gains barely about 1%p. (Figure 3.5.1) Both Metro and Rural lose workers, but Rural's loss is almost twice as large as than Metro's. The difference is driven by rural's lower amenity since the two have a similar TFP. Housing prices drop in all regions. (Panel d) It shows that the additional housing supply from the usable land supply dominates the housing demand in SMA. In Metro and Rural, the shrinking housing demand due to employment loss dominates the reduction in housing supply.

On the other hand, panel (e) and (f) show that the SMA deregulation widens spatial inequality via reallocation, which is another trade-off. All three SMA regions enjoy about a 12.5% increase in regional output per capita, while Metro and Rural undergo almost same loss. These results demonstrate the importance of considering regional characteristics when imposing land-use policy. Imposing the same level of land-use restriction to Metro and Rural imposes a larger toll on Rural in terms of employment loss. Strict land-use regulation on low TFP and amenities regions may exacerbate the regional decline faster than other regions. The SMA regulation moves the economy in exactly opposite direction, which is beneficial to Metro and Rural but inefficient at the aggregate level.

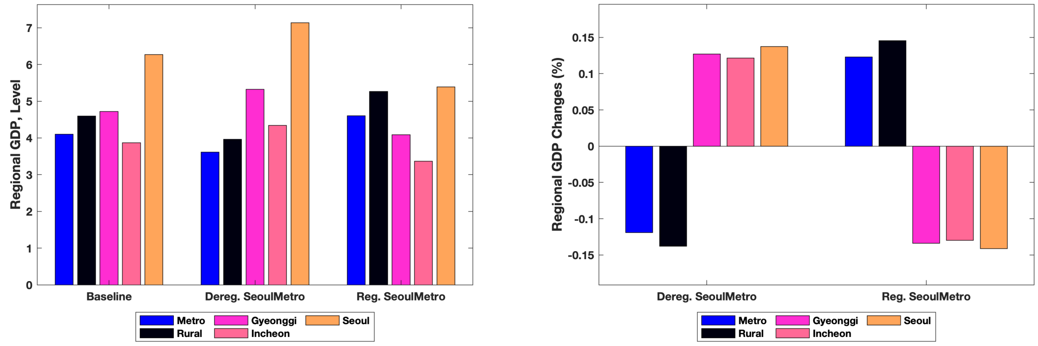
We put those numbers into the context of regional decline and national growth. The decline in regional employment shares and output per capita can be alleviated by regulating the SMAs and deregulating Metro and Rural. This approach comes with the cost of a 1.5% loss in aggregate output and a 2%–5% increase in housing prices throughout the country. While the stark tradeoff partly stems from the fixed national land stock $\overline{x}$, the remaining question is whether heterogeneous treatment of non-SMA regions under the national constraint could do better by any means, given the same cost of regulating SMA.



(a) Employment Shares, Level (b) Employment Shares, Changes



(c) Housing Prices, Level (d) Housing Prices, Changes



(e) Regional Output per capita, level (f) Regional Output per capita, changes

Figure 3.5.2: (De)regulating SMA with uniform treatment of Metro and Rural

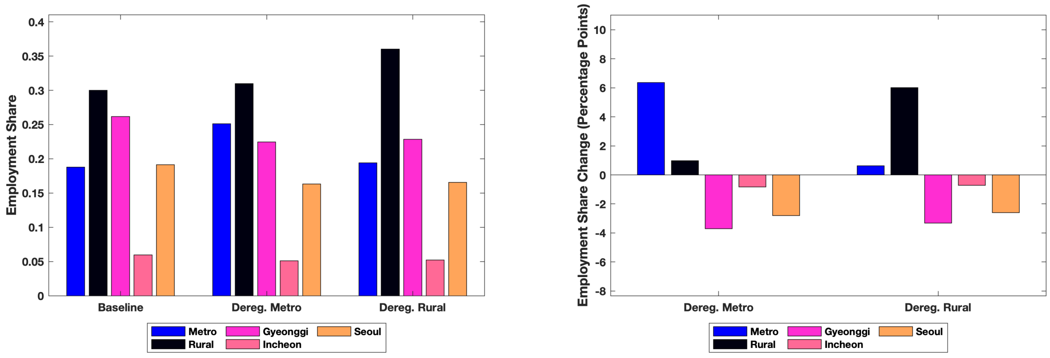
3.5.1.2 SMA regulation with heterogeneous treatment of Metro and Rural

These experiments explore the direction and degree of misallocation between Metro and Rural, accepting the aggregate output and welfare deterioration due to the SMA regulation. Metro has to be deregulated by more than 30%, and Rural by 13%, to keep the national stock of usable land fixed (Table 3.5.1), which shows that Rural has a higher baseline usable land stock.

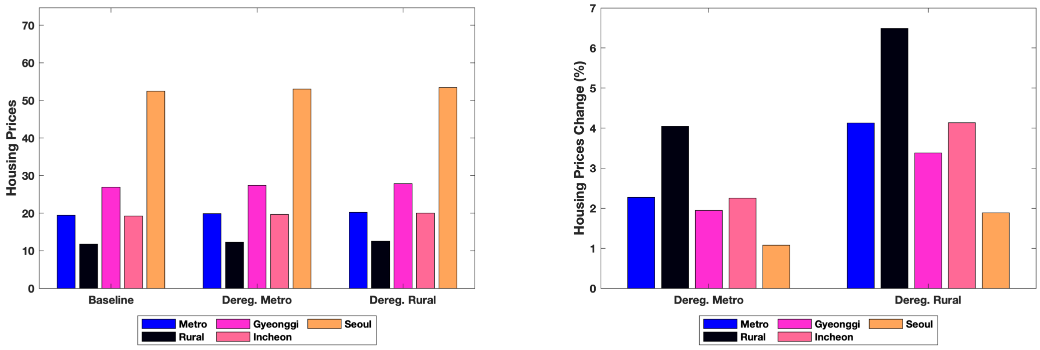
Aggregate Output and Welfare Columns 4 and 5 of Table 3.5.2 show that the output loss from regulating the SMA effectively remains the same as the uniform treatment case (Column 3). However, the welfare gains are more divergent. Deregulating Metro has the smallest welfare loss compared to the uniform case and deregulating Rural. The main channel is amenity differences across regions. Rural has the lowest amenity among the five groups, and the welfare loss due to amenity change is -0.91%p in the deregulating Rural experiment (Column 5). The influx of population into the Rural area suffers from the lower amenities.

The uniform case alleviates the loss by allocating some workers to Metro. The deregulating Metro further alleviates the loss by allocating most SMA-leaving workers to Metro. By doing so, welfare losses from each experiment due to amenity amounts to -0.70%p and -0.20%p, respectively, which are considerably smaller losses than from the Rural deregulation case. In terms of welfare loss, focusing on Metro outperforms the uniform deregulation, given the amenities.

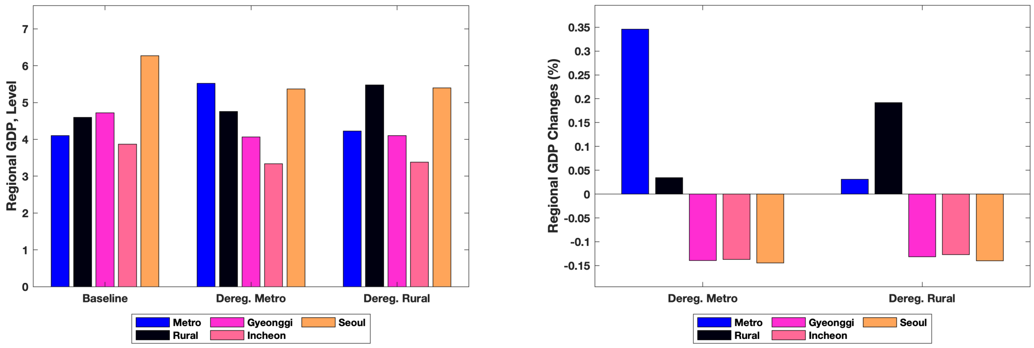
Employment Shares, Housing Prices and Regional Output Figure 3.5.3 shows that the results are qualitatively similar with the uniform case: SMA loses employmet shares and regional output per capita and housing prices rise in all regions. But there are noticable differences as well. In panel (b), expanded regions have higher employment shares. Panel (d) shows that housing prices rise in all regions for both experiments. In the SMA, the decreasing housing supply, due to tightened land use regulation, dominates the shrinking demand. Metro and Rural experience the opposite shift. The demand side due to the incoming population dominates and lifts regional housing prices, regardless of whether usable land stocks increase or remain fixed. The housing price increases are higher if Rural is deregulated. Given that the labor reallocation governs housing demand and housing, panel (f) shows that non-SMA regions enjoy higher regional output per capita, by about 35% (expanded Metro) and 20% (expanded Rural).



(a) Employment Shares, Level (b) Employment Shares, Changes



(c) Housing Prices, Level (d) Housing Prices, Changes



(e) Regional Output per capita, level (f) Regional Output per capita, changes

Figure 3.5.3: Regulating SMA, deregulating either Metro or Rural

The results indicate that any similar output changes may not necessarily come with similar welfare and population distribution changes. Moreover, such differences could be driven by regional amenities. Our results suggest that adjusting land-use restriction with no changes in amenities might be insufficient, even after the national land stock constraint is relaxed. First, in the long-run, a region with a low-amenity but lenient land-use restriction may fail to induce population, although this mechanism is not explicitly operating in the model. Second, if α and a are negatively correlated, due to congestion cost for example, the welfare loss from population reallocation would be more pronounced and land-use restriction would be less effective.

Ulsan Metropolitan City, one of the Metro regions, fits this story well. It has the highest TFP but the lowest amenity in the country, which is in line with the real-world observation. While its regional income is top-notch, it is the smallest region among Metro, the city is not often considered a city can substantially grow by relaxing land-use regulations. This limitation leads us to consider the possibility of alternative policies such as active land supply, which can go beyond tweaking land-use regulation.

3.5.2 Creating New Cities: Active Land Supply Experiments

The active land supply experiments change the usable land stock of regions by changing x_j instead of α_j, and are constrained by the national land stock equation. Since the model defines usable land as a product of land-use restriction and urban land, i.e. $\alpha_j x_j$, in principle, any active land supply $\Delta x_j > 0$ can be replicated by an appropriate adjustment of α_j keeping x_j unchanged.

The active land supply experiments have rather an advantage of being more tightly connected to real-world policy. The New Town Project supplied urban land to a region, converting unused rural land into urban land. It gives us an observed Δx_j and the corresponding government-reported costs of development. Using this data, we can conduct a cost-benefit analysis of the NTP and quantify its regional consequences. Moreover, we can consider counterfactual policies such that the land is supplied to elsewhere, keeping the total costs of development constant. In other words, the active land use supply experiments are about where to spend budget and the land-use restriction ones are about where to adjust frictions. The two sets of experiments are subject to different constraints.

We first quantify the impact of the 2nd New Town Project, which serves as a benchmark of active land supply counterfactuals. To that end, we take the 2019 model steady state and reduce the land stock x by the NTP-supplied amount. The counterfactual losses are defined as the gains from NTP.

Given the benchmark, we simulate counterfactual economies where the NTP takes place outside of the SMA to answer our main question, whether land policies can defy regional decline. The first experiment ("leveling up the country") is to uniformly redistribute the land supplied by the 2nd NTP to the twelve non-SMA regions, keeping the amount of money spent. We first calculate the cost per acre in non-SMA regions using three non-SMA New Town Projects in order to address the fact that land prices are higher in the SMA on average. The cost per acre in the non-SMA area turns out to be around 67% of the 2nd NTP. Thus, the counterfactual land supply is (the 2nd NTP supply)/(0.67). We distribute this land to all non-SMA regions. [10]

The final two experiments push the question of the leveling up the country experiment further, in order to sharpen our points on regional decline, as we did in the land-use restriction experiments. We now distribute the counterfactual land supply unevenly across the country: land supply only to Metro ("NTP in Metro"), then only to Rural ("NTP in Rural"). Again, throughout the experiments, the 2nd-NTP supplied land stock are taken from the SMA. Table 3.5.3 is a list of the active land supply experiments and the corresponding Δx_j.

3.5.2.1 No NTP and Leveling Up the Country

Aggregate Output and Welfare Column 2 of Table 3.5.4 reports that the No NTP economy would have 0.4% lower aggregate GDP, or the 2nd NTP increased the aggregate GDP by 0.4%. Since the model considers the steady-state, it is equivalent to $0.4 \times 20 = 8\%$ discounted sum of future output gains. Since the NTP-incurred the one-shot cost amounting 4.05% of GDP in 2004, the result justifies the NTP by showing its gain

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[10] See Appendix 3.C for more details.

Table 3.5.3: Active Land Supply Experiments (Relative to the Baseline)

	SMA			Metro	Rural
	Seoul	Gyeonggi	Incheon		
(1) Baseline	-	-	-	-	-
(2) No 2nd New Town Project	-0.0006	-0.0207	-0.0027	-	-
	(-6.12)	(-4.23)	(-0.51)		
(3) Leveling up the Country	-0.0006	-0.0207	-0.0027	0.0003×5	0.0003×7
	(-6.12)	(-4.23)	(-0.51)	(3.51)	
(4) NTP in Metro	-0.0006	-0.0207	-0.0027	0.0072×5	-
	(-6.12)	(-4.23)	(-0.51)	(18.0)	-
(5) NTP in Rural	-0.0006	-0.0207	-0.0027	-	0.0051×7
	(-6.12)	(-4.23)	(-0.51)	-	(3.70)

The aggregate measures are reported as a ratio to the baseline. The welfare gain is defined as a consumption equivalence. It means how many percentage points the per-period consumption should change to achieve the new level of aggregate utility, $100 \times [exp(U_{counterfactual} - U_{baseline}) - 1]$.

Table 3.5.4: Active Land Supply Experiments (Relative to the Baseline)

	(1) Baseline	(2) No NTP	(3) Levelling Up the Country	(4) NTP in Metro	(5) NTP in Rural
A. Aggregate Measures					
Output	1	0.996	1.002	1.004	1.001
Consumption	1	0.994	1.005	1.008	1.003
Investment	1	0.996	1.003	1.005	1.002
B. Welfare Gains (Percentage Points)					
Total	0	-0.495	0.342	0.581	0.168
Contribution of Direct Utility (%)	0	0.808	1.122	0.940	1.575
Contribution of Amenity Access (%)	0	0.192	-0.122	0.060	-0.575

The aggregate measures are reported as a ratio to the baseline. The welfare gain is defined as a consumption equivalence. It means how many percentage points the per-period consumption should change to achieve the new level of aggregate utility, $100 \times [exp(U_{counterfactual} - U_{baseline}) - 1]$.

outweighed the cost in the long run by a factor of two, roughly speaking.[11] Welfare

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[11] The 2nd New Town Project was implemented from 2004 and it's estimated spending was 3.6 trillion USD. In 2004, the country's GDP was 908.4 trillion KRW. Since GDP grows over time, if we change the base year, the spending to GDP ratio will fall. Our back-of-the-envelop calculation of the net gain thus works as an lower bound.

rises by similar percentage points, 4.95%p, and mostly from direct utility.

What if the NTP took place in the non-SMA regions, aiming to leveling up the country? Column 3 of Table 3.5.4 is our answer from the model. Compared to the 2nd NTP, the leveling up approach increases 0.2%p higher GDP. It is 0.6% higher than the No NTP case. These results suggest that the Leveling Up strategy could be more efficient approach in that the marginal production of usable land declines faster in the 2nd NTP in the SMA. The welfare gain is also positive and driven by direct utility gain. It completely offsets the loss from lower amenities in the expanded non-SMA regions.

Employment Shares, Housing Prices and Regional Output The key reallocation mechanism in the active land supply experiments are the changes in marginal production of factors due to the additional usable land stock. Namely, higher land stock boosts both MPL and MPK. The magnitude of reallocation is smaller because the new land supply shifts up the national land stock, keeping non-policy regions' land stock unchanged, unlike the land-use restriction experiments.

Panel (b) of Figure 3.5.4 shows that changes in employment shares are smaller than the land-use regulation exercises. While the No NTP experiments take land stock from all SMAs, Gyeonggi, Incheon, and Seoul, Gyeonggi suffers the largest employment loss. While this pattern mechanically reflects that the 2nd NLP mostly took place in Gyeonggi, it also shows that the policy-induced reallocation of workers to Gyeonggi was mostly from Metro and Rural, rather than the other two SMA regions. Panel (d) shows that housing prices would have been higher by 2–4% if there was no NTP. The larger increases in Metro and Rural reflects housing demand decrease in those regions due to the NTP. Lastly, regional output per capita in panel (f) summarizes the message: the 2nd NTP catalyzed the growth of the SMA at the cost of decline of the non-SMA.

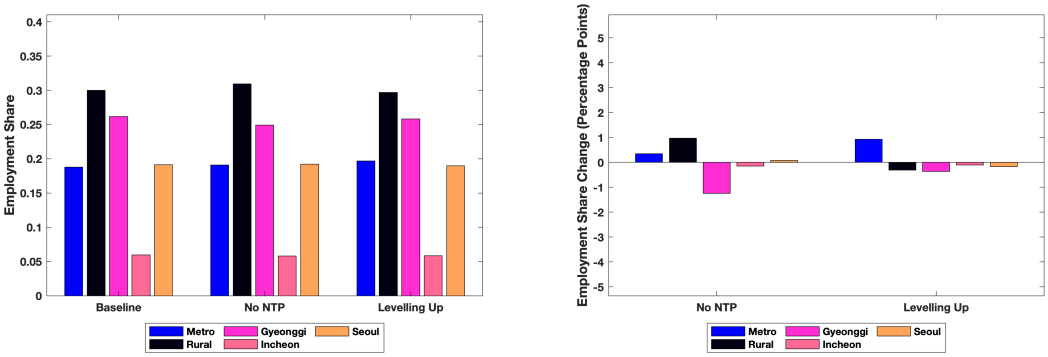
The alternative land supply scheme, "leveling up" suggests an another possibility. In panel (b), the policy induces a reallocation of workers to Metro from all other regions. While the reallocation is tiny compared to the other experiments, it still comes with lower housing prices in all regions as panel (d) illustrates. Panel (f) shows that, as a result, Metro's regional per capita income would have been slightly higher than the data. These estimates suggest that the Metro regions could have served as an engine of "regional revival."

The leveling up approach brings modest gains at the aggregate level and mitigates spatial concentration of population. The cost is insignificant even at the regional level. The results challenge a conventional notion of growth and (spatial) inequality tradeoff, rasing a question of whether a balanced development policy should have been implemented instead of NTP 20 years ago. However, these findings should be viewed as exploratory to examine the main question of regional decline and land policy. All the results are building on the estimated impact of the NTP, which may not be fully captured by the model framework. For instance, the absence of agglomeration forces in the current specification may underestimate the gains from the NTP in SMA. Thus, more concrete policy recommendations calls for a more comprehensive general equilibrium model that incorporates factors such as agglomeration and skill heterogeneity. Our current results, again, are to illustrate the potential of policy evaluation and prescription and the need for further research.

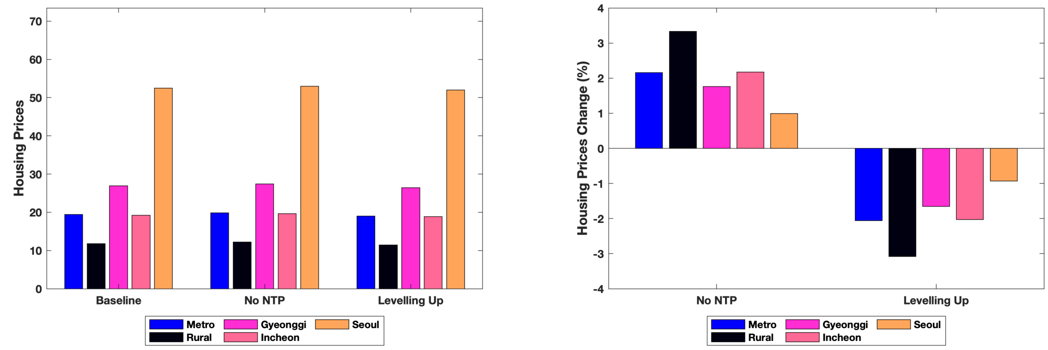
3.5.2.2 NTP in Metro, NTP in Rural

We further consider the possibility of the NTP in alternative regions. The new land stock is supplied to either Metro or Rural, instead of being uniformly distributed to all non-SMA regions. By doing so, we see the impact of the policy accounting for the TFP, amenities, and marginal production of factors, which is a function of the initial land stock.

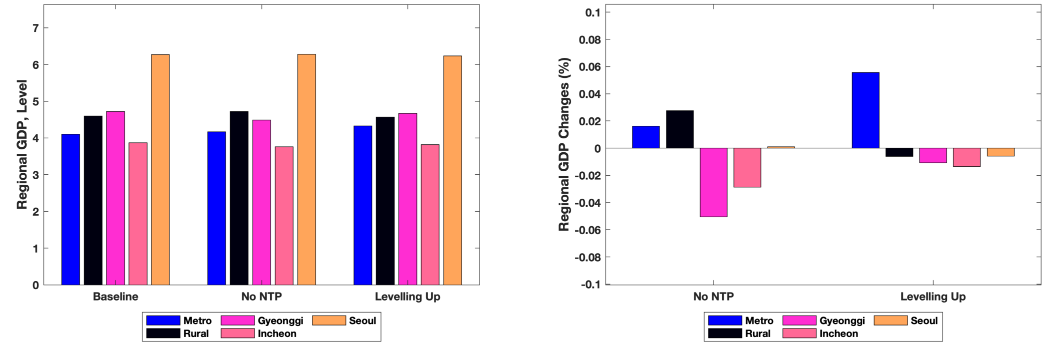
Aggregate Output and Welfare Columns 3 and 4 of Table 3.5.4 show that the output and welfare changes are comparable to the leveling up experiment. Both measures are in the order of NTP in Metro, Leveling up, and NTP in Rural. It is mechanical that the leveling up serves as the median given the two polar cases of Metro and Rural. The



(a) Employment Shares, Level (b) Employment Shares, Changes



(c) Housing Prices, Level (d) Housing Prices, Changes



(e) Regional Output per capita, level (f) Regional Output per capita, changes

Figure 3.5.4: Active Land Supply: No NTP and Levelling Up the Country

welfare change differences are more dramatic because of lower amenities in Rural: NTP in Metro is 0.42%p higher than NTP in Rural.

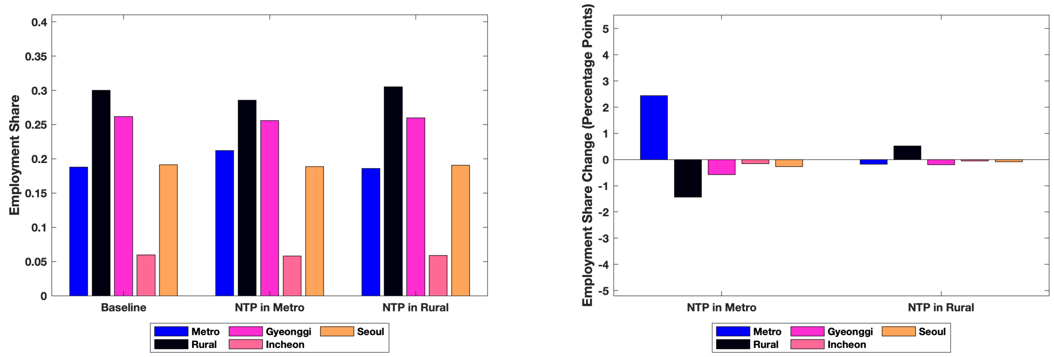
Employment Shares, Housing Prices and Regional Output The two experiments are in the same ballpark at the aggregate level. Figure 3.5.5 reports that the regional

consequences could differ. For example, in panel (b), the NTP-blessed regions attract populations from all the other regions, but the magnitude is much higher in Metro, by more than a factor of 3. The population loss of Rural in the NTP in Metro experiment is much larger than the counterpart of Metro in the NTP in Rural experiment. This discrepancy is partly due to the larger existing land stock in Rural: The supplied land is around 3.7% of total in Rural while 18.0% in Metro. Still, the low TFP and amenities in Rural are another cause of this asymmetry.
Both experiments deliver lower housing prices in all regions as the leveling up experiment. Empowered by the additional land supply, neither Metro nor Rural ends up with a higher housing price in spite of population inflows. This implies that the land supply effect dominates housing demand expansion. Changes in the regional output per capita echo the change in employment shares in Panel (b).

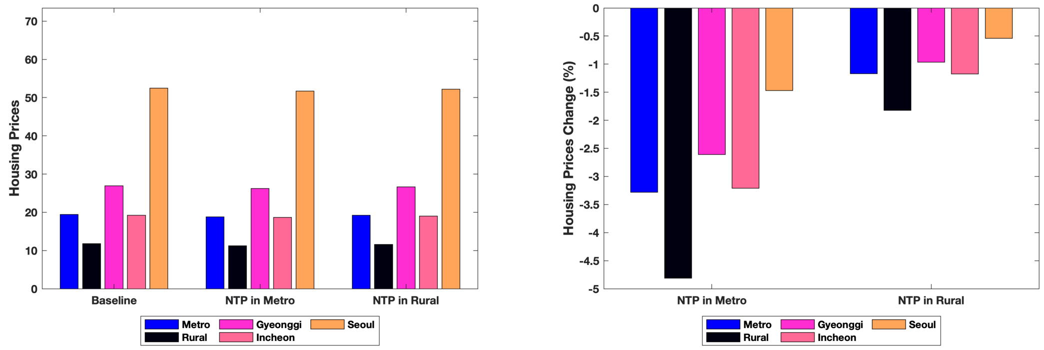
Closing the section, we emphasize that the experiments examining land-use regulation and active land supply are not directly comparable. Each experiment possesses a distinct internal consistency criterion: the "expanding existing cities" experiments are governed by the national usable land stock constraint; the "creating new cities" ones are governed by the total land supplied by NTP. Therefore, the results from the respective experiments on deregulating non-SMA and leveling up the country should not be compared to establish superiority of one to the other. Rather, they serve as separate explorations within the broader investigation of the relationship between land-use regulation and active land supply.

3.6 Conclusion

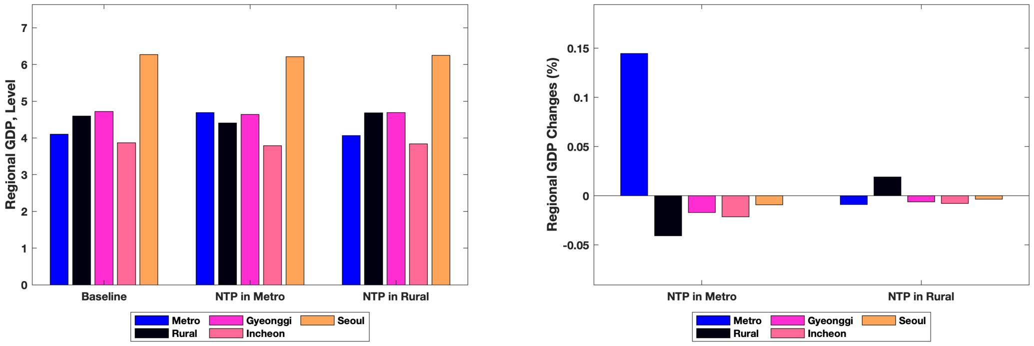
This paper studies land policies in South Korea by applying the general equilibrium spatial model developed by HOP. All regions are characterized by their TFP, amenities, land stock, and land-use restrictions. We first recover those parameters using the model equilibrium conditions, targeting the regional land price distribution of South Korea. The model closely matches the empirical distribution. For further model validation, we



(a) Employment Shares, Level (b) Employment Shares, Changes



(c) Housing Prices, Level (d) Housing Prices, Changes



(e) Regional Output per capita, level (f) Regional Output per capita, changes

Figure 3.5.5: Active Labor Supply: New Town Project in Metro or Rural

compare the model-inferred land-use restriction against two independent data counterparts: the regional-average floor area ratio and building coverage ratio. Simple linear regressions between the data and model show a tight correlation.

We conduct two sets of exploratory counterfactual experiments of land policy. The first set experiments with land-use restriction, given the fixed national stock of usable land. The results suggests that regulating the Seoul Metropolitan Area and deregulating the other regions may mitigate population concentration, but at the cost of universal housing price increase as much as 6% and a net loss in output and welfare around 1.3%. These results suggest that a simple approach of regulating concentrated regions and deregulating declining ones may bring a large cost at the aggregate level and not be successful to stabilize the housing market of the country. In other words, South Korea's land-use restriction to the SMA is already lenient and the economy is sufficiently utilizing the high TFP of the area. The result is opposite to the case of the United States, where superstar regions such as New York and California are "tarnished" and deregulating them would benefit the entire economy (Herkenhoff et al., 2018) This is the international layer that we bring to the literature. While spatial concentration to superstar cities is common in developed economies, their land usage could be substantially different, thus policy should be country- or city-specific.

The second set of experiments are active land supply. We first conduct a cost-benefit analysis of the 2nd New Town Project in South Korea. The benefit, discounted sum of future real output gain amounting to 8% of annual real GDP, exceeds the cost, 4.05% of annual real GDP, by a factor of two. We compare a series of alternative regional land supply policies to the 2nd NTP. Our results indicate that supplying land to non-SMA regions, keeping the amount of spending equal, could have attained higher output, less spatial concentration, and lower housing prices. We provide the first quantitative analysis on this new type of policies, showing that this active land supply policy can affect the aggregate and regional economies significantly.

We conclude by emphasizing that there is no one clear-cut answer on how to execute the land policy efficiently. As our conunterfactuals on land-use restriction show, the effects of land use policies heavily depends on the characteristics of regional economies such as productivities and amenities. Lastly, how the trade-off between aggregate allocative efficiency gain and externalities coming from regional decline works can be different across countries. These tradeoffs imply that the optimal implementation of land-use policy demands thorough inspections of each regional economy.

We underscore that all our results are exploratory and indicate the issue deserves further comprehensive analysis. In future work, we incorporate agglomeration and mobility of workers with heterogeneous skills. The impact of land policy on regional policy could be more pronounced via housing market if it particularly deter or encourage of high-skilled workers to the region and agglomeration is in place.

APPENDIX

3.A Calibrating the Land Share in Housing

To our best knowledge, there is no estimate of the land share in housing $(1-\xi)$ in South Korea. We pin this parameter down by targeting the land price distributions. Land price data from South Korea enabled us to apply this calibration strategy. The Cobb-Douglas technologies of final goods and housing and the land market clearing condition yields the following condition:

$$q_j = \frac{1}{x_j}\Big[(1-\xi)p_j n_j + (1-\theta-\chi)y_j\Big]. \tag{3.11}$$

Provided all the RHS variables x_j, yj, θ and χ, we can calculate a model-implied q_j. We pick $(1-\xi)$ to minimize the distance between the model-implied and observed q_j. Note that Equation (3.11) could be used for model validation if $(1-\xi)$ could be chosen either from literature or data.

3.B Algorithm for Counterfactual Simulations

In this section, we explain the algorithms calculating the counterfactual. Our benchmark economy is the steady state from the estimated (α, a, A), given the observed usable land stock x. These are the estimates that best explain the observed Korean regional data. We then alter either α or x, depending on experiment, and solve for new steady-states, keeping all others unchanged. We separate out the impact of changes in α or x by comparing the new steady states against the benchmark.

3.B.1 Guess on Equilibrium Quantities

Given the parameters, we make a guess on these three optimal policies.

- k_{jt}^h: capital for housing production
- k_{jt}^y: capital for consumption good production
- x_{jt}^h: land for housing production

Given the total quantity of the land in each region (x_v), the housing production function $h_{jt} = q(x_{jt}^h, k_{jt}^h)$, and the labor-housing constraint, these three optimal policies imply the following equilibrium quantities:

- x_{jt}^y: land for consumption good production
- h_{jt}: housing quantity
- n_{jt}: labor allocation

Given all of these equilibrium quantities, we calculate the interest rate r which is the same for all regions. Once we calculate r, we can calculate:

- p_{jt}: Price of housing service
- q_{jt}: Rental rate of land
- w_{jt}: Wage
- π_{jt}^y: Consumption good producer profit
- π_{jt}^h: Housing construction firm profit

These objects allow us to calculate the aggregate consumption c_t from household's budget constraint.

3.B.2 Check Optimality Conditions

We check if the following optimality conditions hold given the obtained equilibrium quantities.

- Labor-Leisure Tradeoff

: $w_{jt}u_{ct} + a_{jt} = -u_{n,jt} - p_{jt}u_{ct}$

- Land Allocation

: Firm Production vs Housing Production

- Interest Rate

: Euler Equation of Representative Households

We use MATLAB's `fsolve()` to verify that the optimal policies satisfy these optimal conditions for every region and repeat until we obtain the solution. The solution would be our counterfactual outcome.

3.C The 2nd New Town Project and Counterfactuals

In this section, we describe the 2nd New Town Project data used in Section 3.5.2. Our goal was to supply land to the non-SMA regions, keeping the policy-related expenditure fixed. It is seemingly straightforward to first calculate the total land supplied in SMA and then divide it by the number of non-SMA regions. However, this approach fails to address the case that the unit cost of land supply may differ across regions. If ignored, the counterfactual results could be taken as a lower bound.

Fortunately, we have additional information from the 2nd New Town Project. It had 15 subprojects. The SMA-related subprojects were 12 out of 15 and took nearly 90% of the total land supplied. On the other hand, there were three subprojects that took place in Daejeon and ChungCheongnam-do (D&C). We leverage their expenditure information to adjust the counterfactual unit costs. Table 3.C.1 summarizes the cost per m^2, land supplied by use, and total expenditure.

Our measure of urban land is "Residential/Commercial (R/C)." The unit cost in the SMA is 798.8, approximately 150% of D&C, 536.3. Since the SMA R/C supply is 42.4, the counterfactual land supplied for the non-SMA is $63.1 = 42.4 \times 1.49$. The land supplied in Table 3.5.2 is a population-adjusted measure. The adjustment is not perfect but lets our experiments account for potential heterogeneity in the new city costs based on real-world information.

This calculation requires land supplied and expenditure by use. We have granular land data, but not expenditure data. Expenditure is available for the total only. We allocate the total expenditure to each category by using land supplied as a weight. For instance, in the SMA, the R/C land supplied is 35.7%. Thus, the R/C expenditure of 33,949.5 is a result of $94,920.6 \times 0.357$. Note that the land-supplied shares by use are similar across the SMA and D&C, which serve as a minimal justification of this approach.

The D&C New Town Project is *not* counted as a part of the 2nd NTP in the No NTP experiment. The land supplied is deducted only in the SMA; the D&C NTP land supplied is treated as if it were the existing land stock. This abstraction stems from the fact that our main goal is to analyze the impact of active land supply on the regional decline and spatial concentration of the SMA. Thus, the counterfactual land supply to the D&C would be an addition on top of the D&C NTP.

It's important to note that the D&C New Town Project was not included in the "No NTP" experiment as a part of the 2nd NTP. The land supplied in D&C was only deducted in the SMA, and the D&C NTP land supplied was treated as if it were part of the existing land stock. Thus, the counterfactual land supply to the D&C region would be in addition to the land already provided through the D&C New Town Project. This approach is motivated by the goal of the research, which is to analyze the impact of active land supply on regional decline and concentration to the SMA.

Table 3.C.1: The 2nd New Town Project: Land supplied and Expenditure

Region	Cost per m2 (KRW)			Land Supplied (billion m^2)			Expenditure (billion KRW)		
	Total	(R/C)	(Ind/Inf)	Total	(R/C)	(Ind/Inf)	Total	(R/C)	(Ind/Inf)
SMA	798.8	800.9	797.6	118.8	42.4	76.4	94,920.6	33,949.5	60,971.1
				(100.0)	(35.7)	(64.3)	(100.0)	(35.8)	(64.2)
Daejeon and Chungnam	536.3	536.8	536.1	14.9	5.3	9.6	7,992.8	2,870.0	5,122.8
				(100.0)	(35.9)	(64.1)	(100.0)	(35.9)	(64.1)
SMA/D&C	1.49	1.49	1.49						
Non-SMA				177.0	63.1	113.8			

Percentages with respect to total in parentheses. "R/C" and "Ind/Inf" stands for "Residential/Commercial Use" and "Industrial/Infrastructure Use", respectively. Non-SMA is hypothetical. Chungnam represents Chungcheongnam-do.

3.D More Results

3.D.1 Wages: Model-Predicted v. Observed

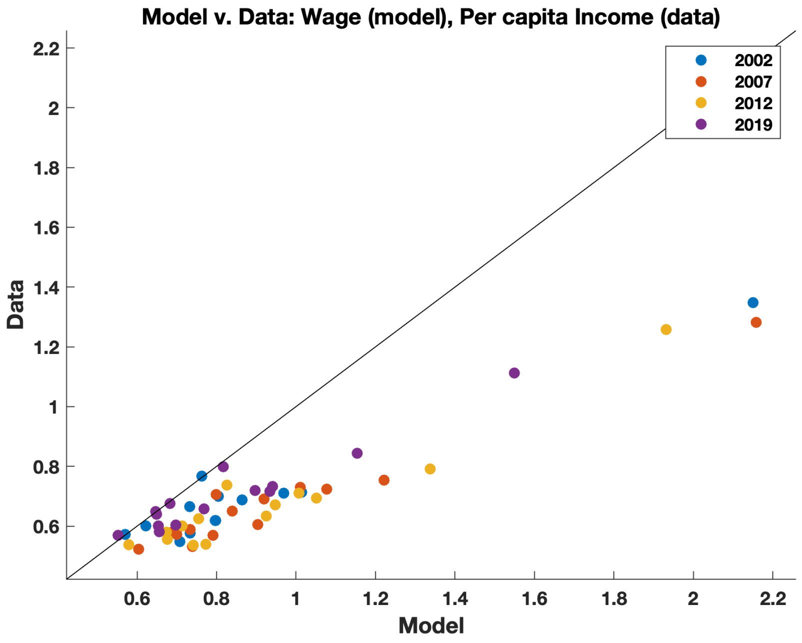


Figure 3.D.1: Model v. Data: Wages

The model underpredicts wages, compared to per capital regional income. Still, the figure exhibits a strong linear relationship.

In one sense, this underprediction is mechanical. We are currently using per capita income as our data counterpart because there are no reliable statistics of average wages at the regional level. Since per capita income includes capital and land as well, it is likely to be higher than wages. Therefore, the figure may understate the model performance systematically.

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