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Essays on Macroeconomics and International Finance

by

Gewei Wang

A dissertation submitted in partial satisfaction of the
requirements for the degree of
Doctor of Philosophy

in

Economics

in the

Graduate Division
of the
University of California, Berkeley

Committee in charge:

Professor Pierre-Olivier Gourinchas, Chair
Professor Yuriy Gorodnichenko
Professor Maurice Obstfeld
Professor Terrance Odean

Fall 2012

Essays on Macroeconomics and International Finance

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Abstract

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Gewei Wang

Doctor of Philosophy in Economics

University of California, Berkeley

Professor Pierre-Olivier Gourinchas, Chair

In Chapter 1, I develop a New Keynesian model with inventories and convex costs of labor adjustment. For each of the three empirically observed responses to monetary policy shocks: (1) the slow adjustment of inventories compared to changes in sales; (2) the delayed and gradual response of inflation; and (3) the transitory movement in the aggregate price level in the same direction as the interest rate, also known as the “price puzzle,” my model has important implications. First, adjustment costs counteract the financing-cost effect of interest rate changes on inventory holdings, but are still inadequate for the calibrated model to generate countercyclical inventory-to-sales ratios. I find that this financing-cost effect needs to be reduced by 80 percent for the model to predict inventory behavior correctly. Second, firm-specific adjustment costs in production increase the degree of real rigidity for price adjustment, so the response of inflation in the presence of high aggregate marginal costs is still slow-moving and persistent. Finally, the motive of cost smoothing for holding inventories implies that marginal costs should move in the opposite direction as the interest rate, which casts doubt on the use of the cost channel to explain the “price puzzle.”

In Chapter 2, I propose a theory of the information channel between home consumption bias and home equity bias. Consumption-revealed information is acquired spontaneously in an investor’s daily life and thus is naturally immobile. For this reason, consumption experience more concentrated in home-produced goods endows domestic residents with information advantage in home equities. This channel also helps to explain many empirical facts such as the 90% correlation between import shares and foreign equity shares.

In Chapter 3, I use individual portfolio data from a China’s brokerage firm to test the predictions of Chapter 2. I find that the fraction of local stocks in the brokerage portfolio is 143 percent higher than the fraction of local stocks in the market portfolio. One third of this portfolio locality is explained by business exposure of listed firms, measured by their sales per capita in the brokerage city. The result shows that a rise in sales per capita by \$2.75 leads to a 32 percent increase in the portfolio share relative to the mean. To examine whether business exposure helps investors to gain information other than familiarity, several indicators of business exposure in nonlocal areas are included in a

regression. The result suggests that if a nonlocal firm's business is concentrated in other areas, local investors tend to shy away from its stock. However, some coefficients are not statistically significant, so we still cannot reach the conclusion that a firm's sales business has significant amount of information content on stock returns.

This thesis is dedicated to my parents

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Chapter 1

Inventory Behavior and the Cost Channel of Monetary Transmission

1.1 Introduction

The monetary transmission mechanism is one of the most studied and yet most debated areas of monetary economics. Understanding how monetary policy affects economic activity and inflation is essential for monetary policymakers to gain an accurate assessment of their policies. Most of the monetary models study the demand channel, through which monetary policy affects aggregate demand. Recent estimates from vector autoregressive (VAR) models, however, have uncovered a transitory rise in inflation in the immediate aftermath of a monetary tightening. This transitory rise in inflation, the so-called “price puzzle”, is difficult to explain in terms of the demand channel. This puzzle has sparked interest in a growing body of literature which seeks to address the possibility that monetary policy may exert an influence on economic variables through the supply channel.¹ The supply channel, also referred to as the cost channel or working capital channel, emphasizes interest costs for firms that hold working capital: when the central bank increases interest rates, aggregate production costs increase in the short run, which consequently, tends to cause an increase in the inflation rate. The view of this supply channel’s importance has a long history in policy perspective. As a matter of fact, cost-push inflation has occasionally been considered by policy makers as a potential consequence of raising interest rates.²

This paper examines the cost channel by considering the effect of interest rates on firms’ inventory holdings. In a theoretical economy without inventories, production always equals sales, so it is difficult to identify whether monetary policy works through demand, supply, or both. In reality, the difference between aggregate sales and production is accounted for by inventory investment, which plays a major role in business cycle fluctuations although the level of inventory investment is small.³ Generally, a demand-side shock should move sales faster than production, and a supply-side shock should move production faster than sales. Therefore, the introduction of inventories allows us to model the transmission of monetary policy with separate predictions for the two channels. As a technology shock is essentially a supply-side shock, I provide empirical evidence corroborating that inventory movement is strongly procyclical in response to a technology shock. In contrast, in response to a monetary policy shock, which presumably has both demand-side and supply-side effects, inventories are acyclical in the short run and inventory-to-sales ratios are countercyclical over the cycle. This implies that the demand-side effect of monetary policy dominates the supply-side effect, which can also be used to evaluate an inventory model’s empirical importance.

¹See [Barth and Ramey \(2001\)](#) and my literature review in section 2.

²For example, [Seelig \(1974\)](#) quotes a famous version of the view that the interest rate affects costs of production, expressed by U.S. congressman Wright Patman, the then chairman of the Joint Economic Committee, who in March 1970 argued that raising interest rates to fight inflation was like “throwing gasoline on fire.”

³For example, [Ramey and West \(1999\)](#) document that, the level of inventory investment is less than 0.5% of GDP in developed countries, however, for quarterly US data, the decline of inventory investment accounts for 49 percent of the fall in GDP for the 1990-1991 recession and on average 69 percent of the fall in GDP for the postwar recessions during the period from 1948 to 1991.

This paper presents a New Keynesian model with inventory holdings and convex costs of adjusting labor inputs. The traditional channel of interest costs implies that a change in the nominal interest rate affects a firm’s financing costs instantly, which leads to a quick response in production. In the model without adjustment friction, aggregate production is raised by almost 50 percent in response to an interest rate shock of 100 basis points, which is clearly at odds with the data. This in turn implies that either the financing-cost effect of monetary policy is relatively weak or other frictions on the supply side exist to counteract the effect of interest costs. Calibrating the model with standard parameters for adjustment costs, I find that the responses of production and inventories become much smoother. One of the main issues in this kind of consideration, however, is that inventories still move faster than sales, but empirical inventory-to-sales ratios are countercyclical. This leads me to model financial friction with a reduced-form approach for which a firm’s financing costs do not fully adjust to the nominal interest rate. The simulation shows that the effect of interest rates requires an 80 percent reduction to bring inventory behavior in line with the data. After all, the sluggish inventory behavior suggests that it is unlikely for my model to generate a rise of marginal costs in response to a monetary tightening, whether this is the result of adjustment costs or financial frictions. This finding casts doubt on the effectiveness of using the cost channel to explain the “price puzzle.”

New Keynesian economics stresses that small nominal frictions at the microeconomic level can have large effects on the macroeconomy. Recently, much literature has sought to assess the effect of both financial and information friction on monetary transmission.⁴ In this paper, I examine real friction, specifically, adjustment costs on the supply side. Such friction has been studied widely in the literature on aggregate investment and inventories. However, little research has been undertaken to study the specific role of adjustment costs in monetary models. A wealth of evidence shows that for macroeconomic variables, including consumption, output, and inventories, their responses to monetary policy shocks are persistent, slow-moving, and hump-shaped. To generate this kind of response curves, recent models assume the role of habit formation, a force from the demand side, in shaping consumption patterns. However, as noted earlier, the dramatic effect of interest costs on inventory behavior in a frictionless world implies that the existence of adjustment costs in production should be relevant to the explanation of the empirical evidence.

In addition to those real effects, adjustment costs also have profound implications for a firm’s pricing behavior. High adjustment costs lead to large swings of marginal costs. Because monopolistic firms set prices according to marginal costs of production, if firms have homogeneous marginal costs at high levels, we should find a surge in inflation, which is inconsistent with the observation of inflation inertia. However, my model, which utilizes Calvo-style pricing, predicts that inflation responses may be moderate due to heterogeneous marginal costs across firms. The real rigidity arising from adjustment costs per se helps to reconcile high adjustment costs with price stickiness.

⁴Two chapters in *Handbook of Monetary Economics* (Vol. 3), [Mankiw and Reis \(2010\)](#) and [Gertler and Kiyotaki \(2010\)](#), provide extensive analysis on monetary models for these two frictions respectively.

This real rigidity has two dimensions. The time-dimension results from the behavior of dynamic cost smoothing. To my knowledge, this type of real rigidity has not been studied previously in the literature on monetary models. In order to reduce the adjustment costs incurred in the future, firms choose to smooth the process of expanding production. They start to produce more in order to be prepared to produce more in the future. For this reason, firms do not have strong incentives to raise prices. Adjustment costs lead to the sluggish movement of production, which means that marginal costs are persistent. This type of real rigidity contributes both to inertia and to the persistence of price adjustment.

The cross-sectional dimension of the real rigidity derives from firm-specific convex adjustment costs. In a Calvo world with pricing frictions, the firms that do not adjust prices in response to rising demand produce less than their expected sales and cut down inventories. The firms that reoptimize and raise prices, meanwhile, curtail sales and build up inventories. Therefore, the firms with high marginal costs stick to their prices and the firms with relatively low marginal costs adjust prices. This effect of complementarity magnifies countercyclical markups for the aggregate price level. The model utilizes large curvatures of adjustment costs and large price elasticities of product demand to show how endogenous marginal cost is an important source of large real rigidity. I demonstrate in my calibration that the conflict between high adjustment costs and price stickiness can be significantly ameliorated by this source of real rigidity.

In my model, two transmission channels of monetary policy, the demand and supply channel, are both at work. For the supply or cost channel to have effect, previous models assume that within each period,⁵ firms must borrow to finance the payments to factors of production before they receive revenues from sales. The unit financing cost is assumed to be the one-period interest rate. Theoretically, however, it is more appealing to model a cost structure with inter-period financing. Inventories can be viewed as the working capital⁶ held and financed over a longer period.⁷ In my model, the opportunity costs of holding inventories are depreciation and interest expenses. In the absence of any financial friction, the economy-wide interest rate naturally measures the unit financing cost of holding inventories for one period. Empirical evidence shows that a monetary policy shock has effect on the nominal interest rate for at least one year. In a dynamic model where interest rate changes persist over such a long period, contemporary adjustment frictions must be much higher to take into account future changes in interest rates than in the case of intra-period financing.

My model features a motive of stockout avoidance to justify inventory holdings on steady state, but the main force that determines inventory holdings is through cost smoothing.⁸ The reason is that the depreciation rate of inventories is rather small in

⁵In a standard model, a period is measured by a quarter.

⁶There are mainly two measures of working capital: gross working capital, which is equal to the value of inventories plus trade receivables; and net working capital, which nets out trade payables.

⁷The turnover period of inventories (the average time a good is held in inventory) used by NIPA is 4 months.

⁸In stockout-avoidance models, holding more inventories helps firm to increase expected sales. *Ex post*

calibration and the benefit of stockout avoidance only accounts for a small part in determining inventory holdings. My results do not depend on this parameter because in response to a monetary policy shock, both the motives of stockout avoidance and interest cost smoothing move inventories in the same direction.

I solve my model analytically by linearizing a system of non-linear equations. Because of adjustment frictions and idiosyncratic shocks, different firms have different states. In my model, the optimal behavior of firms depends on three individual state variables: labor input, the end-of-period inventory stock, and the product price. Although the equation system becomes complicated by individual state variables, it can be solved by an extension of the undetermined coefficients method. The approximation procedure clarifies intuitions in the model, especially the intuition behind pricing behavior.

The paper is organized as follows. Section 2 summarizes related literature. Section 3 reports basic findings of inventory behavior conditional on monetary policy and technology shocks. Section 4 discusses the relationship between adjustment costs and pricing behavior by presenting a baseline model that introduces convex adjustment costs of labor input to an otherwise standard New Keynesian model. Section 5 develops the baseline model by adding to the model inventory holdings. Section 6 describes calibrated results with robustness checks, and Section 7 concludes.

1.2 Related literature

This paper is related to a large body of literature that studies the behavior of price rigidity, inventories, and costs over the business cycle. I start from recent evidence with the observation of sluggish production adjustment in response to monetary policy shocks. This can be seen as indirect evidence of countercyclical movement for inventory-to-sales ratios because inventory investment accounts for the difference between sales and production. Standard recursive VARs⁹ indicate that real GDP, hours worked, and investment barely move during the first quarter in response to a monetary policy shock, but sales and consumption do (for example, see figure 3 in [Christiano, Trabandt, and Walentin, 2010](#)). The production adjustment estimated with the [Romer and Romer \(2004\)](#)'s single-equation approach is even more sluggish. Romer and Romer (in figure 2) shows that industrial production has not started to fall until six months after a monetary contraction. Direct evidence by including inventories explicitly in a VAR also supports this result. [Bernanke and Gertler \(1995\)](#) shows (in figure 2) that inventories appear to build up for 8 months before starting to decrease following an unanticipated contraction of monetary policy. [Gertler and Gilchrist \(1994\)](#), [Jung and Yun \(2005\)](#) and many others have all confirmed countercyclical or acyclical movement of inventory holdings over the

stockout happens for only a few firms, so inventory stocks are exhausted only for these firms. However, the *ex ante* benefit of inventory holdings to sales is the same for all firms. In this sense, inventory behavior in the models of sales promotion ([Bils and Kahn, 2000](#)) and stockout avoidance does not make much difference.

⁹Cholesky decomposition with federal funds rates ordered at the bottom.

business cycle in response to a monetary policy shock. [Bils and Kahn \(2000\)](#) put emphasis on the unconditional behavior of inventory-to-sales ratios. They find in the long run inventories track sales one for one, but the ratio of inventory to sales is highly persistent and countercyclical, which implies production does not keep pace with sales in the short run. In section 3, my paper shows various checks according to different lengths of data series, inventory measures, and empirical strategies. I find that the empirical result of countercyclical inventory-to-sales ratios conditional on monetary policy shocks is robust.

The point estimates from VAR models indicate that inflation moves in a seemingly perverse direction in responses to a monetary policy shock. One explanation is that this “price puzzle” is the outcome of the sort of econometric specification error suggested by [Sims \(1992\)](#). The other explanation suggests that it is indeed the cost channel that causes prices and nominal interest rates to move in the same direction after a monetary policy shock (see [Barth and Ramey, 2001](#)). A growing literature has addressed the cost channel theoretically and empirically. The working capital channel has become one building block in medium-size dynamic stochastic general equilibrium (DSGE) models (for example, see [Christiano et al., 2010](#)). In the models that incorporate the cost channel of monetary transmission, previous literature mainly studies the effect of intra-period financing; changes in interest rates thus directly affect marginal costs of production. [Christiano, Eichenbaum, and Evans \(2005\)](#) argue that the cost decline in intra-period payroll loans helps to explain the “price puzzle.” [Ravenna and Walsh \(2006\)](#) study the optimal monetary policy with the cost channel in a standard New Keynesian framework. They show that its presence alters the optimal policy problem in important ways. [Tillmann \(2008\)](#) shows that the cost channel adds significantly to the explanation of inflation dynamics for the US, the UK, and the Euro area. [Rabanal \(2007\)](#), however, argues that the estimates using Bayesian methods suggest that the demand-side effect of monetary policy dominates the supply side. [Gaiotti and Secchi \(2007\)](#) provide empirical evidence in favor of the presence of a cost channel of monetary policy transmission based on a dataset of Italian manufacturing firms.

The credit channel of financial accelerators proposed by [Bernanke and Gertler \(1989\)](#) has been tested extensively using the evidence from inventory behavior over the business cycle in that it has been argued that the credit channel is at work through the effect of net worth when firms make decisions on their inventory holdings. From this perspective, the credit channel and the cost channel of monetary transmission both rely on the extent to which a firm’s financial situation responds to monetary policy shocks. [Gertler and Gilchrist \(1994\)](#) find that financial factors play an important role in the slowdown of inventory demand as monetary policy tightens. They compare inventory behavior across size classes and confirm that small firms exhibit a greater propensity to shed inventories as sales fall. [Kashyap, Stein, and Wilcox \(1993\)](#) and [Kashyap, Lamont, and Stein \(1994\)](#) provide time-series and cross-sectional empirical evidence that bank-dependent firms have inventory behavior that is sensitive to bank lending conditions.

The literature that studies the incentives to hold inventories has evolved substantially since the 1980s. In general, the incentives in most models are cost reduction, sales pro-

motion, or both. One strand of inventory research is to add to the model a target of the inventory level or inventory-to-sales ratio; for example, the target can be determined by the motive of stockout avoidance (Kahn, 1987), direct sales promotion (Bils and Kahn, 2000), or cost uncertainty (Wang and Wen, 2009). An alternative explanation is the (S, s) theory first brought into the macroeconomic scope by Caplin (1985).¹⁰ Khan and Thomas (2007) develop an equilibrium business cycle model driven by technology shocks where nonconvex delivery costs lead firms to follow (S, s) inventory policies. In such a real model, markups are constant. As Kryvtsov and Midrigan (2010b) argue, if markups are constant, monetary shocks can only generate real effects only if nominal costs are sticky, which gives rise to strong variability in inventories due to intertemporal substitution in production; this result, however, is at odds with the data.

Sluggish production adjustment implies the existence of adjustment frictions. Most macroeconomic research, until recently, has used convex cost functions to slow down changes.¹¹ Although some microeconomic studies argue that firm-level lumpy adjustment of capital and inventory stocks may favor the explanation of non-convex costs, or in a narrower sense, fixed costs, the results in Kryvtsov and Midrigan (2009, 2010a) seem to suggest the choice of fixed cost functions is not a solution to explaining inventory behavior in response to a monetary policy shock. After all, it is hard to think that adjustment frictions are irrelevant to a firm's marginal cost. My New Keynesian model assumes a convex cost function of adjusting inputs to represent the source of all frictions in production adjustment.

Recent attempts to include inventory in a standard New Keynesian model focus on the nominal and real rigidity required to achieve observed inflation inertia. Jung and Yun (2005) develop a general equilibrium model, in which the motive of holding inventories is to promote sales. Their model also includes a simpler form of convex adjustment cost compared to this paper and a sector which does not use inventories. They find that very high nominal rigidity is required to accommodate both countercyclical inventory-to-sales ratios and price rigidity in the model.

My inventory model is based on Kryvtsov and Midrigan (2009, 2010a,b), which provide a thorough study of inventory behavior and real rigidity. They construct a model of stockout avoidance to rationalize inventory holdings, together with Calvo pricing, or

¹⁰The (S, s) theory considers adjustment behavior in the presence of non-convex costs. If fixed costs are incurred at any time a firm wishes to adjust its inventories, Scarf (1959) shows that the firm's optimal decision rule takes a one-sided (S, s) form. This (S, s) policy has different implications compared to inventory targeting in that high or low inventory levels do not pertain to marginal costs of production. On the contrary, inventory targeting with convex adjustment costs indicates that if inventory cannot keep pace with sales, marginal costs of replenishing inventories must increase. Although the (S, s) model has also received considerable attention, due to the cumbersome heterogeneity across firms, it was not until Khan and Thomas (2007) and Kryvtsov and Midrigan (2009) that (S, s) inventory policy is incorporated into a general equilibrium model to analyze business cycles. However, this sort of models must be solved using numerical methods.

¹¹For a survey for theoretical applications and empirical performance of convex costs, see Khan and Thomas (2008).

pricing menu cost. They conclude that the interest rate change in response to a monetary policy shock invokes a strong motive of intertemporal substitution and that standard parameterization cannot reconcile inventory behavior with price rigidity. [Kryvtsov and Midrigan \(2010b\)](#) introduce firm-level decreasing returns to generate a new source of real rigidity and focus on the measure of how much nominal cost rigidity and countercyclical markups account for the bulk of the real effects of monetary policy shocks. However, when I replace the friction of input adjustment costs with decreasing returns in my model, inventory-to-sales are still strongly procyclical because decreasing returns require that the parameter of adjustment response for labor should lie within a range of $[0, 1]$. [Kryvtsov and Midrigan \(2010b\)](#) also use the cash-in-advance assumption to model monetary policy, so changes in the nominal interest rate are weaker. More importantly, my model assumes habit formation to generate a hump-shaped curve for the response of consumption and sales. It is much harder in my model to generate countercyclical inventory-to-sales ratios, therefore, my model implies a much higher reduction of the interest rate effect is required. Another difference between our research is that this paper places emphasis on the implication for the traditional cost channel of monetary transmission. I show that it is theoretically impossible for the cost channel to explain the “price puzzle.”

Recent work of New Keynesian models introduces real rigidity in two ways. The first is internal real rigidity characterized by a price increase associated with a decline in marginal costs at the firm level. Several examples include countercyclical price elasticity ([Kimball, 1995](#); [Eichenbaum and Fisher, 2007](#)), diminishing returns to scale ([Gali, 2008](#); [Kryvtsov and Midrigan, 2010b](#)), firm-specific capital ([Altig, Christiano, Eichenbaum, and Linde, 2011](#)), and firm-specific labor ([Woodford, 2003](#)). The second way is external real rigidity that reduces the responsiveness of real marginal costs at the aggregate level. One widely used approach is sticky wages ([Erceg, Henderson, and Levin, 2000](#); [Christiano, Eichenbaum, and Evans, 2005](#); [Smets and Wouters, 2007](#)). As a matter of fact, medium-sized DSGE models usually include both sources of real rigidity. The source of real rigidity emphasized in my model falls into the first category, but it arises from adjustment costs and has two dimensions. The first cross-sectional dimension is related to heterogeneous adjustment costs, which exerts an effect similar to firm-specific factors. The second dynamic dimension is distinct from all other sources of real rigidity.

1.3 Empirical results

Since the focus of this paper is on the real effect of monetary policy shocks, I mainly document the behavior of inventory and sales in the wake of monetary expansions and contractions. I employ two empirical strategies to estimate the dynamic responses of inventories. One is the vector autoregression (VAR) method with a limited information strategy to identify monetary policy shocks. The other is the single-equation method based on identified Romer and Romer (R&R) monetary policy shocks.

I use real inventory stocks and real sales in the manufacturing and trade industry to

represent the aggregate measure of inventories and compute inventory-to-sales ratios.¹² In the VAR, each period is a quarter and I convert monthly sales to quarterly data. In R&R regressions, I use monthly observations since inventories and R&R shocks are observed on a monthly basis. Except for federal funds rates and R&R shocks, all the data are from NIPA tables.

1.3.1 Evidence from the VAR approach

The VAR analysis includes eight variables. Define the eight-dimensional vector in the VAR, Y_t :

$$Y_t = \begin{pmatrix} \Delta \ln(\text{Real } GDP_t/\text{Hours}_t) \\ \Delta \ln(\text{GDP deflator}_t) \\ \ln(\text{Hours}_t) \\ \ln(\text{Sales}_t/\text{Inventories}_t) \\ \ln(\text{Real Inventories}_t/\text{Real } GDP_t) \\ \ln C_t/GDP_t \\ \ln I_t/GDP_t \\ \text{Federal Funds Rate}_t \end{pmatrix}$$

where $\Delta \ln(\text{GDP deflator}_t)$ measures the inflation rate, I_t denotes investment, and C_t denotes consumption. The reduced-form VAR is specified as

$$Y_t = \alpha + B(L)Y_{t-1} + u_t,$$

where α is a constant vector, $B(L)$ is a p th-ordered polynomial in the lag operator, L , and u_t is a residual vector. This paper chooses a two-period lag: $p = 2$.

$$u_t = C\varepsilon_t$$

where ε_t are “structural” shocks. The identification assumption is that the federal funds rate is the only variable that a monetary policy shock affects contemporaneously. Policy makers set a target for the fed funds rate following a reduced-form Taylor rule:

$$R_t = f(\Omega_t) + \varepsilon_{r,t},$$

where $\varepsilon_{r,t}$ is a monetary policy shock. Here, f is linear, and Ω_t is the information set at period t that contains Y_t, \dots, Y_{t-q} . [Christiano et al. \(1999\)](#) show that the responses to a monetary policy shock do not depend on the ordering of Y_t as long as R_t is ordered at the bottom. Therefore, I assume C is a lower triangular matrix and apply a Cholesky decomposition to the variance covariance matrix of u_t to identify elements of the matrix C :

$$CC' = E[u_t u_t']$$

¹²These two sectors of the economy account for most (85%) of the U.S. inventory stock; the rest of the stock is in mining, utilities, and construction. See [Kryvtsov and Midrigan \(2010b\)](#).

With the exception of inventories and sales in the manufacturing and trade industry, I obtain all the data from the FRED database available through the Federal Reserve Bank of St. Louis (FRED2). Nominal gross product is measured by GDP, real gross product is measured by GDPC96. *GDP* deflator is a measure of the aggregate price index obtained from the ratio of nominal to real product, $GDP/GDPC96$. Nominal investment, denoted by I_t , is measured by PCDG (household consumption of durables) plus GPDI (gross private domestic investment). Nominal consumption, denoted by C_t , is measured by PCND (non-durables consumption) plus PCESV (services) plus GCE (government expenditures). Sales data are for the manufacturing and trade industry. Inventories are measured by trade industry inventories plus the finished-goods inventories in the manufacturing industry. The time range is from 1967 to 2010.

Figure 1.1 shows the impulse responses from the VAR analysis. Solid lines depict impulse responses and shaded areas show 95% confidence zones. The responses of production, inflation, consumption and investment are similar to other established results. For a 1% expansionary monetary policy shock, the inventory-to-sales ratio is countercyclical and peaks at 0.7% one year after the shock. Inventory stocks are procyclical conditional on a monetary policy shock, but they are staggered in the short run. Figure 1.2 presents robustness checks for different periods. Industry categorization in NIPA tables changed from the Standard Industrial Classification (SIC) system to the North American Industry Classification (NAICS) system in 1997. The statistics of aggregate inventories has also been slightly changed ever since. If I only include data for the SIC period, the panel in the second line shows that impulse responses almost do not change except for a larger confidence zone. The panel in the third line excludes current recession period after 2007. The response peaks for inventory-to-sales ratios and inventories slightly decline. The panels in the fourth and fifth lines considers years after the Volcker period. Same as the responses of other macroeconomic variables (also for example, see Coibion, 2012), the confidence bands for inventory responses become much larger. Moreover, inventories peak at a higher level, around 1 percent. However, the basic pattern still remains same. Figure 1.3 presents robustness checks for different empirical strategies. The panels in the first two lines show responses from the stationary VAR same as my benchmark VAR and a level VAR which only include level variables. Because cointegrating relationships are imposed in the stationary VAR, estimates from the stationary VAR should be more efficient theoretically although both approaches deliver consistent estimates. The impulse responses from the two VARs actually are quite similar. The panel in the third line replaces aggregate consumption and investment with real consumption and investment only in the private sector. The panel in the fourth line excludes consumption and investment from the VAR. Both inventory-to-sales ratios and inventories become more persistent, yet these response curves are visually similar to other results. Figure 1.4 presents robustness checks for different measures of inventories. The benchmark VAR uses total finished-goods inventories to be in line with my model. The following panels use (1) total inventories including work-in-progress and materials inventories for the manufacturing industry, (2) finished-goods inventories in manufacturing industries, and (3) finished-goods

inventories in trade industries respectively. All VAR results show that inventory-to-sales ratios are countercyclical in response to a monetary policy shock. Moreover, inventory stocks are acyclical in the short run and procyclical over the business cycle. However, manufacturing and trade industries still differ in their inventory responses. For the manufacturing industry, inventory-to-sales ratios are more countercyclical and inventory stocks show a slightly countercyclical trend for more than two years. The evidence suggests that production frictions or delays are more pervasive in the manufacturing industry.

To verify that a supply-side shock does drive inventory investment, Figure 1.7 shows impulse responses of macroeconomic variables to a neutral technology shock. I adopt the identifying assumption that the only type of shocks that affects the long-run level of average labor productivity is a permanent shock to technology. In contrast to the behavior in response to a shock of monetary tightening, after a positive technology shock, the level of inventories jump up quickly and inventory-to-sales ratios are procyclical over the cycle. Therefore, inventory behavior is closely related to the economic effects from the supply side. The evidence also suggests that costs of adjusting inventories are small. My model applies a cost function of adjusting inputs, rather than a function of inventories.

1.3.2 Evidence from R&R shocks

Monetary policy shocks used in the single-equation approach represent innovations to the intended federal funds rate. Romer and Romer (2004) identify these shocks based on narrative records of FOMC meetings and Federal Reserve’s internal forecasts. This dataset was updated to June 2008 by Barakchian and Crowe (2010).

Responses of inventory stocks and inventory-sales ratios are obtained by estimating the OLS regression following R&R:

$$\Delta y_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta y_{t-i} + \sum_{j=1}^{36} c_j S_{t-j} + e_t,$$

where y_t is the dependent variable, D_k ’s are a full set of monthly dummies, S is the measure of R&R shocks, and e_t is the zero-mean normally distributed error term, which is assumed to be serially uncorrelated. This specification implies policy shocks have no contemporary effect on macroeconomic variables. To be consistent with this assumption, the same timing restriction will be applied in my model. My analysis for robustness checks in section 6 shows that this assumption is essentially innocuous for the responses of most variables given the response of interest rates

Figure 1.5 reports impulse responses to R&R shocks with various periods. Solid lines denote point estimates of the different response functions, and shaded areas represent 95% confidence intervals computed by bootstrapping. The response of inventory investment is slightly countercyclical for about one year after the shock, reflecting the fact that inventory stocks are adjusted with lags. I corroborate the evidence of countercyclical inventory-sales ratios conditional on a monetary policy shock: after an expansionary monetary shock, the ratio declines until one and a half year later.

Figure 1.6 provides additional robustness checks with different measures of inventories. Inventory stocks are strongly countercyclical for the manufacturing industry, but only acyclical for the trade industry during the first year after a shock. Inventory-to-sales ratios exhibit countercyclical behavior for all the checks.

1.4 Adjustment costs and pricing in a baseline model

1.4.1 A simple example

This section illustrates the relationship between adjustment costs and pricing behavior. I start with a stylized example showing how heterogeneous adjustment costs across firms contribute to larger real rigidity at the aggregate level. Consider an economy with a continuum of firms, whose optimal pricing decisions are characterized by the following log-linearized best-response:

$$p(i) - p = mc(i)$$

where $p(i)$ denotes firm i 's optimal price, $p = \int p(i) di$ denotes the average price for all firms, and $mc(i)$ denotes firm i 's marginal cost. This equation can be derived from a static pricing strategy with a constant markup. When individual marginal costs are determined only by aggregate production y , that is, $mc(i) = \xi \cdot y$, the equation can be rewritten as

$$p_i = \xi(p + y) + (1 - \xi)p, \quad \xi > 0$$

Therefore, the closer ξ is to zero, the more slowly price adjustment responds to a shock of nominal spendings. Given a certain level of nominal rigidity like Calvo frictions, for some firms, $p(i) \neq p$, then monetary policy has real effects. ξ is a measure of cost stickiness. Accordingly, $1 - \xi$ is a measure of strategic complementarity among firms. When individual marginal costs are decreasing functions of relative product prices:

$$mc(i) = \xi y - \eta(p(i) - p), \quad \eta > 0 \tag{1.1}$$

it follows that

$$p(i) = \frac{\xi}{1 + \eta}(p + y) + \frac{1 + \eta - \xi}{1 + \eta}p, \quad \xi > 0 \text{ and } \eta > 0$$

which suggests that if a firm's marginal cost is sensitive to its relative product price, large real rigidity is possible because of the strategic complementarity implied in equation (1.1). An alternative explanation is that in a Calvo world, it is reoptimizing firms who determine the aggregate price level. Selectively, those reoptimizing firms are the firms who have lower marginal costs compared to non-reoptimizing firms. In my model to be formulated below, this measure, η , essentially depends on the price elasticity of demand and the curvature of cost functions.

I continue to explain this effect of complementarity in this section by presenting a DSGE model. All elements in the model follow medium-sized New Keynesian models such as in [Christiano et al. \(2005\)](#), except for convex adjustment costs of labor inputs.

1.4.2 A New Keynesian model with labor adjustment costs

In this baseline model with two factors in production, differentiated goods are produced by a continuum of monopolistically competitive firms, indexed by $i \in [0, 1]$, using a Cobb-Douglas production function:

$$Y_t(i) = K_t(i)^\alpha L_t(i)^{1-\alpha}$$

where $Y_t(i)$ denotes the individual production of firm i at period t , $L_t(i)$ denotes labor input in production, and $K_t(i)$ denotes the input of capital service. α is the share of capital income. A firm needs to hire $\Upsilon\left(\frac{L_t(i)}{L_{t-1}(i)}\right) L_t(i)$ units of labor to adjust employment in production. $\Upsilon(\cdot)$ is a convex cost function of labor adjustment such that $\Upsilon(1) = \Upsilon'(1) = 0$ and $\Upsilon''(1) \equiv \tau > 0$. τ denotes the curvature of the cost function when no adjustment is needed. The real cost function therefore includes a component of labor adjustment costs:

$$\frac{W_t}{P_t} L_t(i) + \frac{W_t}{P_t} \Upsilon\left(\frac{L_t(i)}{L_{t-1}(i)}\right) L_t(i) + R_{K,t} K_t(i)$$

where P_t is the price index, W_t is nominal wage, and $R_{K,t}$ is the rental rate of capital service. The demand curve for firm i is given by

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta} C_t$$

where C_t denotes aggregate consumption.

Firm i 's objective function is given by

$$E_t \sum_{j=0}^{\infty} D_{t,t+j} \left[\frac{P_{t+j}(i)}{P_{t+j}} Y_{t+j}(i) - \frac{W_{t+j}}{P_{t+j}} L_{t+j}(i) - \frac{W_{t+j}}{P_{t+j}} \Upsilon\left(\frac{L_{t+j}(i)}{L_{t+j-1}(i)}\right) L_{t+j}(i) - R_{K,t+j} K_{t+j}(i) + Q_{t+j}(i) \left(K_{t+j}^\alpha(i) L_{t+j}(i)^{1-\alpha} - Y_{t+j}(i) \right) \right]$$

where $Q_t(i)$ is the Lagrangian multiplier or the marginal cost (also known as the shadow value of time t inventories) for firm i , and $D_{t,t+j}$ is the stochastic discount factor for evaluating real income streams received at period $t+j$. $D_{t,t+j}$ is defined as $\beta \Lambda_{t+j} / \Lambda_t$, where $0 < \beta < 1$ is the discount factor of the representative household and Λ_t is the Lagrangian multiplier of the budget constraint for consumption optimization.

Firms set prices according to a variant of the mechanism introduced by [Calvo \(1983\)](#). In each period, a firm faces a constant probability, ξ_p , of not being able to re-optimize its nominal price. The first-order conditions for $K_t^*(i)$, $L_t^*(i)$, and $P_t^*(i)$ are stated in Appendix A. Following standard literature, the household problem determines varieties demand, aggregate consumption, labor supply, and capital accumulation. See Appendix A for more details.

1.4.3 Log-linearization and the New Keynesian Phillips Curve

In this paper, unless otherwise noted, an English/Greek letter in lower case indicates a deviation from steady state, expressed as a fraction of steady state. For instance, $x_t \equiv dX_t/X_t$, where X is the steady state value of X_t and dX_t is a small deviation: $X_t - X$. I refer to x_t as the log deviation of X_t from steady state, or, simply, as the “log deviation”. I also denote $\tilde{x}_t(i) \equiv x_t(i) - x_t$, the log deviation of $X_t(i)$ from its aggregate level X_t . Without causing confusion, I will omit “log deviations” sometimes hereafter.

With heterogeneous marginal costs, the individual marginal cost $q_t(i)$ may not equal aggregate q_t . Subtracting the aggregate equation for q_t from $q_t(i)$ gives¹³

$$q_t(i) - q_t \equiv \tilde{q}_t(i) = (1 - \alpha) \tau \cdot \left(\tilde{l}_t(i) - \tilde{l}_{t-1}(i) - \beta \left(E_t \tilde{l}_{t+1}(i) - \tilde{l}_t(i) \right) \right), \quad (1.2)$$

which suggests that other than standard parameters, the deviation of the individual marginal cost depends on (1) the curvature of adjustment costs, (2) the contemporaneous input change, and (3) the input change in the next period.

The pricing equation for firm i after linearization is given by

$$p_t(i) - p_t \equiv \tilde{p}_t(i) = (1 - \xi_p \beta) E_t^{\bar{p}} \sum_{j=0}^{\infty} (\xi_p \beta)^j q_{t+j}(i) + E_t^{\bar{p}} \sum_{j=1}^{\infty} (\xi_p \beta)^j \Delta_{\varrho} \pi_{t+j}. \quad (1.3)$$

The inflation rate is denoted by $\pi_t \equiv \log P_t - \log P_{t-1}$. If a firm does not change price during the period from t to $t + j$, since $q_{t+j}(i)$ is determined by $l_{t+j}(i)$, it must be determined by $l_{t-1}(i)$ and $p_{t-1}(i)$. Hence, $p_t(i)$ is a function of $p_{t-1}(i)$. I posit that

$$\tilde{p}_t(i) = \psi \tilde{p}_{t-1}(i) + p_t^*$$

Intuitively, ψ is larger than zero because if input is low at time $t - 1$, to avoid high adjustment costs, input at time t still stays low; ψ should also be less than one because of the requirement of system stationarity. It follows that the individual marginal cost is determined by

$$q_t(i) = q_t + (1 - \alpha) \tau \varepsilon (\tilde{p}_{t-1}(i) - \phi \tilde{p}_t(i)), \quad \phi \equiv 1 + \beta (1 - \xi_p - (1 - \xi_p) \psi)$$

We find that the function of the individual marginal cost is decreasing with the individual product price as $\phi > 0$, which is consistent with the stylized example. Denote the average price for re-optimizing firms by p_t^* . Aggregating the re-optimized prices thereby gives

$$\begin{aligned} p_t^* &= E_t^{\bar{p}} \sum_{j=1}^{\infty} (\xi_p \beta)^j \Delta_{\varrho} \pi_{t+j} + (1 - \xi_p \beta) E_t^{\bar{p}} \sum_{j=0}^{\infty} (\xi_p \beta)^j q_t \\ \text{new } \{ & \quad -\varepsilon (1 - \alpha) \tau (\phi - \xi_p \beta) \left(p_t^* - E_t^{\bar{p}} \sum_{j=1}^{\infty} (\xi_p \beta)^j \Delta_{\varrho} \pi_{t+j} \right) \end{aligned} \quad (1.4)$$

¹³For all the derivations, see my Technical Appendix, which can be downloaded from my website.

where the second line is new due to the introduction of adjustment costs. After simplification, the New Keynesian Phillips Curve is given by

$$\Delta_e \pi_t = \frac{(1 - \xi_p \beta)(1 - \xi_p)}{\xi_p} \frac{1}{1 + \kappa} q_t + \beta E_t \Delta_e \pi_{t+1}, \quad (1.5)$$

where

$$\kappa \equiv \varepsilon \tau \cdot (1 - \alpha) (\phi - \xi_p \beta) \quad (1.6)$$

Here κ is a measure of real rigidity resulted from adjustment costs. κ has a lower bound of zero when there are no adjustment costs. It depends basically on the value of ε and τ since $\phi - \xi_p \beta$ is close to one in my calibration. Because $\tau < 5$ is fairly reasonable, κ can be considerably large. Figure 1.8 shows that the relationship between κ and τ is almost linear given ε , ξ_p , α , and β . The slope is approximately 3.5.

The intuition of this complementarity can be seen in equation (1.4). A firm's price is based on its own marginal cost. As individual marginal costs are endogenous, they increase with production, thereby decrease with relative prices. When production is elastic with relative prices, and adjustment friction is high, individual marginal costs are sensitive to relative product prices. On average, individual marginal costs deviate more from the aggregate marginal cost if price elasticity and cost curvatures are larger. As a result, optimal prices respond less to aggregate marginal costs. In other words, strategic complementarity is stronger.

The effect of large firm-specific adjustment costs on inflation is through two channels (see equation (1.5)). The first is through higher κ , which increases strategic complementarity in pricing and therefore inflation responds less to a change in aggregate marginal costs.¹⁴ The second is through q_t : the higher individual adjustment costs, the higher aggregate marginal costs are. These two channels exert effects in opposite directions. Figure

¹⁴The sort of strategic complementarity depends on the assumption of nominal rigidities. In the model with Calvo pricing, for each period, a certain part of firms do not adjust prices, no matter how far their prices are from the optimal levels. This is equivalent to assume that a random proportion of firms face extremely high costs to adjust prices. If we apply convex costs on price adjustment, a.k.a. Rotemberg (1982) pricing, endogenous costs will not contribute to real rigidity. With Rotemberg pricing, each firm has chance to adjust prices, so the dispersion of firm prices is small and strategic complementarity cannot exert a significant influence. With Calvo pricing, however, reoptimizing firms are reluctant to set their prices far from the average price of non-reoptimizing firms. As a result, only firms with low marginal costs set prices; high aggregate marginal costs do not contribute to a high aggregate price level. Aggregate markups thereby exhibit countercyclical behavior. For more intuition, see the New Keynesian Phillips Curve under the scheme of Rotemberg pricing:

$$\pi_t = \frac{\varepsilon}{\tau_p} q_t + \beta E_t \pi_{t+1},$$

where τ_p denotes the curvature of price adjustment costs. High adjustment costs only lead to high aggregate marginal costs denoted by q_t .

Empirical evidence shows that prices do not change continuously. Nominal stickiness is a pervasive feature of the data. Convex costs of price adjustment therefore are at odds with this fact. (See Klenow and Malin, 2010)

1.10 shows the impulse responses to an expansionary monetary policy shock.¹⁵ The inflation response with a larger cost curvature is even flatter. Because the aggregate price level is determined by reoptimizing firms, this means that they charge even lower prices when they face higher wage rates and adjustment costs. The complementarity effect cannot explain this interesting behavior. However, we can find clues from the dynamic structure of adjustment costs. Equation (1.2) shows that firms need to take into consideration future adjustment costs. When firms are sluggish in adjusting prices, they wish to adjust inputs quickly in response to a shock in order to reduce expected adjustment costs in the future. In my calibration, the optimal price is even lower for larger adjustment costs. This implies that the effect of enlarged real rigidity dominates the effect of rising aggregate marginal costs. As a result, price adjustment is more sluggish.

The source of real rigidity arising from dynamic cost smoothing is a novel finding. In order to smooth adjustment costs, firms choose to increase input purchase immediately after an expansionary shock instead of raising price. They start to produce more in order to be prepared to produce more in the future. This motive for inter-temporal substitution is different from other sources of real rigidity like strategic complementarity among firms or counter-cyclical markups that works intra-temporally.

1.5 A model with inventories

I formulate in this section a New Keynesian model with inventories. Following [Kryvtsov and Midrigan \(2009, 2010a,b\)](#), I introduce a motive for stockout avoidance to justify positive inventory holdings on steady state. I solve the model analytically by linearizing the system of non-linear equations. Idiosyncratic shocks and adjustment frictions imply that different firms have different states at each point in time. In my model, the optimal behavior of firms depends on three individual state variables: labor input, the end-of-period inventory stock, and product price. Although the equation system becomes complicated by individual state variables, it can be solved by an extension of the undetermined coefficients method. The advantage of this approximation procedure is to clarify intuitions, especially the intuition behind pricing behavior.

1.5.1 Household

Denote $v_t(i)$ a preference shock specific to each good in the CES aggregator. Assume $v_t(i)$ follows a log-Normal distribution: $\log(v_t(i)) \sim N\left(-\frac{\sigma_v^2}{2}, \sigma_v^2\right)$. t is a time index. $i \in [0, 1]$ is an index for varieties produced by a continuum of monopolistically competitive firms. Assume $v_t(i)$ for all t and i are uncorrelated over time and across firms. Preference shocks at each period unfold to all firms after they make decisions on the quantity of goods supplied to the market. Therefore, in this economy the representative consumer's demand for

¹⁵See Appendix A for the parametrization based on quarterly data

some varieties will occasionally be satisfied only in part by firms with insufficient inventory available. Denote each firm's available stock of inventories by $Z_t(i)$: the consumer cannot purchase more than $Z_t(i)$ units. The consumer's optimization problem is defined as

$$\begin{aligned} & \max E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \\ \text{st. } & \int_0^1 P_t(i) C_t(i) di + E_t D_{t,t+1} B_{t+1} \leq B_t + W_t N_t + \Pi_t \end{aligned}$$

where

$$\begin{aligned} C_t(i) & \leq Z_t(i) \\ C_t & = \left(\int_0^1 v_t(i)^{\frac{1}{\theta}} C_t(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}} \end{aligned}$$

B_{t+1} denotes a portfolio of nominal state contingent claims in the complete contingent claims market, $D_{t,t+1}$ denotes the stochastic discount factor for computing the nominal value in period t of one unit of consumption goods in period $t+1$, W_t denotes aggregate nominal wage, N_t denotes labor supply, and Π_t denotes a lump-sum transfer. θ is the elasticity of substitution across goods varieties. $P_t(i)$ and $C_t(i)$ denote the price and consumption for each variety i . $0 < \beta < 1$ is the discount factor for the representative household. $U(\cdot)$ is the utility function defined on aggregate consumption C_t and aggregate labor supply N_t .

The inter-temporal Lagrangian is given by

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta^t \left(U(C_t, N_t) + \Lambda_t \left(W_t N_t - \int_0^1 P_t(i) C_t(i) di \right) + \int_0^1 \mu_t(i) (Z_t(i) - C_t(i)) di \right)$$

where Λ_t is the multiplier on the consumer's budget constraint and $\mu_t(i)$ are the multipliers on the constraint $C_t(i) \leq Z_t(i)$ for all i .

The first order condition for consumption varieties yields the price index:

$$P_t \equiv \frac{U_{c,t}}{\Lambda_t} = \left(\int_0^1 v_t(i) \left(P_t(i) + \frac{\mu_t(i)}{\Lambda_t} \right)^{1-\theta} di \right)^{\frac{1}{1-\theta}}$$

For goods that happen to be out of stock, shadow prices are higher than market prices such that demand equals supply. The demand function for a variety i is given by

$$C_t(i) = \begin{cases} v_t(i) \left(\frac{P_t(i)}{P_t} \right)^{-\theta} C_t & \text{if } v_t(i) \left(\frac{P_t(i)}{P_t} \right)^{-\theta} C_t < Z_t(i) \\ Z_t(i) & \text{otherwise} \end{cases}$$

Labor supply is determined by the standard intra-temporal equation:

$$U_{n,t} = -U_{c,t} \frac{W_t}{P_t}$$

Note that

$$P_t C_t \neq \int_0^1 P_t(i) C_t(i) di,$$

so the consumer cannot merely optimize with respect to C_t while keeping the share of $C_t(i)$ fixed. The reason is that P_t now is not exogenous but contains information about stockout, which in turn relates to demand. Hence, when the consumer solves the problem, P_t cannot be used as the unit price of C_t . Some of goods are out of stock. As a result, even if P_t is paid at the margin, one cannot get the same consumption basket as before. Instead, with extra payment of P_t , the consumer needs to reallocate consumption across goods in stock and compute marginal utility from this new consumption basket.

I specify that

$$U(C_t, N_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} - \frac{N_t^{1+\chi}}{1+\chi}$$

which implies labor supply is given by

$$N_t^\chi C_t = \frac{W_t}{P_t}$$

The optimization condition for bonds holding is

$$D_{t,t+1} = \beta \frac{\Lambda_{t+1}}{\Lambda_t}.$$

I denote $D_{t,t+j} = \frac{\beta^j \Lambda_{t+j}}{\Lambda_t}$. Hence, if R_t represents the gross nominal interest rate in period t , absence of arbitrage gives the following Euler equation:

$$E_t(D_{t,t+1} R_t) = 1$$

To generate a hump-shaped consumption response to a monetary shock, I add an assumption of habit formation for the consumer preference as in the standard literature. As in [Erceg et al. \(2000\)](#), I introduce sticky wages to dampen the rise of nominal wage rates in response to an increase of labor demand.

1.5.2 Firms

1.5.2.1 Production function, inventory, and goods demand

Storable final goods are produced by monopolistically competitive firms using a production function linear in labor:

$$Y_t(i) = \exp(e_t^A) L_t(i)$$

where $Y_t(i)$ denotes individual production of firm i at period t , $L_t(i)$ denotes labor input, and e_t^A represents the technology shock with zero mean. Goods are storable and can be held as finished goods inventory. A firm needs to hire $\Upsilon\left(\frac{L_{t+j}(i)}{L_{t+j-1}(i)}\right)L_t(i)$ units of labor to adjust employment in production.¹⁶ $\Upsilon(\cdot)$ is a convex cost function of labor adjustment such that $\Upsilon(1) = \Upsilon'(1) = 0$ and $\Upsilon''(1) \equiv \tau > 0$. Hence, the cost function of production is given by

$$C(Y_t(i)) = W_t \left(L_t(i) + \Upsilon\left(\frac{L_t(i)}{L_{t-1}(i)}\right) L_t(i) \right)$$

Firms cannot observe idiosyncratic demand shocks before production, therefore, inventory can be used to ensure market clearing. Denote sales by S . It is possible that sales do not equal production for individual firms and the economy: $S_t(i) \neq Y_t(i)$ and $S_t \neq Y_t$. The demand function for firm i is given by

$$S_t(P_t(i), Z_t(i)) = \min \left(v_t(i) \left(\frac{P_t(i)}{P_t} \right)^{-\theta} C_t, Z_t(i) \right)$$

The beginning-of-period inventory stock of firm i evolves over time according to

$$Z_t(i) = (1 - \delta)(Z_{t-1}(i) - S_{t-1}(i)) + Y_t(i)$$

where $Z_t(i)$ is defined as inventory holdings at the beginning of period t after production, and δ is the constant marginal cost of inventory stocks measured in the form of iceberg loss. Inventory costs can take several forms. Besides natural attrition, storage and maintenance costs are incurred when a firm stocks and moves inventory. External financing premium is also one main type of inventory costs if a firm borrows short-term loans to finance inventory holdings.

Consumers cannot resell the goods purchased. They do not choose to store goods because the expected return is negative while I assume the riskfree rate is always positive. In the literature, there are basically two benefits to induce firms to hold inventories on steady state when firms may face idiosyncratic shocks but no aggregate shocks: cost reduction and sales promotion. The DSGE inventory models of cost reduction assume idiosyncratic cost uncertainty (Wang and Wen, 2009) or (S, s) policy for fixed ordering cost (Khan and Thomas, 2007). Sales promotion models can be specified with the motive of stockout avoidance (Kryvtsov and Midrigan, 2009, 2010a,b) by idiosyncratic demand uncertainty, which my model is based upon. Because the rate of inventory depreciation cannot be very large, after an expansionary monetary policy shock, the increase of benefit from sales promotion is relatively small and it turns out that the shadow value of inventory stock is primarily affected by the decline of interest rates. In this case, the motive of

¹⁶The first order condition is isomorphous to the condition derived from a variant of decreasing returns:

$$Y_t(i) = L_{t-1}^\tau(i) L_t^{1-\tau}(i)$$

However, the model of decreasing returns requires $\tau \leq 1$.

cost smoothing dominates any other incentives for firms to determine the optimal level of inventory stocks. As we will see, this cost structure has profound implications on inventory behavior.

1.5.2.2 Objective function and optimal conditions

Firms set prices according to a variant of the mechanism spelled out by Calvo pricing. In each period, a firm faces a constant probability, ξ_p , of not being able to re-optimize its nominal price.

$$\mathcal{L} = E_t \sum_{j=0}^{\infty} D_{t,t+j} \left[P_{t+j}(i) S_{t+j}(i) - W_{t+j}(i) L_{t+j}(i) - W_{t+j}(i) \Upsilon \left(\frac{L_{t+j}(i)}{L_{t+j-1}(i)} \right) L_{t+j}(i) \right. \\ \left. + Q_{t+j}(i) ((1 - \delta) (Z_{t+j-1}(i) - S_{t+j-1}(i)) + L_{t+j}(i) - Z_{t+j}(i)) \right]$$

where $Q_t(i)$ is the Lagrangian multiplier and the shadow value of time t inventory for firm i . The model does not explicitly impose a borrowing constraint on holding inventories across periods. Because firms discount future revenues by stochastic discount factors $D_{t,t+j}$, the opportunity cost of holding inventories includes interest payment besides depreciation.

The first-order conditions for $Z_t(i)$, $L_t(i)$, and $P_t(i)$ can be summarized as follows. Firms that do not re-optimize prices simply follow the indexation rule. Therefore, the optimal condition of pricing is only applied to those firms that re-optimize.

The first-order condition for inventory holdings $Z_t(i)$ is given by

$$Q_t(i) = P_t(i) \frac{\partial E_t S_t(i)}{\partial Z_t(i)} + E_t (1 - \delta) D_{t,t+1} Q_{t+1}(i) \left(1 - \frac{\partial E_t S_t(i)}{\partial Z_t(i)} \right) \quad (1.7)$$

This equation defines a dynamic equation for inventory holdings. The left hand side is the marginal cost of accumulating one unit of inventory at period t . The right hand side comes from the benefit of sales promotion and the discounted marginal cost at period $t + 1$. If demand is less than stocks, inventory leftovers must be restocked. This equation describes the motive for holding inventories. It shows that firms equate marginal costs of production for all t . Once there is a decline in the interest rate, it suggests that future costs become more important; namely, contemporary costs become relatively lower. For example, a decline in the interest rate raises the discount factor $D_{t,t+1}$. If there are no adjustment costs, marginal costs are equal to real wage rates. In order to take advantage of lower interest rates, firm i builds up inventories aggressively and the benefit of inventories to promote sales $P_t(i) \frac{\partial E_t S_t(i)}{\partial Z_t(i)}$ thereby falls. The secondary effect is that when expected sales $E_t S_t(i)$ increase, it adds more incentives to increase inventory holdings.

The first-order conditions for labor input $L_t(i)$ is given by

$$Q_t(i) = W_t \left(1 + \Upsilon' \left(\frac{L_t(i)}{L_{t-1}(i)} \right) \frac{L_t(i)}{L_{t-1}(i)} + \Upsilon \left(\frac{L_t(i)}{L_{t-1}(i)} \right) \right) - E_t D_{t,t+1} W_{t+1} \Upsilon' \left(\frac{L_{t+1}(i)}{L_t(i)} \right) \left(\frac{L_{t+1}(i)}{L_t(i)} \right)^2$$

which shows that marginal costs of production equals the wage rate plus adjustment costs.

The first-order conditions for price-setting $P_t(i)$ is given by

$$E_t^{\bar{p}} \sum_{j=0}^{\infty} \xi_p^j \frac{D_{t,t+j} S_{t+j}(i)}{P_{t+j}(i)} \left[P_{t+j}(i) - \frac{\varepsilon_{t+j}(i)}{\varepsilon_{t+j}(i) - 1} (1 - \delta) D_{t+j,t+j+1} Q_{t+j+1}(i) \right] = 0$$

where $\varepsilon_{t+j}(i) \equiv -\frac{P_{t+j}(i) E_t S_{p,t+j}^{\bar{p}}(i)}{R_{t+j}(i)}$. This equation describes a standard pricing equation with Calvo frictions. Individual markups become time-varying when inventories are considered. In addition, pricing at period t is based on the discounted marginal cost of the following period $t + 1$ because of cost smoothing indicated in equation (1.7).

Note that E_t and $E_t^{\bar{p}}$ are different operators because the expectations are conditional on different events. $E_t^{\bar{p}} X_{t+k}(i)$ denotes the expectation of the random variable $X_{t+k}(i)$, condition on date t information and on the event that firm i optimizes its price in period t , but does not do so in any period up to and including $t + k$. For any aggregate state variable X_{t+k} , $E_t^{\bar{p}} X_{t+k} = E_t X_{t+k}$. However, these two conditional expectations differ for firm i 's individual variables. This distinction is emphasized in [Woodford \(2005\)](#).

1.5.3 Social resource constraint and monetary policy

The aggregate production equation and labor market clearing imply that

$$Y_t + \int_0^1 \Upsilon \left(\frac{Y_t(i)}{Y_{t-1}(i)} \right) Y_t(i) di = N_t$$

Aggregating individual inventory holdings gives us the law of motion for aggregate inventory stock

$$Z_t = (1 - \delta) (Z_{t-1} - S_{t-1}) + Y_t \quad (1.8)$$

One can see that the aggregate market clearing condition can be written as

$$Y_t = S_t + I_{Z,t} \quad (1.9)$$

where $I_{Z,t} \equiv Z_t - S_t - (1 - \delta) (Z_{t-1} - S_{t-1})$ denotes inventory investment.

Finally, the monetary policy rule is assumed to follow a variant of [Taylor \(1993\)](#) rule with partial adjustment of the form

$$\log \left(\frac{R_t}{R} \right) = \rho_r \log \left(\frac{R_{t-1}}{R} \right) + (1 - \rho_r) \left(\rho_\pi \pi_t + \rho_y \log \left(\frac{Y_t}{Y} \right) \right) + e_t^r, \quad (1.10)$$

where ρ_r is the partial adjustment parameter, ρ_π measures the responsiveness of the policy interest rate with respect to inflation rate, ρ_y measures the responsiveness of the policy interest rate with respect to real production, and e_t^r is an exogenous (possible stochastic) component with zero mean. It is also assumed that it takes one period for private agents to observe monetary shocks, so e_t^r is not included in the period t information set of the agents in the model. This ensures that the model satisfies the restriction used in the empirical analysis to identify a monetary policy shock.

1.5.4 Log-linearization and aggregation

Denote the end-of-period inventory stock for firm i at period t by $X_t(i) \equiv Z_t(i) - S_t(i)$. At period t , re-optimizing firms choose different prices and inputs, depending on individual state variables $\tilde{x}_{t-1}(i)$, $\tilde{l}_{t-1}(i)$, and $\tilde{p}_{t-1}(i)$. This is a complication that is absent in the usual Calvo setting, where all price-optimizing firms choose the same price. It turns out that, following the logic laid out in [Woodford \(2005\)](#), if I assume only first moments matter for all stochastic processes, every choice variable for firm i at period t , $\tilde{l}_t^*(i)$, $\tilde{z}_t^*(i)$, and $\tilde{p}_t^*(i)$, is a linear function of the state variable plus a term which only depends on aggregate variables. In other words, I assume that according to the distributions of firm-level variables, the aggregate shocks in consideration do not change any moments other than first moments. The strategy for computing the parameters of linear policy functions is based on the undetermined coefficient method. This method has been applied and extended in several recent papers. For example, [Altig et al. \(2011\)](#) features a model with firm-specific capital and thereby individual marginal costs are a function of individual capital stocks for each period.

Denote

$$\Delta_\varrho \pi_t \equiv \pi_t - \varrho \pi_{t-1} \tag{1.11}$$

$$\Delta_\varrho w_t \equiv w_t - w_{t-1} - \varrho_w (w_{t-1} - w_{t-2}) \tag{1.12}$$

where ϱ and ϱ_w are two indexation parameters in price and wage setting.¹⁷ Then I posit (and later verify) linear policy functions for a firm's labor hiring, pricing, and inventory holdings decision under three specific states as in [Table 1.1](#).

¹⁷As in [Christiano et al. \(2005\)](#), I assume a firm which cannot re-optimize its price sets $P_t(i)$ according to: $P_t(i) = \left(\frac{P_{t-1}}{P_{t-2}}\right)^\varrho P_{t-1}(i)$, $0 \leq \varrho \leq 1$, where ϱ controls the degree of lagged inflation indexation. Firms and the representative household all take the market nominal wage as given for each period. The labor contract stipulates that the nominal wage rate is indexed with lagged inflation by the rule if it is not to be changed

$$W_t(i) = \left(\frac{W_{t-1}}{W_{t-2}}\right)^{\varrho_w} W_{t-1}(i), \quad 0 \leq \varrho_w \leq 1,$$

where ϱ_w controls the degree of wage indexation. This indexation rule differs from [Christiano et al. \(2005\)](#) in that the index is aggregate nominal wage, not the aggregate price level.

Table 1.1. Linear policy functions

	State A	State B
	optimize p_t	non-optimize p_t
Probability	$1 - \xi_p$	ξ_p
$\tilde{l}_t(i) =$	$\psi_1^l \tilde{x}_{t-1}(i) + \psi_2^l \tilde{l}_{t-1}(i) + \psi_3^l \hat{p}_t(i)$	$\psi_1^l \tilde{x}_{t-1}(i) + \psi_2^l \tilde{l}_{t-1}(i) + \psi_3^l \hat{p}_t(i)$
$\hat{p}_t(i) =$	$\psi_1^p \tilde{x}_{t-1}(i) + \psi_2^p \tilde{l}_{t-1}(i) + \hat{p}_t^*$	$\hat{p}_{t-1}(i) - \Delta_\rho \pi_t$
$\tilde{q}_t(i) =$	$\psi_1^q \tilde{x}_{t-1}(i) + \psi_2^q \tilde{l}_{t-1}(i) + \psi_3^q \hat{p}_t(i)$	$\psi_1^q \tilde{x}_{t-1}(i) + \psi_2^q \tilde{l}_{t-1}(i) + \psi_3^q \hat{p}_t(i)$

Here ψ_1^l , ψ_2^l , ψ_3^l , ψ_1^p , and ψ_2^p are five undetermined coefficients. ψ_1^q , ψ_2^q , and ψ_3^q , can be solved as functions of these five unknowns. I add sign restrictions in calibration because they should intuitively all be negative. The aggregated equations for the linearized economy are listed as follows. The solution details are in Technical Appendix available upon request.

The linearized discount factor is obtained by log-linearizing the Euler equation around the steady state with a zero inflation rate

$$E_t d_{t,t+1} + r_t - \pi_{t+1} = 0. \quad (1.13)$$

The equation for the stochastic discount factor gives

$$E_t d_{t,t+1} = E_t \lambda_{t+1} - \lambda_t \quad (1.14)$$

With habit formation, consumption dynamics is

$$c_t = -\frac{(1-b)(1-\beta b)}{\sigma(1+\beta b)} \lambda_t + \frac{b}{1+\beta b^2} c_{t-1} + \frac{\beta b}{1+\beta b^2} E_t c_{t+1} \quad (1.15)$$

where b denotes the degree of habit persistence.

Following [Erceg et al. \(2000\)](#), in each period, a labor union faces a constant probability, ξ_l , of not being able to re-optimize its nominal wage rate. Labor supply is given by

$$\Delta_\rho w_t = \frac{(1-\xi_l)(1-\xi_l\beta)}{\xi_l(1+\chi\varepsilon_w)} v_t + \beta E_t \Delta_\rho w_{t+1}, \quad (1.16)$$

where $v_t = \chi l_t - \lambda_t - w_t^r$ is the deviation from the Pareto-optimal allocation, when $v_t = 0$. Without the Calvo-style adjustment of wage rates, labor supply is given by $w_t^r = \chi l_{t+1} - \lambda_t$, which is equivalent to $v_t = 0$. The law of motion for the level of aggregate real wages is given by

$$w_t^r = w_{t-1}^r + w_t - w_{t-1} - \pi_t. \quad (1.17)$$

The linearized aggregate equation for inventories is

$$z_t = (1-\delta) \left(z_{t-1} - \frac{S}{Z} s_{t-1} \right) + \frac{Y}{Z} y_t. \quad (1.18)$$

It is obtained directly from (1.8).

A, B, G, H in the following are functions of structural parameters. The law of motion for the average shadow value of inventory is

$$z_t - c_t = A q_t + B E_t (d_{t,t+1} + q_{t+1}) \quad (1.19)$$

Calibration shows a large, positive value for B , so inventory holdings z_t is very responsive to a change in the interest rate. The input dynamics for labor demand is given by

$$q_t = w_t - p_t + \tau (l_t - l_{t-1} - \beta (E_t l_{t+1} - l_t)) \quad (1.20)$$

This shows clearly that marginal costs equal the real wage rate plus a term representing adjustment costs. I have shown in section 4 that the source of real rigidity arises from this type of adjustment costs. Inflation dynamics has a slightly different form compared to standard New Keynesian models because of the introduction of inventories.

$$\begin{aligned} \Delta_\theta \pi_t &= \beta E_t \Delta_\theta \pi_{t+1} \\ &+ \frac{(1 - \xi_p)(1 - \xi_p \beta)}{\xi_p H} \frac{1}{1 + \kappa} (z_t - c_t) \\ &+ \frac{(1 - \xi_p)(1 - \xi_p \beta)}{\xi_p G} \frac{1}{1 + \kappa} E_t (d_{t,t+1} + q_{t+1}) \end{aligned} \quad (1.21)$$

where κ is a non-linear function of the parameters of the model, so κ can be viewed as a measure of real rigidity. Specifically, in an inventory model without adjustment costs, $\tau = 0$, we have $\kappa = 0$. The second line of equation (1.21) is an adjustment term to take into account the small difference between z_t and c_t . Therefore, this New Keynesian Phillips Curve is well analogous to those in other New Keynesian models. We can numerically make plots to see how real rigidity is affected by structural parameters. Figure 1.9 shows that κ increases with cost curvature, but the slope is noticeably smaller than in the model without inventories.

Here, it should be noted that up to first-order log-linear approximations, measures of relative price and input distortions turn out to be zero, following the literature. Thus, log-linearizing the aggregate production function yields

$$y_t = l_t + e_t^A. \quad (1.22)$$

The equilibrium in goods market is given by

$$s_t - c_t = \left(\frac{\varepsilon_\Phi \theta (1 - \varepsilon_\Psi)}{1 - \theta + \theta \varepsilon_\Phi} + \varepsilon_\Psi \right) (z_t - c_t) \quad (1.23)$$

in which it should be noted that $s_t \neq c_t$ in my model with stockout avoidance. Besides, the Taylor rule leads to

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) (\rho_\pi \pi_t + \rho_y y_t) + e_t^r. \quad (1.24)$$

This completes the equation system of my linearized economy.

Proposition 1.1. *An equilibrium is a stochastic process for the prices and quantities which has the property that the household and firm problems are satisfied, and goods and labor markets clear. If there is an equilibrium in the linearized economy, then the following 14 unknowns*

$$z_t, y_t, l_t, q_t, \pi_t, s_t, c_t, r_t, w_t, w_t^r, d_{t,t+1}, \lambda_t, \Delta_\varrho \pi_t, \Delta_\varrho w_t$$

can be solved for using 14 equations (1.11) (1.12) (1.13) (1.14) (1.15) (1.16) (1.17) (1.18) (1.19) (1.20) (1.21) (1.22) (1.23) (1.24).

1.6 Calibration

I evaluate the model's quantitative implications by calibrating parameter values to qualitatively match empirical impulse functions obtained above. Following the empirical analysis, I set the length of the period as one month and therefore choose a discount factor of $\beta = .96^{1/12}$. The utility function is assumed to be logarithmic ($\sigma = 1$) and the inverse of Frisch labor supply elasticity is one ($\chi = 1$).

Table 1.2. Parameter Values (Monthly data)

Parameter	Values	Description and definitions
σ	1	Inverse of inter-temporal substitution
χ	1	Inverse of labor supply elasticity
β	$0.96^{1/12}$	Time discount factor
ϱ	1	Degree of inflation indexation
ϱ_w	0.6	Degree of wage indexation
$1 - \xi_p$	1/8	Frequency of price changes in each month
$1 - \xi_l$	1/12	Frequency of wage changes in each month
$\frac{Z}{S}$	1.9	Beginning-of-month inventory-sales ratio
θ	6	Elasticity of substitution across good varieties
ε_w	6	Elasticity of substitution across labor varieties
σ_v	.5406	Standard deviation of the logarithm of demand shocks
δ	.0078	Rate of inventory depreciation
b	0.95	Degree of habit persistence
τ	38	Curvature of labor adjustment costs
ρ_r	0.95	Interest rate smoothing (Taylor Rule)
ρ_π	1.15	Interest rate responsiveness to inflation (Taylor Rule)
ρ_y	0.5/12	Interest rate responsiveness to production gap (Taylor Rule)

Table 1.2 reports the parameter values I use in my quantitative analysis. I set the elasticity of substitution across good and labor varieties, $\theta = \varepsilon_w = 6$. This implies the steady-state demand elasticity equals 5.43, which corresponds to a markup of 23%, in the range of estimates according to existing work. I assume that the frequency of wages

changes is once a year: $1 - \xi_t = 1/12$, consistent with what is typically assumed in existing studies. My model uses the same nominal rigidity assumed by the literature to generate inflation inertia. Specifically, I assume that the average of price durations lasts for 8 months. This is consistent with recent empirical findings on the frequency of price adjustment.¹⁸

The calibration of inventory parameters follows [Kryvtsov and Midrigan \(2010b\)](#). Specifically, I calibrate two parameters, the rate of inventory depreciation δ and the standard deviation of the logarithm of demand shocks σ_v , to ensure that the model accounts for two facts about inventories and stockout in the data: a 5% frequency of stockout and a 1.4 inventory-sales ratio. I assume a smooth turnover of production and sales, so the calibrated beginning-of-period inventory ratio is 1.9.

The curvature of adjustment costs is the reciprocal of the adjustment response considered in Tobin's q -theory of investment. A typical value for the adjustment response in the q literature is 0.05 at annual rates, corresponding to an annual adjustment-cost parameter of 20 and a monthly adjustment-cost parameter of 244. [Hall \(2004\)](#) estimates the adjustment-cost parameters for labor and capital using annual data from two-digit industries. He finds that the parameters are on average small, not much above zero. However, the model of [Hall \(2004\)](#) only considers optimal conditions without inventories. With a similar methodology, [Shapiro \(1986\)](#) finds zero adjustment costs for production workers and moderate adjustment cost for nonproduction workers. [Cooper and Willis \(2009\)](#)'s estimate of this parameter for labor is 2.77 at the annual frequency. This paper calibrates $\tau = 38$, corresponding to an annual parameter 2.74.

1.6.1 The cost channel and inventory behavior

Figure 1.11 presents a side-by-side comparison between the impulse responses from the inventory model without adjustment costs and the responses with adjustment costs. The left panel without adjustment costs shows that changes in interest rates have strong effects on the supply side. In response to an interest rate shock of 100 basis points, aggregate production is raised by almost 50 percent at the period after the shock. Correspondingly, inventory stocks rise by more than 20 percent. As a result, inventory-to-sales are strongly procyclical, which is clearly at odds with the data. Because firms expand production only for one period to take advantage of low interest costs, firms continue to offer low prices. The left panel therefore shows a spuriously low, persistent curve for the inflation rate. The right panel introduces labor adjustment costs to the model. The response of output becomes less dramatic than the model without adjustment costs. Output peaks at 2.5 percent and inventories peak at 10 percent. Both are still much higher than the levels implied by the data. Inventory-to-sales in this case, therefore, are still procyclical. The inflation rate peaks at 0.4 percent around the third quarter after the shock. Its curve responds to the shock too quickly and too strongly compared to the inflation inertia

¹⁸For example, [Nakamura and Steinsson \(2008\)](#) find an uncensored median duration of regular prices of 8–11 months and 7–9 months including substitutions.

shown in the data. High marginal costs dampen the responses of inventories, whereas high marginal costs also lead to responsive inflation. The source of real rigidity from adjustment costs exerts its effect, but cannot bring inflation completely in line with the data.

1.6.2 Alternative explanation of financial frictions

The cost-smoothing motive for holding inventories implies that countercyclical inventory-to-sales ratios cannot coexist with low costs after a monetary easing. The introduction of adjustment costs is simply one way to counteract the interest cost channel with high production costs. However, in a calibrated model, monetary policy still has significant effects on the supply side through the cost channel even with adjustment costs in production. This leads us to consider an alternative explanation of financial frictions. Conceptually, large firms have convenient access to the financial market, so they react quickly to interest rate changes. However, the average firm may not see large effects from the cost channel in the short run. For example, small firms with bank loans should have lags to be affected by interest rate changes due to time constraints of their loan contracts.

I assume a reduced-form source of friction on the financial side. Specifically, in the condition of optimal inventory holdings, firms discount future value of inventories not with the nominal interest rate prevalent in the economy, but with a partial indexation to steady-state interest rates. The new aggregate equation for inventory holdings is given by

$$Q_t(i) = P_t(i) \frac{\partial E_t S_t(i)}{\partial Z_t(i)} + E_t (1 - \delta) \check{D}_{t,t+1} Q_{t+1}(i) \left(1 - \frac{\partial E_t S_t(i)}{\partial Z_t(i)}\right) \quad (1.25)$$

where $\check{D}_{t,t+1} \equiv \bar{D}^{1-\gamma} D_{t,t+1}^\gamma$. This implies that the interest rate charged on inventory holdings is a weighted average of the steady-state interest rate and current interest rate. For calibrating the parameter γ , I aim at achieving the peak value of -0.6% for the response of inventory-to-sales ratios (see Figure 1.1).

Figure 1.12 shows the calibration result. In the left panel the interest rate for inventories is fixed and does not respond to a monetary policy shock. In this case, because of adjustment costs, aggregate inventory stocks are countercyclical for two years after a shock, and the trough of inventory-to-sales ratios exceeds 2 percent. This implies that the model still needs some effects of interest rates to generate consistent inventory behavior. The calibration shows that the indexation parameter should equal 0.2, which means that the model needs to reduce the effect of interest costs to 20 percent in order to get predictions consistent to the data.

1.6.3 Adjustment costs and real rigidity

By setting $\kappa = 0$, my model allows us to conduct an experiment of removing the source of real rigidity. The left panel of Figure 1.13 shows that in this case inflation rises quickly due to high aggregate marginal costs. Moreover, inflation becomes less persistent and the price level falls back to the original level at the sixth quarter after a shock. The inflation

rate peaks at 0.65 percent at the sixth month after a shock, which is also higher than the peak at 0.4 percent when we take into account the source of real rigidity arising from adjustment costs.

Firm-specific adjustment costs reduce a firm's pricing response to aggregate marginal costs. However, heterogeneous adjustment costs or countercyclical markups cannot completely help the model to reconcile inflation inertia and high marginal costs. The reason is that the main role of adjustment costs in the model is to drive up marginal costs in order to dampen firms' incentives to change inventory holdings.

1.6.4 Decreasing returns

Essentially, a model with decreasing returns instead of adjustment costs implicitly assumes that the adjustment response is between zero and one. Hence, the impulse responses from decreasing returns are similar to the left panel of Figure 1.1, which is far from being consistent with the data. My model indicates that a formal analysis of adjustment costs is necessary to understand inventory behavior.

1.6.5 More robustness checks

There is a debate about whether it is valid to assume that monetary policy shocks do not have contemporaneous effect on macroeconomic variables. The evidence from R&R identified shocks actually shows relaxing this assumption only changes the response of federal funds rates to a hump-shaped curve. Figure 1.14 shows that the calibration also supports that my result for inventory behavior is robust to this assumption. Because changes in interest rates are larger, we need to reduce more effects of interest rates on inventory holdings ($\gamma = 0.1$).

1.7 Conclusion

Cost structure is closely related to a firm's production and pricing behavior. This paper examines the quantitative behavior of aggregate production and inventories to infer the cost structure that the average firm should have. The cost channel of monetary transmission cannot explain the "price puzzle" if high marginal costs are required to support the empirically observed inventory behavior. In a New Keynesian model with inventories, the real puzzle now is why the cost channel does not show a strong effect on the supply side in the data like what theory predicts.

Adjustment costs in production help the model to fit the data, but they are still not adequate. One issue is the quick inflation response corresponding to high marginal costs. The source of real rigidity arising from adjustment costs indicates that the model is still able to reconcile inflation inertia with adjustment costs to a large degree. The other issue we are confronted with is that empirically the adjustment response of labor and capital is not large. My calibration shows that inventory-to-sales ratios are still procyclical when

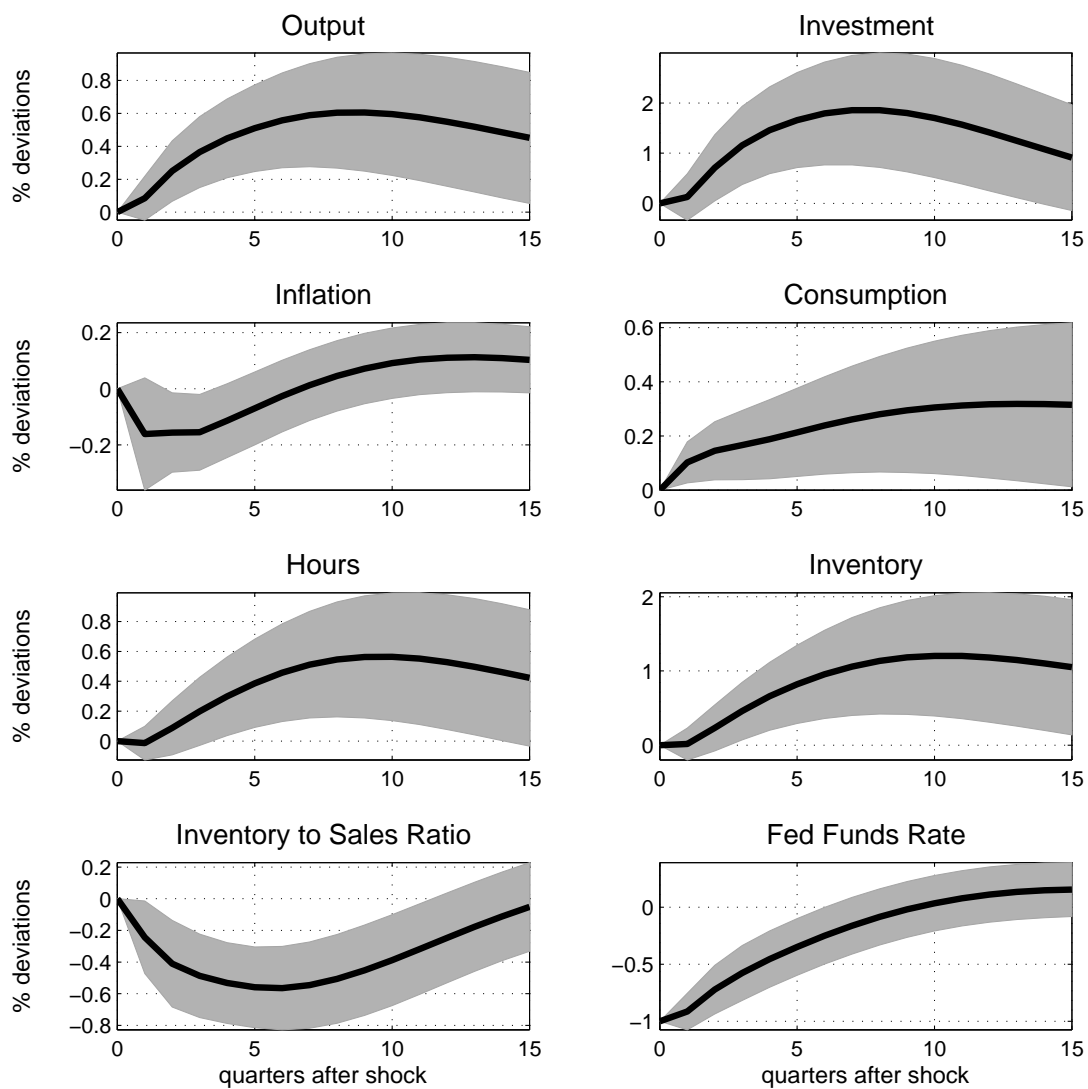
the cost function is calibrated with standard parameters. This motivates us to consider the effectiveness of the interest cost channel. I show that the model needs to reduce the effect of interest rates by eighty percent to bring inventory behavior in line with the data.

My findings on the cost channel have implications for the channel of financial accelerators, which also operates through firm-level financing. Because we know the interest rate response to a monetary policy shock is short-lived relative to other macroeconomic variables, if the credit channel is not effective in the short run, the direct impact of a monetary policy shock on a firm's net worth may also not be large. Current research on the credit channel mainly focuses on the balance-sheet effect from the side of financial intermediaries due to the recent financial crisis. But it is still interesting to think whether it is because of a decline in net worth or worse outlook on future profitability that places a firm's financing opportunities in jeopardy.

The analysis of the cost channel sheds light on the conduct of monetary policy. The adverse impact of interest rate hikes on the price level during a typical restriction cycle is theoretically impossible and still needs more empirical support. This question becomes pressing in an environment where the central bank deliberately manipulates the interest rate in the pursuit of macroeconomic stabilization. [Ravenna and Walsh \(2006\)](#) argue that if a cost channel exists, any shock to the economy generates a trade-off between stabilizing inflation and stabilizing the output gap. So they suggest that both the output gap and inflation are allowed to fluctuate in response to productivity and demand shocks under optimal monetary policy. The optimal monetary policy that operates through a more complicated cost channel with inventories should be an interesting avenue for future work.

Figure 1.1. Response to a -1% Fed Funds Rate shock

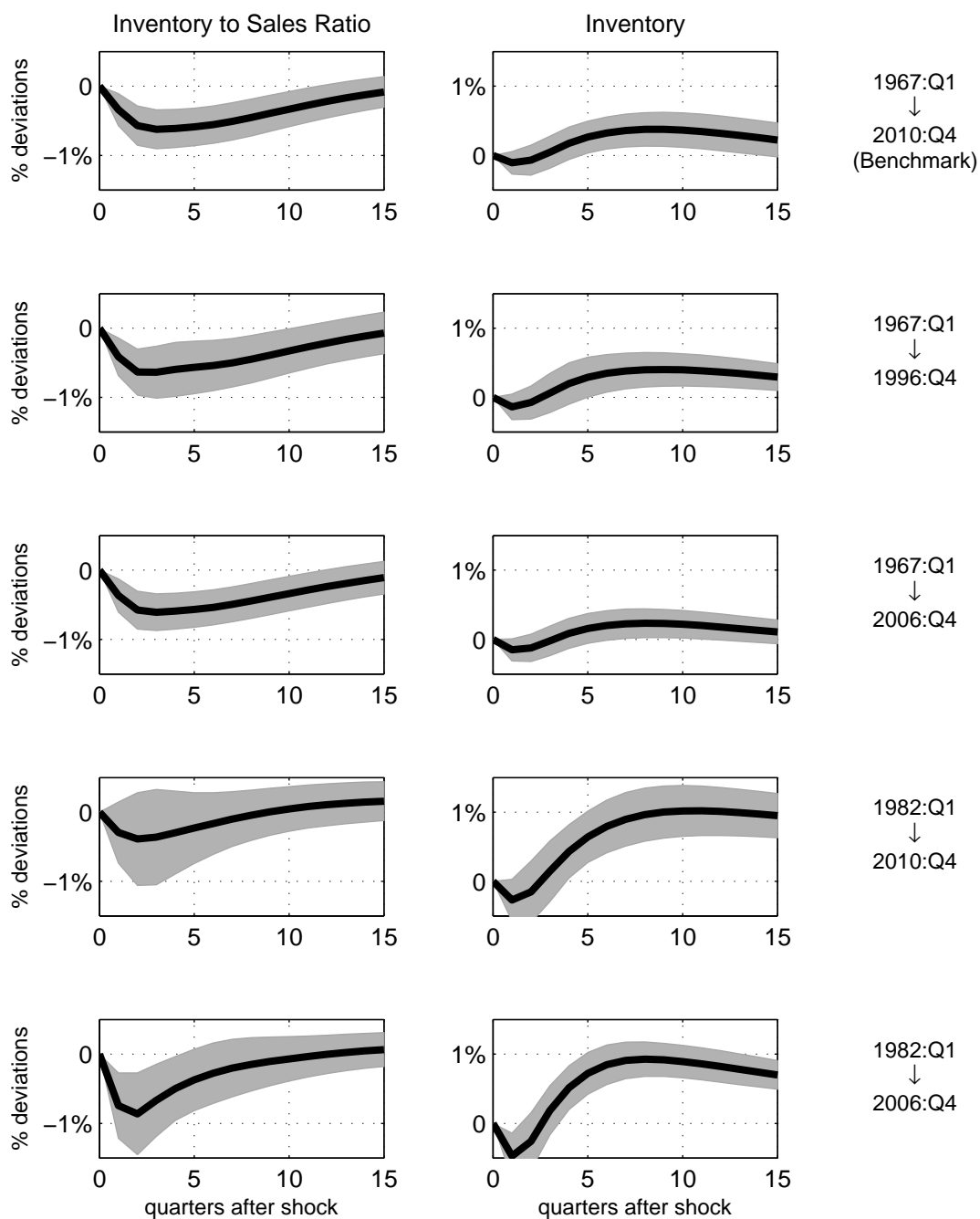
(Stationary VAR with cointegrating relationships)
 [Period: 1967:Q1 - 2010:Q4]



Notes: —: impulse response, shaded area: 95% confidence interval

Figure 1.2. Response to a -1% Fed Funds Rate shock

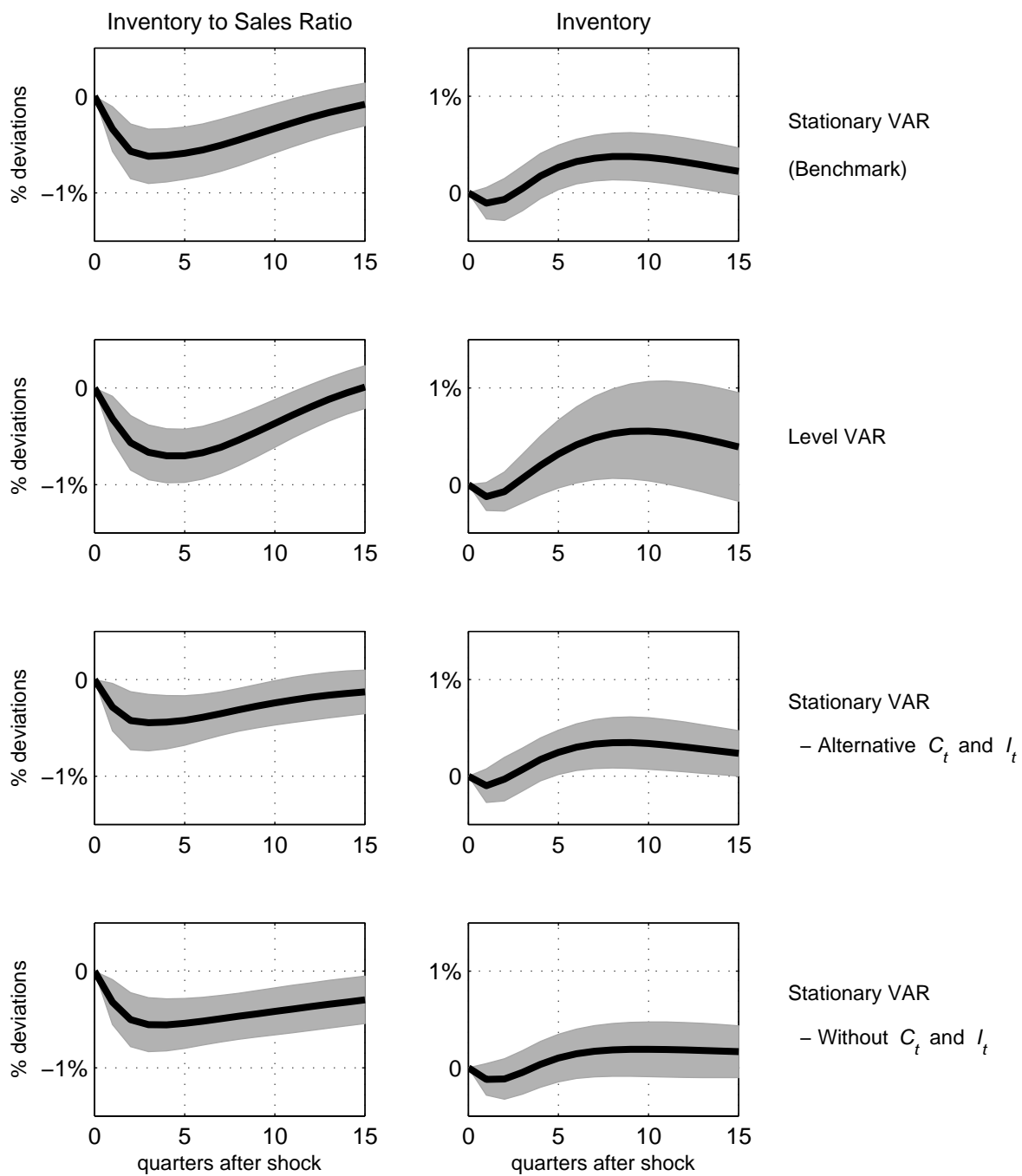
(Stationary VAR with cointegrating relationships)
[Robustness check for various periods]



Notes: —: impulse response, shaded area: 95% confidence interval

Figure 1.3. Response to a -1% Fed Funds Rate shock

(Robustness check for various VARs)
 [Period: 1967:Q1 - 2010:Q4]



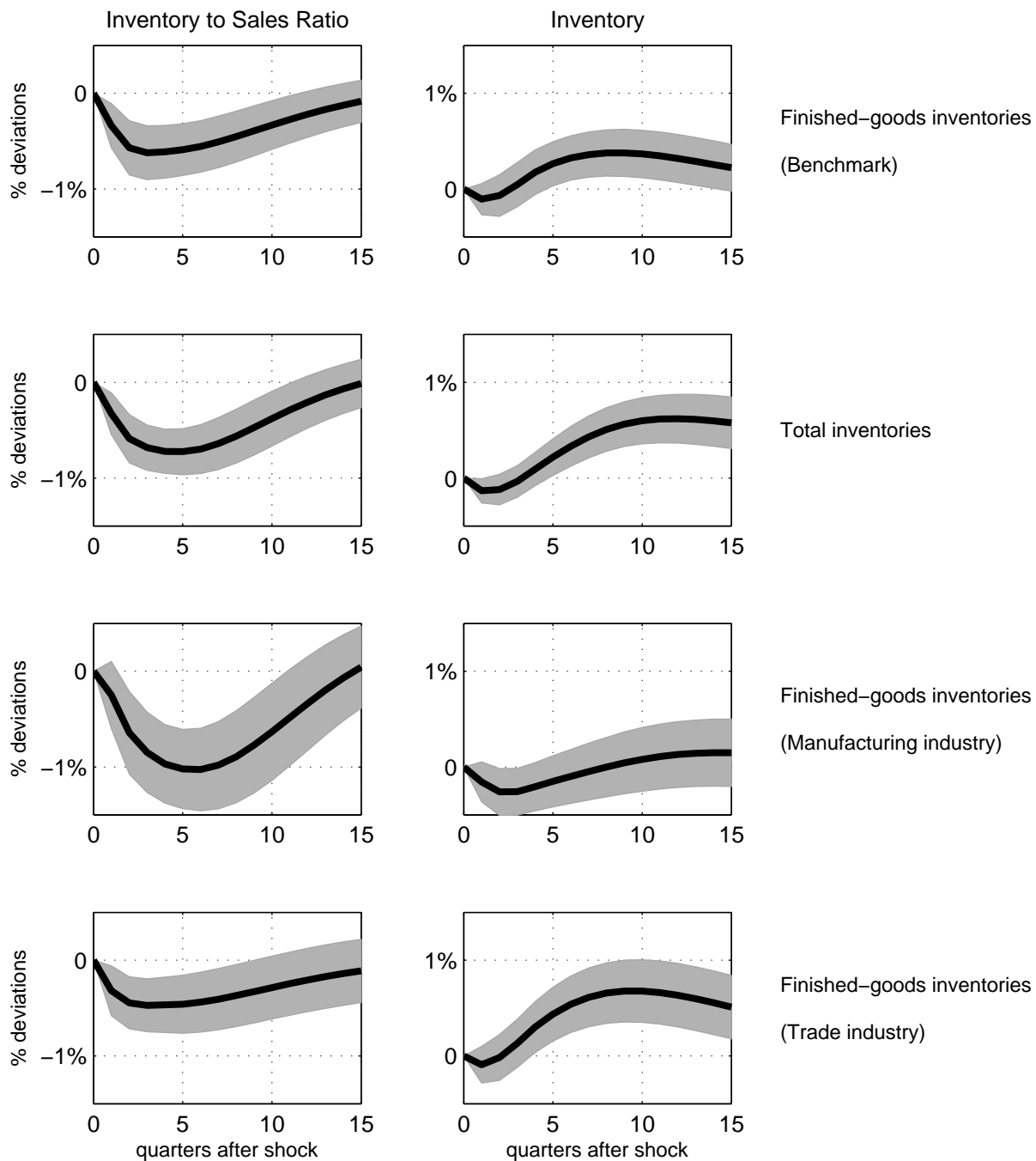
Notes: —: impulse response, shaded area: 95% confidence interval

Figure 1.4. Response to a -1% Fed Funds Rate shock

(Stationary VAR with cointegrating relationships)

[Period: 1967:Q1 - 2010:Q4]

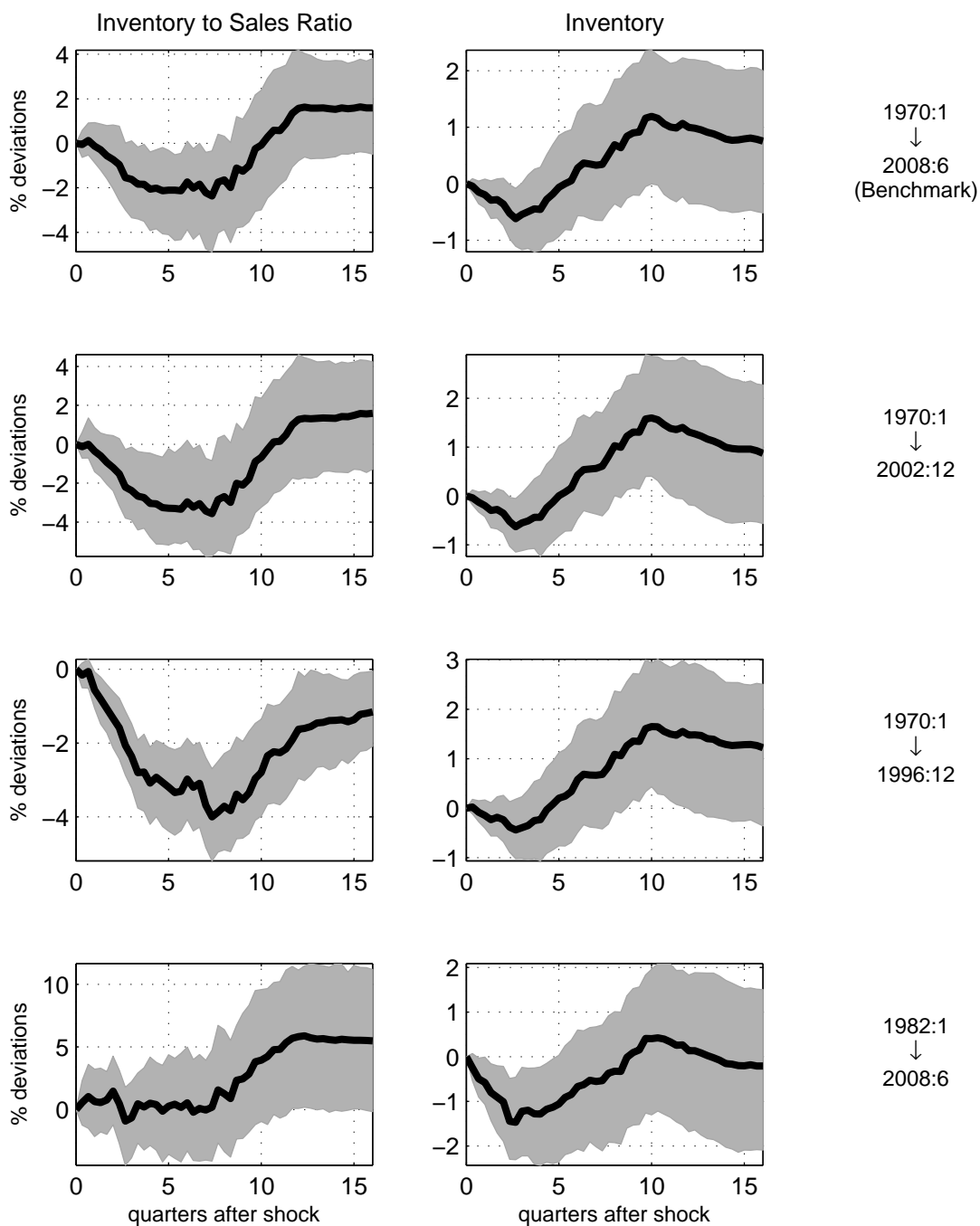
Robustness check for various measures of inventories



Notes: —: impulse response, shaded area: 95% confidence interval

Figure 1.5. Response to a -1% Fed Funds Rate shock

(Romer and Romer shocks and regression)
 [Robustness check for various periods]



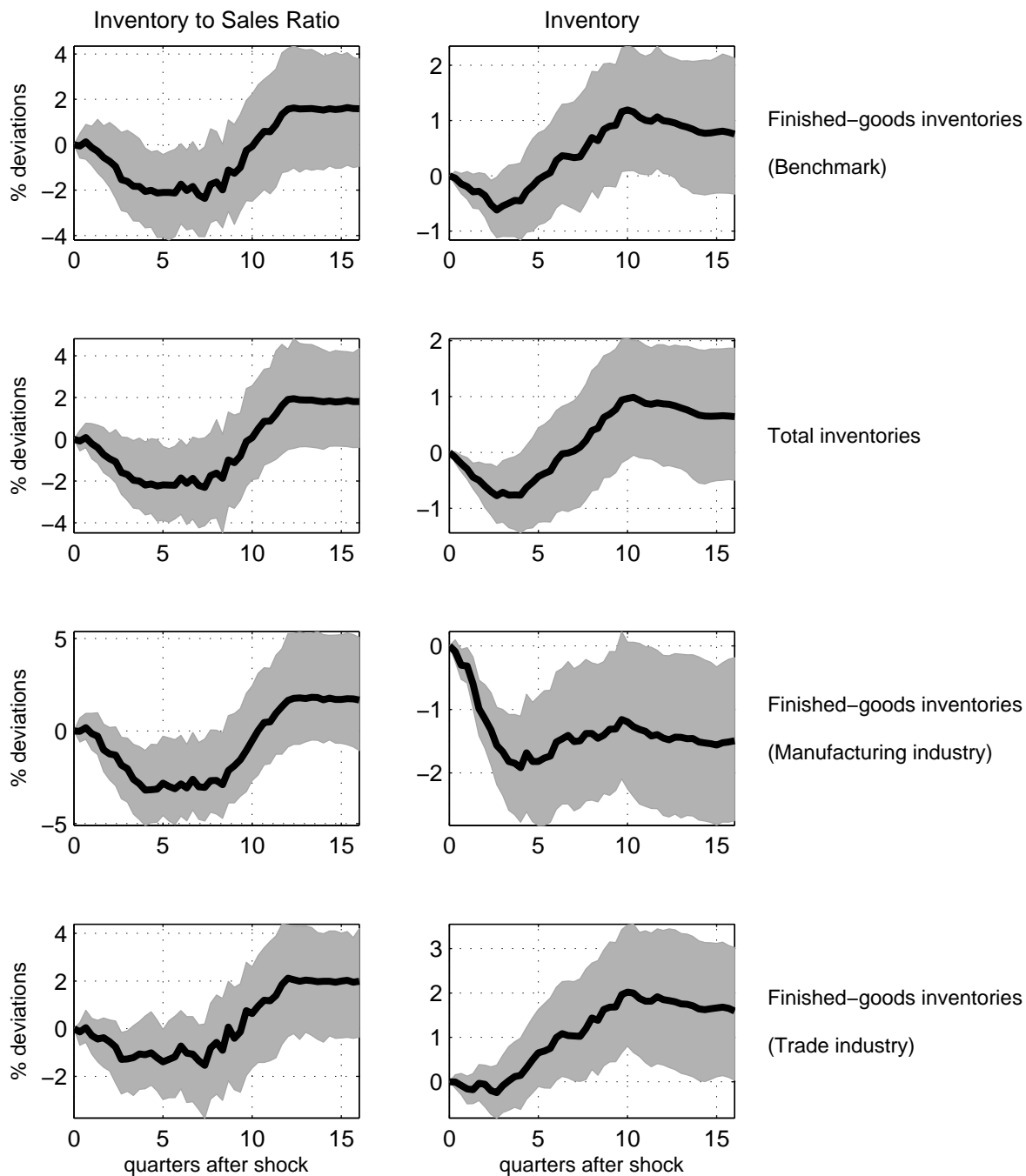
Notes: —: impulse response, shaded area: 95% confidence interval

Figure 1.6. Response to a -1% Fed Funds Rate shock

(Romer and Romer shocks and regression)

[Period: 1967:Q1 - 2010:Q4]

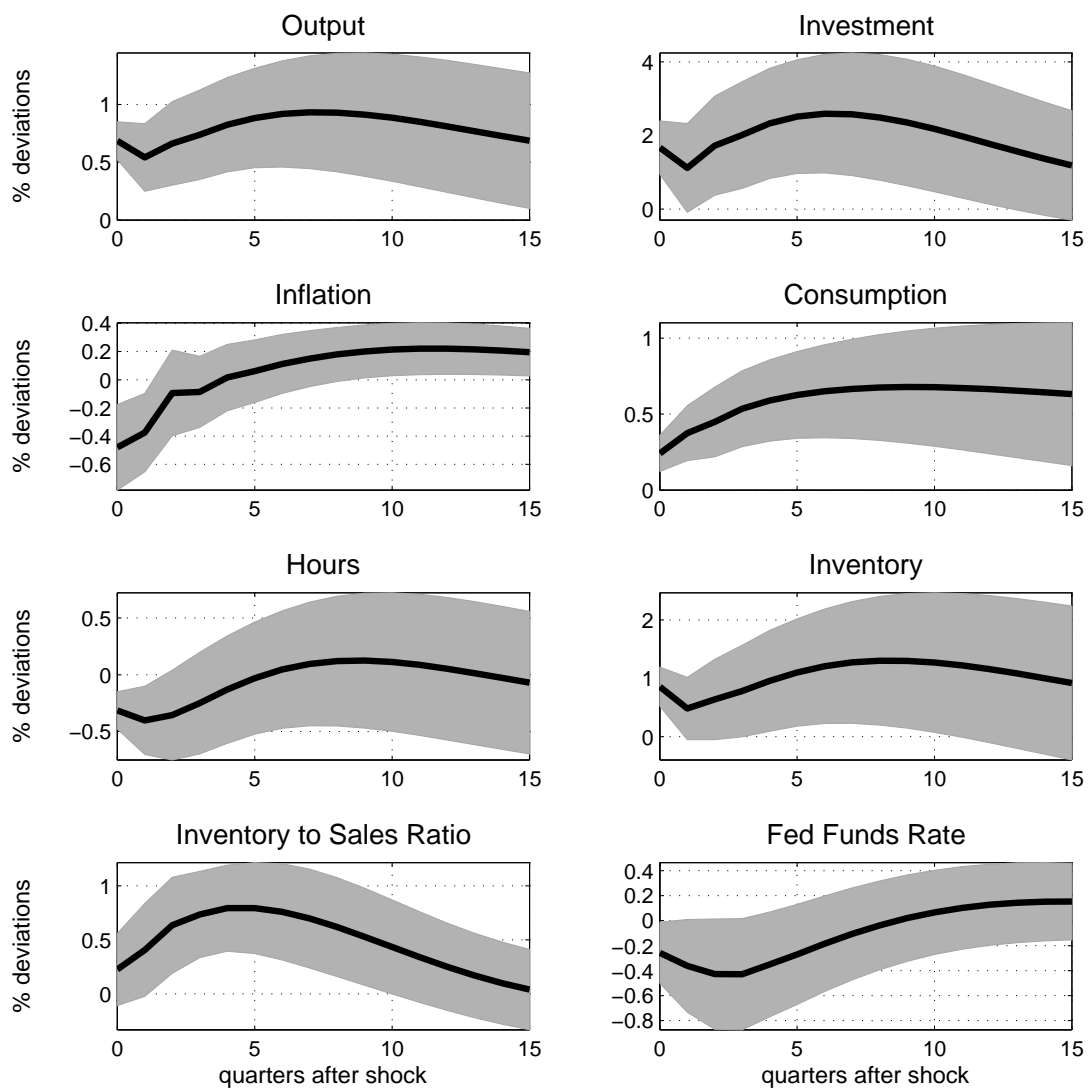
Robustness check for various measures of inventories



Notes: —: impulse response, shaded area: 95% confidence interval

Figure 1.7. Response to a +1% neutral technology shock

(Stationary VAR with cointegrating relationships)
 [Period: 1967:Q1 - 2010:Q4]



Notes: —: impulse response, shaded area: 95% confidence interval

Figure 1.8. Real rigidity and the curvature of cost functions

This figure shows the calibrated relationship between the measure of real rigidity κ and the curvature of the function of adjustment costs in a model without inventories. The formula used to calculate κ is Equation (1.6): $\kappa \equiv \varepsilon\tau \cdot (1 - \alpha)(\phi - \xi_p\beta)$, where τ denotes the curvature. κ has a lower bound of zero when there are no adjustment costs. Its value depends basically on the value of ε and τ since $\phi - \xi_p\beta$ is close to one in my calibration. Because $\tau < 5$ is fairly reasonable, κ can be considerably large.

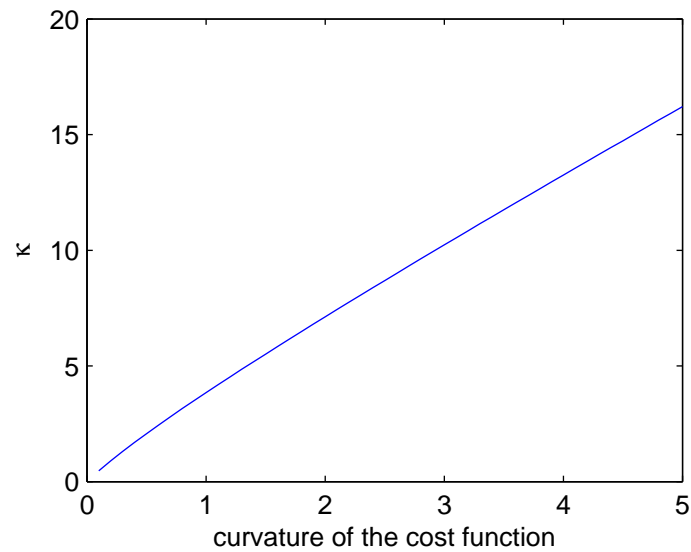


Figure 1.9. Real rigidity and the curvature of cost functions (with inventories)

This figure shows the calibrated relationship between the measure of real rigidity κ and the curvature of the function of adjustment costs in a model with inventories. The formula used to calculate κ can be found in the technical appendix.

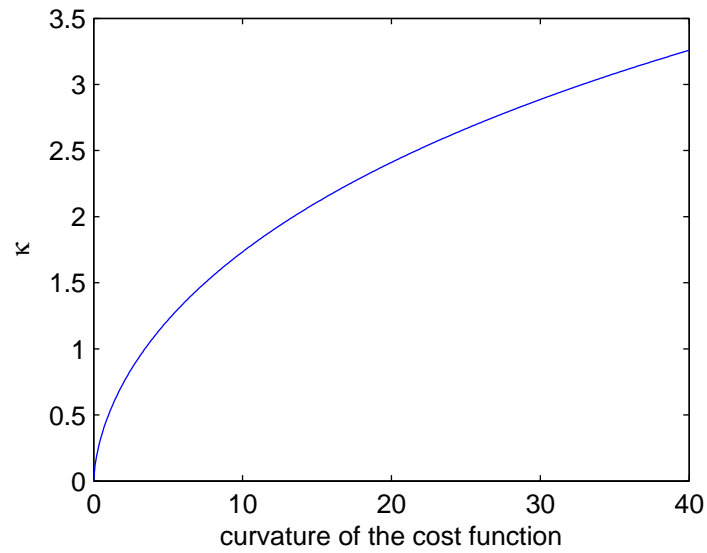


Figure 1.10. Calibrated response to a -1% Fed Funds Rate shock

Model in section 4.2

- No inventories

- Convex costs of labor adjustment

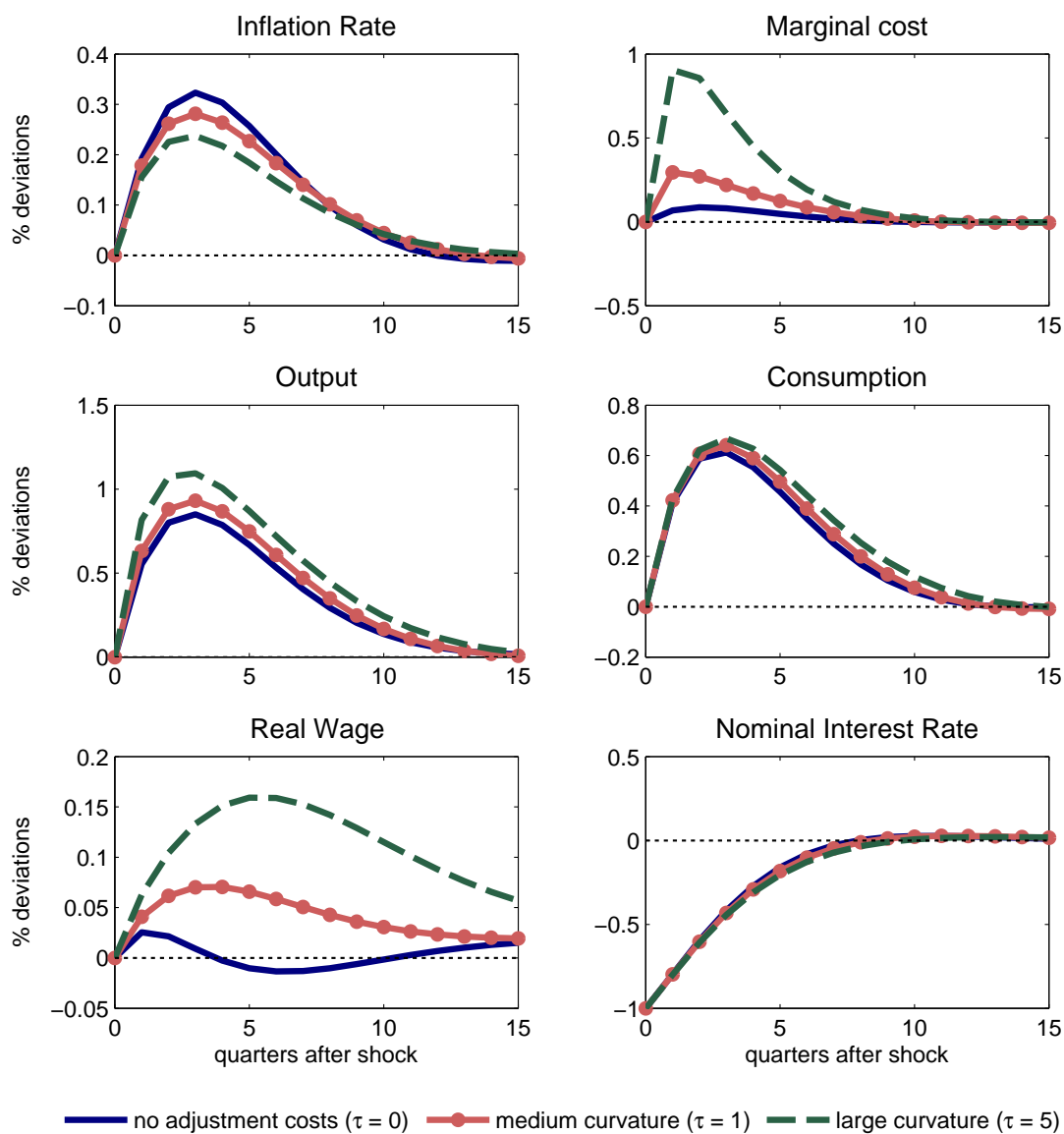


Figure 1.11. Calibrated response to a -1% Fed Funds Rate shock

Inventory model

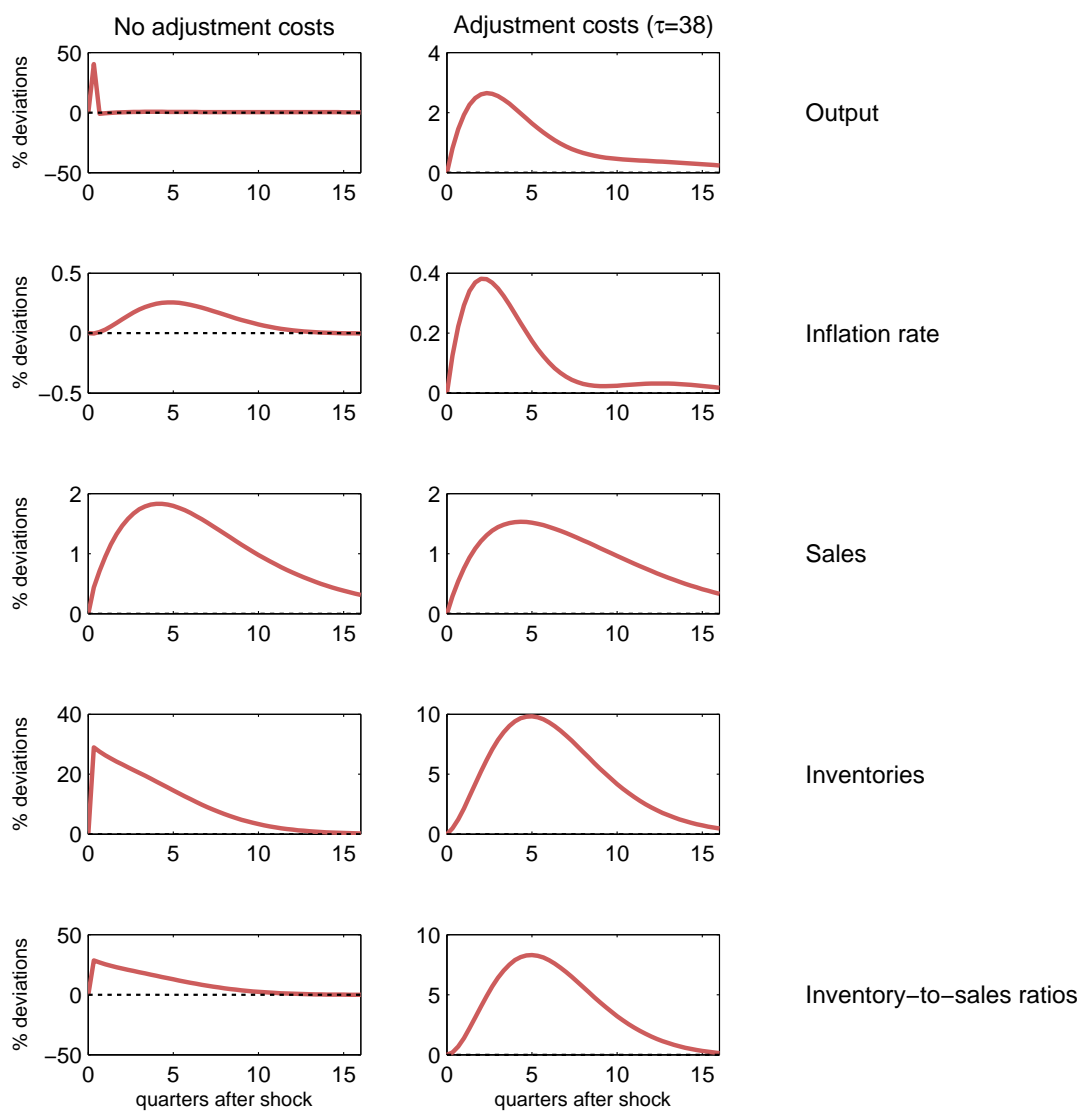
- No adjustment costs vs. adjustment costs ($\tau = 38$)

Figure 1.12. Calibrated response to a -1% Fed Funds Rate shock

Inventory model with financial frictions
 - No interest rate effect vs. partial indexation ($\gamma = 0.2$)

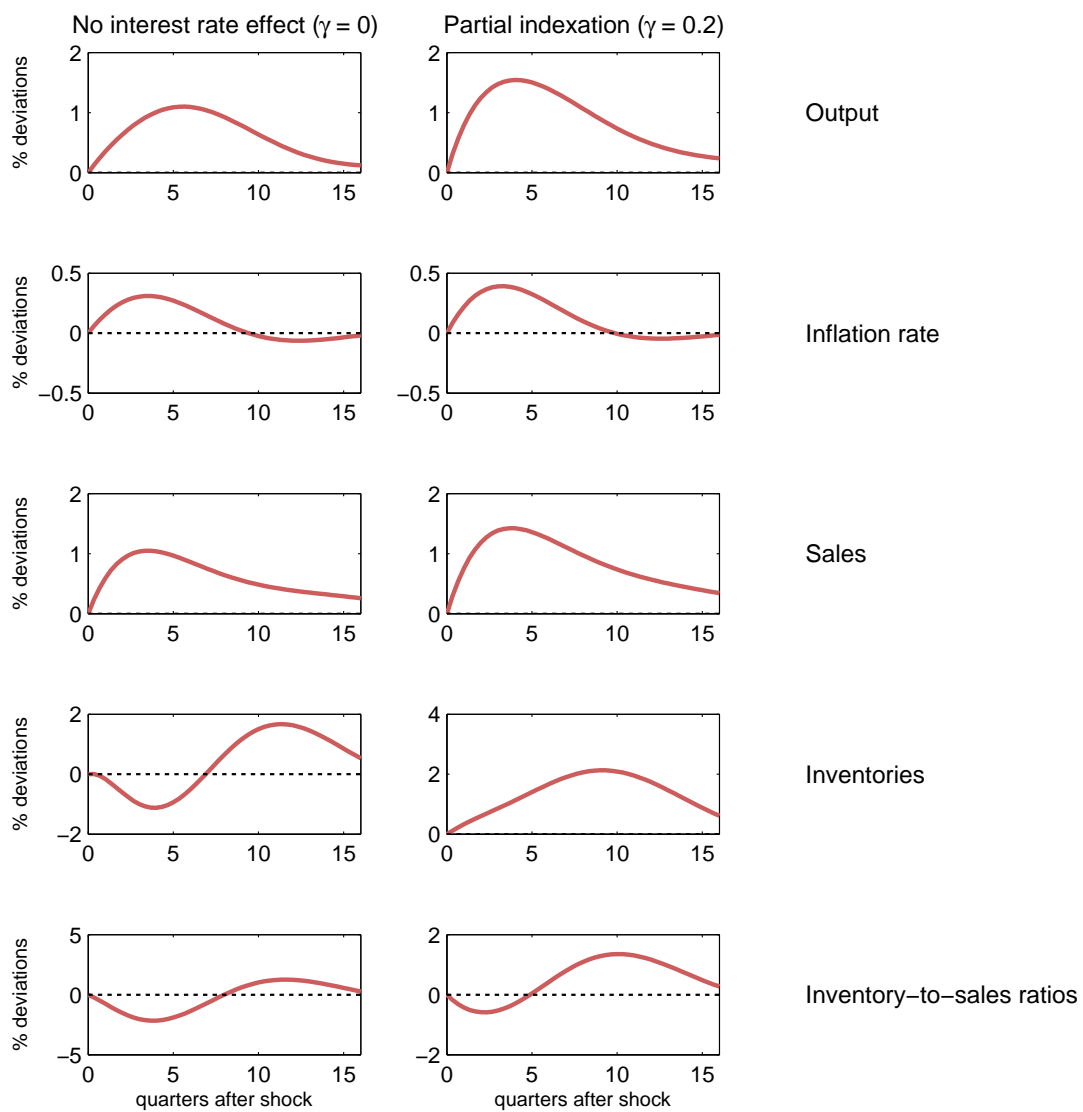


Figure 1.13. Calibrated response to a -1% Fed Funds Rate shock

Inventory model with financial frictions
 - No real rigidity ($\kappa = 0$) vs. real rigidity ($\kappa = 2.25$)

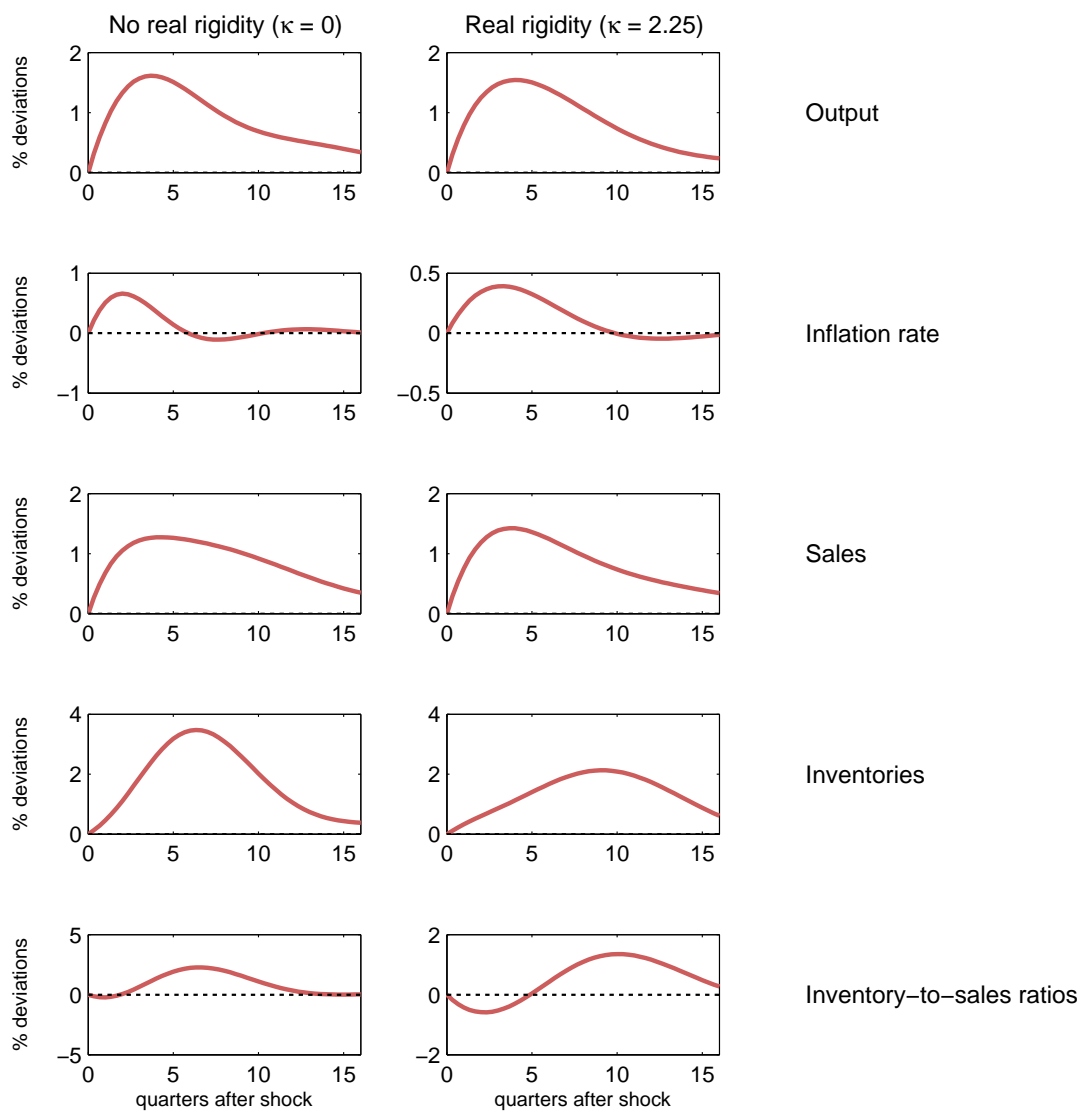
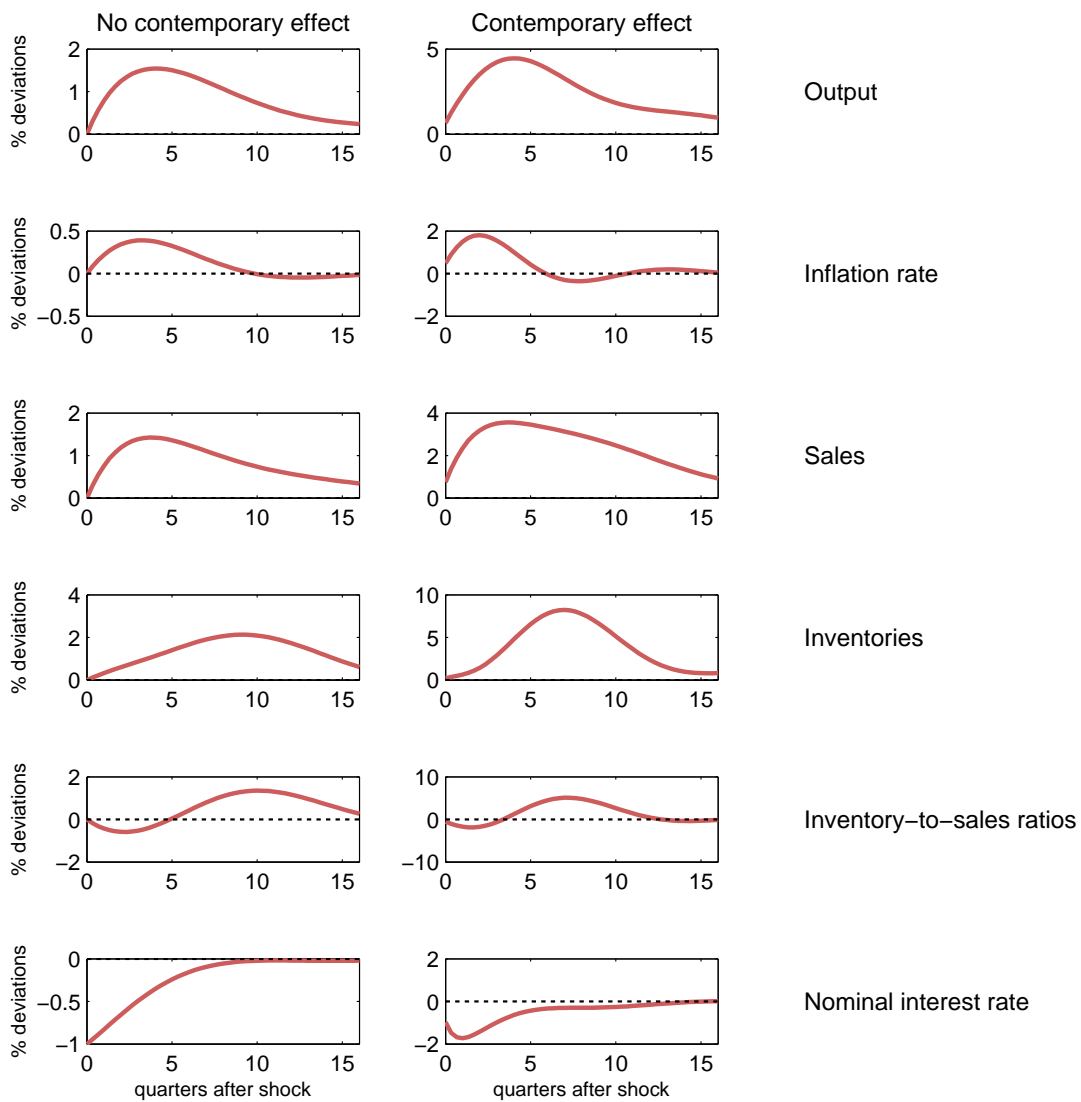


Figure 1.14. Calibrated response to a -1% Fed Funds Rate shock

Inventory model with financial frictions
 - Non-existence vs. existence of contemporary effects
 for monetary policy shocks



Chapter 2

Learning by Consuming: Explaining Home Equity Bias with Consumption Bias

2.1 Introduction

The fact that consumers consume mainly domestically-produced goods is termed home consumption bias. In a similar vein, home equity bias describes that investors tend to hold significantly less foreign equities than the requirement that standard financial theory of portfolio diversification suggests. [Obstfeld and Rogoff \(2000\)](#) raise the question whether these two biases are linked together. Several recent papers like [Coeurdacier \(2009\)](#), [Collard, Deltas, Diba, and Stockman \(2007\)](#), and [Heathcote and Perri \(2007\)](#) also deal with this question.

This paper shows that home consumption bias can lead to home equity bias through the channel of information asymmetry. This information asymmetry arises from demand uncertainty about a company's product if quality preference and country-specific preference are determinants of the product's aggregate demand. This paper assumes that more consumption gives investors more opportunities observing quality and preference signals. In this way, home consumers naturally are endowed with more information on a product's demand. This consumption-based explanation for information asymmetry is similar to [Nelson \(1970\)](#)'s use of experience goods. Furthermore, when a firm sells more to domestic consumers than foreigners, its performance depends more on home preference shocks, which may be difficult to be observed by foreigners. This effect can be related to the word-of-mouth effect or the social network effect in the information literature. When hedging needs play a small role in portfolio choice, investors tend to focus more on the variance of each equity's return. In the presence of a large set of equities, uncertainty may be still important if investors are more concerned about additive risks. My calibration shows that even signals of low home equity returns can still result in large home equity bias.

2.1.1 Goods Trade and Home Equity Bias

[Collard et al. \(2007\)](#) regress foreign equity shares on import shares for 15 developed countries, and find that the fit line almost overlaps the 45° line with a R -squared of .71. For G5 countries (US, Japan, UK, Germany, and France) over the period 1995-2004, the correlation coefficient between these two shares is 0.92. After correcting the import shares for re-exports and the equity shares for housing and equities listed in foreign stock markets, their results are quite robust. [Portes and Rey \(2005\)](#) show that a gravity model explains international transactions in equities at least as well as goods trade transactions. They argue that distance represents both the proxies for information costs and trade costs. [Obstfeld and Rogoff \(2000\)](#) conjecture that trade cost¹ is the common cause of the two biases, which is later reconsidered by [Coeurdacier \(2009\)](#) and [Obstfeld \(2007\)](#).²

¹The cost of asset trade doesn't seem to be the reason. [Lewis \(1999\)](#) deems .8% a very high cost for asset trade. [Tesar and Werner \(1995\)](#) and [Warnock \(2002\)](#) both find high turnover rates on foreign equity investments.

²[Uppal \(1993\)](#) is an early study with the consideration of trade cost.

Interestingly, there seems to be some disagreement in the literature of macroeconomics and finance on explaining the puzzle of local or home equity bias. The literature of international macroeconomics provides discrete-time general equilibrium models in which holding domestic equities serves as a better hedge against the real exchange rate risk in the presence of home consumption bias. The introduction of non-traded goods helps the models better to explain this puzzle (Stockman and Dellas, 1989; Obstfeld, 2007; Matsumoto, 2007), although the specification of the utility function still matters (Baxter et al., 1998; Coeurdacier, 2009). Many other attempts have been conducted but always lead to inconclusive results. Furthermore, to enrich Dynamic Stochastic General Equilibrium (DSGE) models is often at the expense of complicated algebra and weak intuition. For instance, Coeurdacier, Kollmann, and Martin (2007) propose a model with three types of shocks: supply, demand, and the distribution of income between labor and capital, however, demand shocks and the income share shocks in this paper may not be realistic and how these two shocks affect equity return is still unknown.

Obstfeld (2007) shows that the welfare loss from the portfolio holdings under different rules turns out to be minuscule in regard to risk sharing. Therefore, it may be reasonable to seek for other explanations such as information asymmetry for home equity bias.

2.1.2 Evidence of Familiarity Breeding Investment

French and Poterba (1991) is an early paper measuring typical international equity portfolios. They find that to justify home equity bias the expected return in the domestic equity market needs to be several hundred basis points higher than returns in other markets.

Huberman (2001) documents that the shareholders of a Regional Bell Operating Company (RBOC) tend to live in the area which the company serves, and an RBOC's customers tend to hold its shares rather than other RBOCs' equity. Huberman interprets this bias as "familiarity breeds investment": familiarity may represent (1) information available to the investor, but not yet to the market (information advantage); (2) the investor's illusion that he has superior information (overconfidence); (3) the investor's belief that he will have superior information (feeling safe).

Kang and Stulz (1997) studies stock ownership in Japanese firms by non-Japanese investors from 1975 to 1991. They document that foreign investors underweight small, highly levered firms, and firms that do not have significant exports, which they claim may be a response to the severe information asymmetries associated with such firms. Coval and Moskowitz (1999) show that the preference for investing close to home also applies to portfolios of domestic stocks. Specifically, US investment managers exhibit a strong preference for locally headquartered firms, particularly small, highly levered firms that produce non-traded goods. The authors claim that asymmetric information between local and non-local investors may drive the preference for geographically proximate investments. Grinblatt and Keloharju (2001) document that Finnish investors are more likely to hold, buy, and sell the stocks of firms that are located close to them, that communicate in the

tongue, and that have chief executives of the same cultural background. ³

2.1.3 Evidence of Relatively High Returns from Local Investment

Cumby and Glen (1990) examine fifteen US-based internationally diversified mutual funds between 1982 and 1988 and find no evidence that these funds, either individually or as a whole, provide investors with performance that surpasses a broad, international equity index over this sample period. In contrast, Coval and Moskowitz (2001) find that fund managers earn substantial abnormal returns in nearby investments. They suggest that investors trade local securities at an informational advantage. Similar results are also found in Germany (Hau, 2001). Dvořák (2005) shows that Indonesian domestic investors have short-term higher profits than foreign investors and suggests that local information matters. Bae, Stulz, and Tan (2008) use a sample of 32 countries and find that after controlling for firm and analyst characteristics, analyst local advantage is still statistically significant and strong.

2.1.4 Consumption and Information

Given the above evidence in the finance literature, it is straightforward to think of the role of information asymmetry on home equity bias.

Home equity bias has prevailed in most of countries since 1970s. However, no convincing theories have been able to provide a conclusive explanation. Information asymmetry is often used as an explanation in the conventional wisdom, and also has been discussed in Gehrig (1993) and Brennan and Cao (1997). Lewis (1999) criticizes this explanation: “Greater uncertainty about foreign returns may induce the investor to pay more attention to the data and allocate more of his wealth to foreign equities.” Van Nieuwerburgh and Veldkamp (2009) argues that information immobility is unrealistic and initial information advantages could disappear when investors can choose which information to collect.⁴

The information referred to in this paper is about demand uncertainty. Demand uncertainty not only can arise from quality uncertainty which has been extensively studied since Akerlof (1970), but also is related to other general preference shocks like fashion. In my model, demand uncertainty results from imperfect information on product evaluations of the general public.

Consumers, including investment managers, experience consuming and shopping as an important part of life. Goods and service consumption is a life-time process in which people accumulate past information since their childhood. Rational expectation hypothesis assumes that everyone uses all the information available, not just restricted to accounting

³Other than familiarity, there are a wealth of literature studying the cause of home equity bias. For example, these causes include patriotism (Morse and Shive, 2011), loyalty (Cohen, 2009), attention (Barber and Odean, 2008), and overoptimism (Shiller, Kon-Ya, and Tsutsui, 1996; Strong and Xu, 2003).

⁴Van Nieuwerburgh and Veldkamp (2009) claim that information asymmetry is sustainable if investors consider information acquisition while choosing portfolios. However, this argument depends crucially on the cost structure of acquiring information. For more details, see Appendix B.1.

reports and economic data. In my model, since the information signals received for the true quality and the preference shock are imperfect and heterogeneous among consumers, product demand is uncertain to every consumer or investor. The consumption process is a learning process. The amount of acquired information increases with the amount of consumption. Individual investors can infer their own preference shocks from their own consumption so that they can forecast more precisely future demand of the goods they consume.

This type of information advantage is mostly immobile due to the persistence of consumption bias which is in turn generated by trade costs and the existence of non-traded goods. Furthermore, people have time and physiological constraints to consume. There is a limit of total varieties people are able to consume no matter how rich they are. Because it is difficult to collect and aggregate this type of information, the speed of information dispersion is rather slow.

Consumption-revealed information matters also because it is personal. Consumption is naturally personal behavior. Consumers observe the trend of fashion while they shop in stores. They get feedback from family members, friends, and colleagues. Personal experience is more convincing for oneself than consumer surveys and external data source.

Therefore, a piece of information from consumption may not be economically important, but it can be important for an individual investor because it's immobile and personal.

2.1.5 Invest in What You Know: Anecdotes

Peter Lynch is a stock superstar who ran Fidelity Investments' Magellan Fund from 1977 to 1990. He invested in a company called Hanes in the 1970s after his wife bought and loved its new L'eggs pantyhose line: the first department-store-quality pantyhose sold to American women via supermarkets. Lynch was worried that somebody would come out with a competitive product, so he always kept an eye on the market. About a year and a half after L'eggs were on the market another large company came out with a product called No Nonsense. Peter Lynch went to buy 48 pairs at the supermarket, with different colors, shapes, and sizes. He brought it into the office and gave it to everybody. People came back to him in a couple weeks and said, "It's not as good." Lynch knew Hanes had a winner, so he held onto Hanes, which became Magellan's biggest position and a 'ten bagger' before it was bought out. Peter Lynch said, "That's what fundamental research is."

'Know what you own' is the first investment principle of Warren Buffett. Buffett purchased Gillette in 1989 for \$600 million. Every night when he shaves, he is always pleasant with the thought that 2.5 billion men go to sleep growing beard while Gillette owns 70 percent of the worldwide shaving market (Miles, 2004).

2.1.6 Contribution to the Literature

To my knowledge consumption-revealed information has not been explored. Previous literature of information theory only discuss abstract sources of information. It's hard to quantify the information disparity among different investors. Although measuring information from consumption raises another difficulty, this kind of information is conceivable and it is easier to find proxies for it.

I provide a source of information not directly coming from equity corporations, such as insider information. Demand uncertainty has been largely ignored in explaining home equity bias. The exceptions are [Pavlova and Rigobon \(2007\)](#) and [Coeurdacier et al. \(2007\)](#).

Information advantage links consumption bias and equity bias together and we don't have to resort to hedging needs to explain the correlation between import shares and foreign equity shares. [Cole and Obstfeld \(1991\)](#) and [Obstfeld \(2007\)](#) shows that the benefit from diversification or hedging might not be large. My theory explains many empirical facts, such as the cross-border correlation between goods trade and equity holdings, and the gravity equation of equity flows. Furthermore, my theory is supported by the within-country relevance of consumption to portfolio holdings, for example, that local holdings tend to tilt to small firms which produce non-traded goods or fewer exports. Chapter 3 presents an empirical analysis on the question whether individual portfolio choice is relevant to a firm's business exposure.

2.1.7 Structure of this paper

The rest of the paper is structured as follows. Section 2 shows the model and how the consumption channel works. This section presents the time line of the model, how home consumption bias is related to demand uncertainty, and a model of consumption-based information asymmetry. Portfolio choice is discussed at the end of this section based on the information asymmetry derived in the model. Section 3 calibrated foreign equity shares with import shares. This section shows that without hedging needs, information asymmetry indicated by variance difference can be dominant in international portfolio decisions. Section 4 concludes.

2.2 The model

2.2.1 Timeline of the Model

I adopt an overlapping generation framework that simplifies the decision process of portfolio choice. There are two almost symmetric countries, home and foreign. In each country there are two generations of agents. Each generation is a continuum of heterogeneous consumers or investors with mass 1 indexed by $i \in [0, 1]$. Young agents are consumers. They each are endowed with wealth W . Young agents turn old in their second period and become investors. Old agents are also endowed with wealth W and invest this much

in the stock market. The objective of old agents is to maximize expected CARA utility of their final wealth. Each country also has a continuum of heterogeneous firms with mass N indexed by $j \in [0, 1]$. Each firm produces its specific variety and trades in a monopolistically competitive market. The two periods for one generation are specified as follows:

1. Young. Young agents consume, firms produce, and goods markets clear. After consumption, the information according to each consumer's consumption experience is only observed by oneself. Young people don't learn any information from the stock market and old people.
2. Old. A finite number of firm equities are listed in the stock markets of both countries. Investors invest W into the stock markets and choose optimal portfolios based on the information revealed from past consumption experience. Firms distribute dividends using the profit earned in each period.

2.2.2 Demand Uncertainty

2.2.2.1 Consumers

The model is notationally heavy but still easy to solve. Each variable for the foreign country has an asterisk on the superscript and is defined symmetrically like its corresponding variable for the home country. All the parameters denoted with Greek letters in the model are common priors known by everyone. The home country consumer i 's utility for each period is specified as:

$$C_i = \left(\omega^{1/\eta} C_{Hi}^{1-1/\eta} + (1 - \omega)^{1/\eta} C_{Fi}^{1-1/\eta} \right)^{\frac{\eta}{\eta-1}}, \quad \eta > 1, \omega > \frac{1}{2}, \quad (2.1)$$

where ω measures the aggregate home bias in preference and η is the elasticity of substitution between C_{Hi} and C_{Fi} , the CES aggregations of i 's domestic and foreign goods consumption:

$$C_{Hi} = \left[\int_0^1 \theta_{Hij}^{1/\sigma} y_{Hij}^{1-1/\sigma} dj \right]^{\frac{\sigma}{\sigma-1}}, \quad C_{Fi} = \left[\int_0^1 \theta_{Fij}^{1/\sigma} y_{Fij}^{1-1/\sigma} dj \right]^{\frac{\sigma}{\sigma-1}}. \quad (2.2)$$

y_{Hij} and y_{Fij} are i 's consumption of the goods produced by domestic firm j and foreign firm j' . σ is the elasticity of substitution between goods produced within one country. θ_{Hij} and θ_{Fij} are i 's demand coefficients over the goods produced by domestic firm j and foreign firm j' . θ can be a function of product quality and individual preference. Note that ω is constant, so there are no aggregate demand shocks on domestic goods relative to foreign goods, a.k.a. iPod shocks in [Coeurdacier et al. \(2007\)](#).

Since the optimization problem for consumers is to allocate expenditure among all the goods, only relative magnitude matters. Without loss of generality, I normalize

$$\int_0^1 \theta_{Hij} dj = \int_0^1 \theta_{Fij} dj = \int_0^1 \theta_{Hij}^* dj = \int_0^1 \theta_{Fij}^* dj = 1, \quad \text{for all } i. \quad (2.3)$$

This adds (the only) one restriction on the means⁵ of $\{\theta_{Hj}\}_{j \in [0,1]}$ and $\{\theta_{Fj}\}_{j \in [0,1]}$ by Chebychev's weak law of large numbers:

$$\int_0^1 \mathbb{E}\theta_{Hj} dj = \int_0^1 \mathbb{E}\theta_{Fj} dj = 1. \quad (2.4)$$

The budget constraint for i is denoted by

$$\int_0^1 p_{Hj} y_{Hij} dj + \int_0^1 p_{Fj} y_{Fij} dj = W, \quad (2.5)$$

where p_{Hj} and p_{Fj} are the prices for the goods produced by domestic firm j and foreign firm j' .

2.2.2.2 Firms

I assume iceberg shipping costs denoted by τ so that for every unit of home (foreign) goods shipped abroad, only a fraction $1 - \tau$ arrives at the foreign (home) shore. No arbitrage in trade requires that

$$p_{Hj} = (1 - \tau) p_{Hj}^*, \quad p_{Fj}^* = (1 - \tau) p_{Fj}, \quad (2.6)$$

Only labor is used in production. Firm j is endowed with a cost function

$$L_j = \varphi_j y_j + l, \quad (2.7)$$

where y_j is output, l is fixed input, and φ_j is an exogenous cost parameter measuring marginal cost. Domestic and foreign cost parameters are drawn from the distribution of one random variable. Neither country has aggregate absolute advantages. In the equilibrium,

$$y_j = y_{Hj} + \frac{1}{1 - \tau} y_{Hj}^*, \quad (2.8)$$

where $y_{Hj} \equiv \int_0^1 y_{Hij} di$ and $y_{Hj}^* \equiv \int_0^1 y_{Hij}^* di$. The labor endowment in each country is \bar{L} such that the wage rate is equal to 1. Market clearing implies that $\bar{L} = \int_0^1 L_j dj$.

There are N types of firms according to different cost parameters: each type has same cost φ_j and quality u_j . The mass measure of a type of firms is 1. The equity of a type of firms is bundled together and traded in the stock market. If without confusion, an equity is also indexed by j . The quality u_j of each type is drawn from a normal distribution, $u_j \sim iid N(\mu_j, \sigma_0^2)$. μ_j is the common prior of the quality mean of product j , which increases with marginal cost of production. For instance, $\mu_j = \varphi_j^{2\sigma}$: higher costs on average implies higher quality.

⁵In this paper, "mean" is average, which possibly differs from "expectation" if the process is not i.i.d. so that the law of large number cannot apply.

2.2.2.3 Goods Market Equilibrium

Result 1. In a goods market equilibrium, individual demand functions for domestic consumer i are characterized by

$$y_{Hij} = \theta_{Hij} C_{Hi} \left(\frac{p_{Hj}}{P_H} \right)^{-\sigma} \quad \text{and} \quad y_{Fij} = \theta_{Fij} C_{Fi} \left(\frac{p_{Fj}}{P_F} \right)^{-\sigma}, \quad \text{for each } j \quad (2.9)$$

where P_H and P_F are price indexes for C_{Hi} and C_{Fi} : $P_H = \left[\int_0^1 p_{Hj}^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}}$ and $P_F = \left[\int_0^1 p_{Fj}^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}}$.

Proof. See Appendix B.2. □

Equation (2.9) shows that individual demand functions have constant price elasticities σ . Because initial wealth is same for everyone, $C_{Hi} = C_{Hi'}$ for all i, i' . The difference in individual demand is only due to different θ . However, heterogeneity in individual demand doesn't change a firm's pricing behavior in my model. Each firm charges a constant mark-up over marginal costs: $p_{Hj} = \frac{1}{1-1/\sigma} \varphi_j$.

Result 2. The profit function for domestic firm j is

$$\pi_j = k_j \left[\gamma \bar{\theta}_{Hj} + \bar{\theta}_{Hj}^* \right] - l, \quad (2.10)$$

where $k_j = \frac{1}{\sigma} P_F C_F (p_{Hj}/P_H)^{1-\sigma}$ and $\gamma \equiv P_H C_H / P_F C_F = \frac{\omega}{1-\omega} (1-\tau)^{1-\eta} > 1$ is the measure of home consumption bias. $\bar{\theta}_{Hj}$ and $\bar{\theta}_{Hj}^*$ are the means of θ_{Hj} and θ_{Hj}^* .

Proof. See Appendix B.3. □

Further assume consumer preference for each type of firms is same. Therefore, the payoff⁶ for an equity j is total profits of the firms bundled in the equity:

$$\pi_j = k_j \left[\gamma \bar{\theta}_{Hj} + \bar{\theta}_{Hj}^* \right] - l.$$

2.2.2.4 Idiosyncratic risks

A type of firms with same cost and quality is listed in the stock market as one stock. Because individual investors might not know the aggregate demand for a type of firms, equity payoffs are uncertain.

The unconditional variance of equity j for old agents is

$$\text{Var}(\pi_j) = k_j^2 \left[\gamma^2 \text{Var}(\bar{\theta}_{Hj}) + \text{Var}(\bar{\theta}_{Hj}^*) \right], \quad (2.11)$$

which implies that home preference shocks are more relevant to the volatility of firms' profits because of home consumption bias.

⁶The downside to using normal distributions is that shocks are unbounded and negative θ_{ij} makes no sense. However, this happens with very small possibility.

2.2.3 A Model of Consumption-Based Information Asymmetry

2.2.3.1 Aggregate Quality Uncertainty

Aggregate preference $\bar{\theta}_{Hj}(\bar{\theta}_{Hj}^*)$ can be determined by a product's quality or some other country-specific characteristics, which investors are not perfectly informed of. Various source can provide new information to investors. For example, the data disclosing firm profits may provide an imperfect signal of aggregate demand, and investors can acquire information from their social network. To simplify the learning process, I assume that investors only acquire information from personal experience.

Young agents each receive an individual signal for each product's quality before consumption. $\varepsilon_{ij} \sim iid N(u_j, \sigma_\varepsilon^2)$. Using this signal and the common prior, consumers form their preferences with the posterior expectation of a product's quality. Specifically, individual preference is determined by the posterior expectation of a product's quality before consumption $\mathbb{E}_i u_{ij}$ and country-specific preference v_j :

$$\theta_{ij} = \mathbb{E}_i u_{ij} + v_j = \frac{\sigma_0^{-2} \mu_j + \sigma_\varepsilon^{-2} \varepsilon_{ij}}{\sigma_0^{-2} + \sigma_\varepsilon^{-2}} + v_j$$

where $v_j \sim iid N(0, \sigma_v^2)$. Domestic preference v_{Hj} can only be observed by domestic investors and foreign preference v_{Fj} can only be observed by foreign investors.

In the following, the country index $\{H, F\}$ and the firm index j will be omitted when no confusion is caused. Because independent belief errors average out to zero, the preference parameter for aggregate demand is given by

$$\bar{\theta}_j = \int_0^1 \theta_{ij} di = \frac{\sigma_0^{-2} \mu_j + \sigma_\varepsilon^{-2} u_j}{\sigma_0^{-2} + \sigma_\varepsilon^{-2}} + v_j,$$

which is random for individual investors because individual information on quality u_j is imperfect and foreigners cannot observe v_j .

2.2.3.2 Learning by Consumption

The learning of quality is referred to as the *experience effect*. More past consumption leads to more chances receiving quality signals, although new signals are less valuable than old signals. I assume consumers can learn product quality only through personal (household) consumption.

Assumption 1. *More consumption enables investors to acquire more signals of product quality.*

Before consumption, consumer i 's prior belief for quality is denoted by

$$u_{ij} \sim N(\mathbb{E}_i u_{ij}, \sigma_u^2),$$

where $\bar{\mu}_{ij} = \mathbb{E}_i u_{ij} = \frac{\sigma_0^{-2} \mu_j + \sigma_\varepsilon^{-2} \varepsilon_{ij}}{\sigma_0^{-2} + \sigma_\varepsilon^{-2}}$ and $\sigma_u^2 = (\sigma_0^{-2} + \sigma_\varepsilon^{-2})^{-1}$. If after each unit of consumption, each consumer receives an i.i.d. signal $f_c \sim N(u_j, \sigma_f^2)$, the posterior quality belief with integer consumption m is $u_i | y_{in} \sim N(\frac{\sigma_u^{-2} \bar{\mu}_{ij} + m \sigma_f^{-2} \bar{f}}{\sigma_u^{-2} + m \sigma_f^{-2}}, (\sigma_u^{-2} + m \sigma_f^{-2})^{-1})$, where the pair $\{\bar{f}, m\}$ is a sufficient statistics for u_j . Hence, a specification for continuous values of consumption is that for consumer i with past consumption $y_{in} = y_{ij}$, his posterior belief of quality is

$$u_i | y_{in} \sim N(\hat{\mu}_{ij}, (\sigma_u^{-2} + y_{in} \sigma_f^{-2})^{-1}). \quad (2.12)$$

where

$$\hat{\mu}_{ij} = \frac{\sigma_u^{-2} \bar{\mu}_{ij} + y_{in} \sigma_f^{-2} \bar{f}}{\sigma_u^{-2} + y_{in} \sigma_f^{-2}}$$

The posterior variance decreases with y_{in} , which implies that a consumer with more consumption is better informed about the quality.

2.2.3.3 Information Asymmetry

I am interested in the conditional variances of u_{Hj} and u_{Hj}^* . For a domestic investor's posterior belief of product quality,

$$\text{Var}(u_{Hj} | y_{Hij}) = (\sigma_u^{-2} + y_{Hij} \sigma_f^{-2})^{-1}. \quad (2.13)$$

For a foreigner's posterior belief of home product quality,

$$\text{Var}(u_{Hj} | y_{Hij}^*) = (\sigma_u^{-2} + y_{Hij}^* \sigma_f^{-2})^{-1}. \quad (2.14)$$

Therefore, for a domestic investor's posterior belief of domestic aggregate demand,

$$\text{Var}(\bar{\theta}_{Hj} | y_{Hij}) = (\sigma_u^{-2} + y_{Hij} \sigma_f^{-2})^{-1}. \quad (2.15)$$

For a foreigner's posterior belief of home aggregate demand,

$$\text{Var}(\bar{\theta}_{Hj} | y_{Hij}^*) = (\sigma_u^{-2} + y_{Hij}^* \sigma_f^{-2})^{-1} + \sigma_v^2. \quad (2.16)$$

The conditional version of Equation (2.11) for a domestic investor can now be transformed into

$$\begin{aligned} \Sigma_{ij} &\equiv \text{Var}(\pi_j | y_{Hij}) = k_j^2 \left[\gamma^2 \text{Var}(\bar{\theta}_{Hj} | y_{Hij}) + \text{Var}(\bar{\theta}_{Hj}^* | y_{Hij}) \right] \\ &= \kappa_j \left[\gamma^2 \left((\sigma_u^{-2} + y_{Hij} \sigma_f^{-2})^{-1} \right) + (\sigma_u^{-2} + y_{Hij} \sigma_f^{-2})^{-1} + \sigma_v^2 \right] \\ &= \kappa_j \left[(\gamma^2 + 1) \left((\sigma_u^{-2} + y_{Hij} \sigma_f^{-2})^{-1} \right) + \sigma_v^2 \right] \end{aligned} \quad (2.17)$$

where

$$\kappa_j = k_j^2 \left(\frac{\sigma_\varepsilon^{-2}}{\sigma_0^{-2} + \sigma_\varepsilon^{-2}} \right)^2$$

Information asymmetry between a home investor and a foreign investor for firm j is given by

$$\frac{\Sigma_{ij}}{\Sigma_{i'j}} = \frac{(\gamma^2 + 1) \left((\sigma_u^{-2} + y_{ij} \sigma_f^{-2})^{-1} \right) + \sigma_v^2}{(\gamma^2 + 1) \left((\sigma_u^{-2} + y_{i'j} \sigma_f^{-2})^{-1} \right) + \gamma^2 \sigma_v^2}.$$

Home consumption bias exerts two effects on information asymmetry. The one related to the first terms in the nominator and denominator is associated with learning by consumption. Investors acquire more information with more consumption. The other related to the second terms in the nominator and denominator indicates that domestic preference is of more importance on knowing a stock's return.

Information asymmetry for home consumer i can be quantified as the ratio of the conditional variance of π_j to the conditional variance of $\pi_{j'}^*$:

$$\frac{\Sigma_{Hij}}{\Sigma_{Fij'}} = \frac{\text{Var}(\pi_j | y_i)}{\text{Var}(\pi_{j'}^* | y_i)}. \quad (2.18)$$

This ratio compares i 's information on a home firm with his information on a foreign firm.

The conditional expectation of $\bar{\theta}_j$ on y_{ij} is:

$$\mathbb{E} \left[\frac{\sigma_0^{-2} \mu_j + \sigma_\varepsilon^{-2} u_j}{\sigma_0^{-2} + \sigma_\varepsilon^{-2}} + v_j | y_{Hij}, v_j \right] = \hat{\mu}_{ij} + v_j. \quad (2.19)$$

Then the conditional expectation of π_j for domestic investors is

$$m_{ij} \equiv \mathbb{E}[\pi_j | y_{Hij}] = k_j [(\gamma + 1) \hat{\mu}_{ij} + \gamma v_j] - l \quad (2.20)$$

and the conditional expectation of π_j for foreign investors is

$$m_{ij} \equiv \mathbb{E}[\pi_j | y_{Fij}] = k_j [(\gamma + 1) \hat{\mu}_{ij} + v_j^*] - l$$

2.2.3.4 Portfolio Choice

A noisy rational expectation equilibrium can be derived as in [Admati \(1985\)](#) to incorporate the idea that stock price reveals information to less-informed investors. The consideration of price-revealed information essentially doesn't change qualitative results. Theoretically, it is commonly assumed that the observation of stock price provides an extra signal of the fundamentals. I choose to ignore this information source in this paper to simplify my exposition. At each period, N equities are listed in home and foreign stock markets, each paying its profit π_j as the payoff for its stock.

Agents invest fixed amount W between a riskfree asset and these N equities. Preferences are exponential $U_i = \mathbb{E}[-e^{-\rho W_i}]$, where ρ is absolute risk aversion and W_i is the final wealth. Because profits have not yet realized and demand is uncertain when

each investor makes decisions, the investment of firm equities is risky. The return to the riskfree asset is $r > 1$. i 's final wealth is given by

$$W_i = (W - q'_i p) r + q'_i \pi = W r + q'_i (\pi - p r), \quad (2.21)$$

where q_i is the vector of i 's holdings of the equities, p is the price vector of equity prices, and π is the vector of payoffs. Home individual i has posterior beliefs about payoffs: $\pi_j \sim N(m_{ij}, \Sigma_{ij})$, where m_{ij} is given in equation (2.20) and Σ_{ij} is given in equation (2.17). The supply of each equity x is equal to the mass of its firms, which is normalized to 1. When the number of equities is large, equity returns are approximately uncorrelated. Hence, I can study the portfolio for each equity separately.

Result 3. Investor i 's portfolio in equity j is

$$q_{Hij} = \frac{m_{ij} - r p_j}{\rho \Sigma_{ij}}, \quad (2.22)$$

where the equilibrium price $r p_j = (\gamma + 1) k_j u_j - l + \bar{\Sigma}_j^w \bar{\Sigma}_j^{-1} k_j \gamma v_j + \bar{\Sigma}_j^w \bar{\Sigma}_j^{*-1} k_j v_j^* - \rho \bar{\Sigma}_j^w x$, is determined by the market clearing condition

$$\int_0^1 q_{Hij} di + \int_0^1 q_{Hij}^* di = x.$$

Proof. See Appendix B.4. □

The home aggregate portfolio is given by

$$\int_0^1 q_{Hij} di = \frac{1}{\rho} \bar{\Sigma}_j^{-1} (-l - r p_j + k_j \gamma v_j) + k_j \frac{1}{\rho} \int_0^1 \Sigma_{ij}^{-1} \left((\gamma + 1) \frac{\sigma_0^{-2} \mu_j + (\sigma_\varepsilon^{-2} + y_{in} \sigma_f^{-2}) u_j}{\sigma_0^{-2} + \sigma_\varepsilon^{-2} + y_{in} \sigma_f^{-2}} \right) di$$

Investors tilt their portfolios to the equities that they are optimistic about (high m_{ij}), that delivers high returns (low $r p_j$), and that they consumed more in the childhood period and have more information on (low Σ_{ij}). As [Van Nieuwerburgh and Veldkamp \(2009\)](#) show, i 's expected holdings of home equity j is

$$\mathbb{E}[q_{Hj}] = \frac{\bar{\Sigma}_j}{\Sigma_{ij}} x.$$

Before observing any signals, investors expect to hold more equities of which the average agent is less informed and they are individually more informed. This implies that the ex-ante home equity holdings are positively correlated with consumption-revealed information. Therefore, if I assume there are enough many equities⁷ and there are no systemic

⁷[Jeske \(2001\)](#) argues that if there is only one asset in the market, low-enough signals reverse the home bias. However, if there are many assets, low signals don't outnumber high signals because signals are symmetrically distributed around positive means. When investors put enough wealth into stock markets, their aggregate portfolio holdings are the same as the portfolio of the asset with the mean return if their signals average out to zero.

difference between common priors and product quality, we have the ex-post domestic holdings of domestic stocks

$$\int_0^1 q_{Hj} dj \approx \int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} dj$$

and the ratio of domestic stocks in the home portfolio is given by

$$\phi \equiv \frac{\int_0^1 q_{Hj} dj}{\int_0^1 q_{Hj} dj + \int_0^1 q_{Fj} dj} = \frac{\int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} dj}{\int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} dj + \int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j^*} dj}$$

Denote this ratio by ϕ .

2.3 Calibration

Suppose all the firms have same cost parameters φ_j . In this case, firms are symmetric and their equities have same properties in posterior variances. The aggregate posterior variance of a domestic stock for domestic investors is given by

$$\begin{aligned} \bar{\Sigma} \equiv \bar{\Sigma}_j &= \left[\int_0^1 \Sigma_{ij}^{-1} di \right]^{-1} \\ &= \kappa \left[\int_0^1 \left[(\gamma^2 + 1) (\sigma_u^{-2} + y_{Hij} \sigma_f^{-2})^{-1} + \sigma_v^2 \right]^{-1} di \right]^{-1} \\ &= \kappa \sigma_u^2 \left[\int_0^1 \left[(\gamma^2 + 1) \left(1 + y_{Hij} \frac{\sigma_f^{-2}}{\sigma_u^{-2}} \right)^{-1} + \frac{\sigma_v^2}{\sigma_u^2} \right]^{-1} di \right]^{-1} \end{aligned}$$

The aggregate posterior variance of a foreign stock for domestic investors is

$$\begin{aligned} \bar{\Sigma}^* \equiv \bar{\Sigma}_j^* &= \left[\int_0^1 \Sigma_{ij}^{*-1} di \right]^{-1} \\ &= \kappa \left[\int_0^1 \left[(\gamma^2 + 1) ((\sigma_u^{-2} + y_{Fij} \sigma_f^{-2})^{-1}) + \gamma^2 \sigma_v^2 \right]^{-1} di \right]^{-1} \\ &= \kappa \sigma_u^2 \left[\int_0^1 \left[(\gamma^2 + 1) \left(1 + y_{Fij} \frac{\sigma_f^{-2}}{\sigma_u^{-2}} \right)^{-1} + \gamma^2 \frac{\sigma_v^2}{\sigma_u^2} \right]^{-1} di \right]^{-1} \end{aligned}$$

Hence, the domestic equity share of home investors can be calibrated by

$$\begin{aligned} \phi &= \frac{\int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} dj}{\int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} dj + \int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j^*} dj} \\ &= \frac{\bar{\Sigma}^*}{\bar{\Sigma} + \bar{\Sigma}^*} \end{aligned} \tag{2.23}$$

Table 2.1. Calibration parameters

ω increases when home consumption is more biased towards home-produced goods. When $\omega = 1/2$, there is no bias of home preference in consumption. η is the elasticity of substitution between domestic goods and foreign goods. σ_u^2 is the prior variance for quality defined in $u_{ij} \sim N(\mathbb{E}_i u_{ij}, \sigma_u^2)$, where u_{ij} is the prior belief of consumer i on firm j . σ_f^{-2} is the precision of consumption signals defined in $f_c \sim N(u_j, \sigma_f^2)$. σ_v^2 is the variance of country-specific shocks.

Parameters		Value
Home preference bias in consumption	ω	1/2
ES b/w home and foreign consumption	η	6
Quality uncertainty before purchase	σ_u^2	.04
Signal precision from consumption experience	$\sigma_f^{-2}/\sigma_u^{-2}$	1, 2
Uncertainty of country-specific shocks	σ_v^2/σ_u^2	1, 2

Given the informativeness of priors and signals, σ_u , σ_v , and σ_f , the portfolio share ϕ is determined by two factors both related to home consumption bias: (1) learning by consuming, and (2) domestic information advantage on country-specific shocks. On the one hand, with more consumption, consumers accumulate more experience on learning product quality. On the other hand, because a company's profit depends more on domestic demand, domestic preference shocks are more of importance for investors.

2.3.1 Import shares and foreign equity shares

The mean of product quality μ_j is normalized to 1. Other parameters chosen for calibration are shown in Table 2.1. The standard deviation of quality priors before consumption is calibrated as .2. Because home preference bias in consumption ω and trade cost τ jointly determine import shares, I choose ω to be 1/2 and calibrate import shares with τ . The elasticity of substitution between domestic goods and foreign goods is 6. The relative precision of consumption signals to priors takes two values 1 and 2. The standard deviation of foreign consumption preference shocks is also calibrated with the values 1 and 2.

Figure 2.1 shows the calibrated foreign equity shares $(1 - \phi)$ with import shares. Equation (2.23) gives us the formula of ϕ . The portfolio is obtained by assuming every investor consumes at the aggregate level. If I calibrate the portfolio by using Monte Carlo draws for heterogeneous consumption levels, the results are quantitatively and visually similar. Figure 2.1 shows that when import shares are low, domestic investors naturally obtain more quality signals than foreign investors, so that they tilt more to domestic

equities. It is also the case for country-specific shocks which cannot be observed for foreigners. Because a stock's payoff depends more on home sales when trade cost is large, domestic preference shocks might be an important factor in choosing international portfolios. Numerically, it is possible for a country to have a low foreign equity share when its import share is significantly low. The range of foreign equity shares in the four panels in Figure 2.1 is from 0.13 to 0.22 when import shares are fixed at the level of 0.2.

2.3.2 Expected return and uncertainty

With a signal of low return for an equity, a home investor may choose smaller holdings than foreigners. When the number of equities is large, aggregate expected returns for one country's equities conceived by a home investor and a foreign investor become closer. Without the consideration of risk hedging, international portfolios are determined by both return difference and variance difference. Figure 2.2 shows a measure of information asymmetry by variance ratios calibrated with import shares. Variance ratios are sensitive to import shares when home consumption bias is large. For example, even if the expected excess return of domestic equities is 10 percent lower than foreign equities for a domestic investor, foreign equity share is still mainly determined by variance ratios. The only requirement is that expected excess returns need to be positive.

Figure 2.1. Import shares and foreign equity shares by calibration

This figure shows the calibrated foreign equity shares ($1 - \phi$) with import shares. Import shares are in turn calibrated with trade cost τ . Panel A shows the result when $\sigma_f^{-2}/\sigma_u^{-2} = 1$ and $\sigma_v^2/\sigma_u^2 = 1$. Panel B shows the result for the case of high signal precision from consumption when $\sigma_f^{-2}/\sigma_u^{-2} = 2$ and $\sigma_v^2/\sigma_u^2 = 1$. Panel C shows the result for the case of being less informative of foreign shocks when $\sigma_f^{-2}/\sigma_u^{-2} = 1$ and $\sigma_v^2/\sigma_u^2 = 2$. Panel D shows the result for Panel B and Panel C combined when $\sigma_f^{-2}/\sigma_u^{-2} = 2$ and $\sigma_v^2/\sigma_u^2 = 2$.

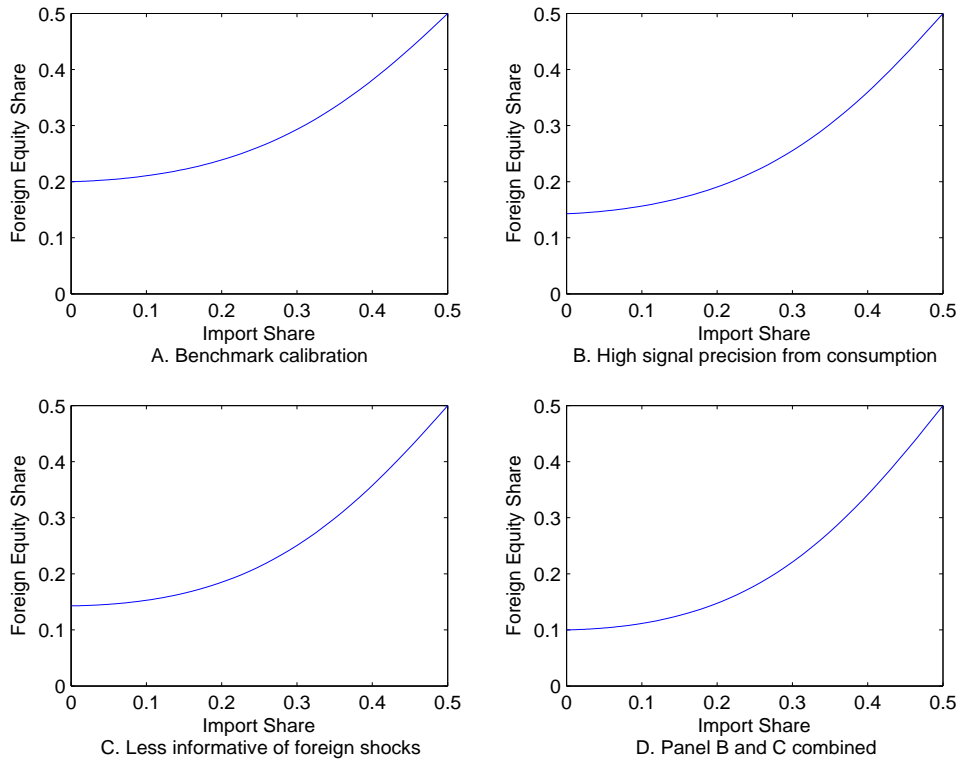
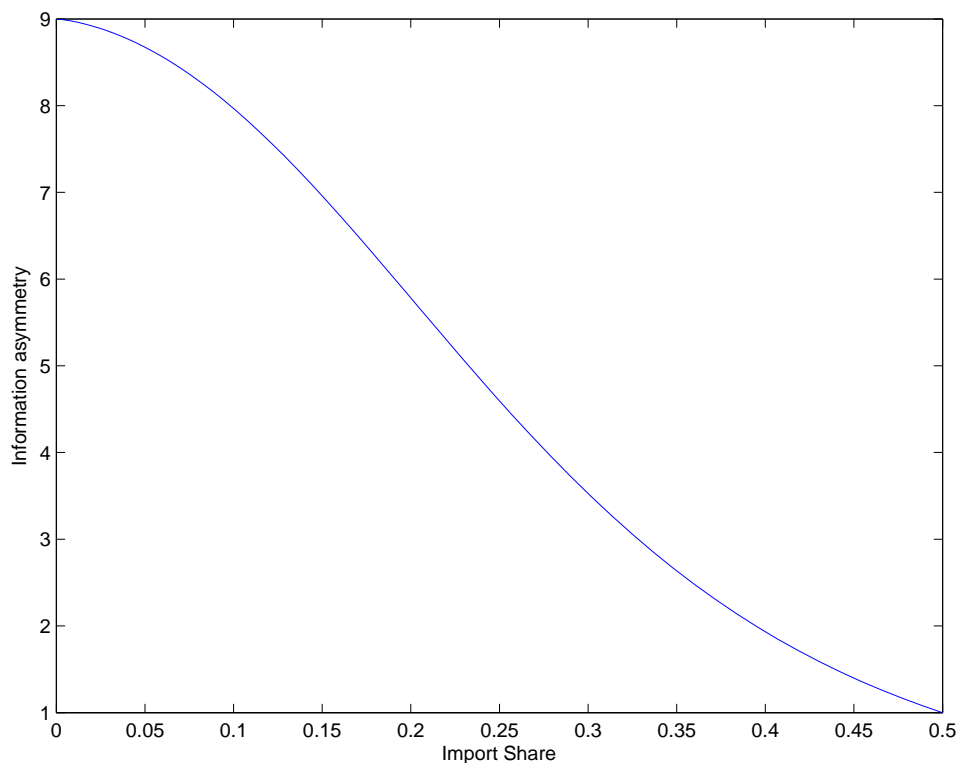


Figure 2.2. Variance ratios for domestic and foreign equities

This figure shows the relationship between variance ratios and import shares. The variances are for foreign equities and domestic equities respectively from the perspective of a domestic investor. I refer to variance ratios as a measure of information asymmetry. The formula of variance ratios is $\bar{\Sigma}^*/\bar{\Sigma}$. The calibration parameters follow those used in Panel D of Figure 2.1.



2.4 Concluding Remarks

Why can daily consumption reveal substantial information on product demand? This paper sheds light on two possible channels. One channel is product quality. More consumption increases the informativeness of a product in quality. Quality is not only relevant to a product's future demand but also relevant to a company's innovation ability. This channel is important for experience goods and durable goods. Furthermore, due to the variety constraint and the existence of non-traded goods, domestic consumers generally only consume a small number of foreign goods, so the quality channel may not be trivial. The other channel is the role of consumption on observing region-specific preference shocks. To be informed of product popularity, consumers go shopping in different stores to increase the observation scope of customer behavior. Social network, for example, the word-of-mouth effect, is also an important source of popularity information. Regional bor-

der is a natural division of shopping boundaries and social network, therefore is a barrier of this kind of information.

This paper shows that demand uncertainty can be one channel that deters domestic investors from holding foreign equities if quality preference and country-specific preference are determinants of aggregate demand. Home consumption bias implies that domestic consumers consume more home goods and the profit of domestic firms also depends more on domestic demand. Therefore, home consumption bias can lead to substantial information asymmetry on home and foreign equities.

The link between consumption bias and portfolio bias can explain many other empirical facts.

1. Local Bias. The theories based upon risk hedging are less powerful in explaining local equity bias within one country. Consumption bias is everywhere closely related to local information advantage and serves as a natural explanation of local equity bias.
2. Portfolio out-performance. Because the information acquired from consumption is immobile, local investors can earn high risk-adjusted excess returns by holding more local stocks.
3. The declining home bias. [Lewis \(2006\)](#) provides evidence that home equity bias has modestly declined during recent years. The upward trend of goods trade among countries lends support to my consumption-based interpretation.

Chapter 3

Business Exposure and Portfolio Locality: An Empirical Analysis of Individual Investors

3.1 Introduction

Individual investors tend to hold more of local stocks. Using individual portfolio data from a China's brokerage firm, this paper finds the fraction of local stocks¹ in the brokerage portfolio is 143 percent higher than the fraction of local stocks in the market portfolio. The average distance of brokerage portfolios from the brokerage city is also 3.34 percent to 4.66 percent closer than the average distance of benchmark portfolios.

Portfolio locality has important implications on asset pricing.² Familiarity and information asymmetry have so far been two main explanations for local equity bias. When individual investors make portfolio decisions based on returns and conceived risks, they buy stocks they are more informed of and more familiar with. Previous studies have mixed evidence about whether local investments earn short-term higher profits.³ If investors are more able to pick local stocks, it is likely because they have information advantage for local stocks. If investors do not earn abnormal returns from local investments, familiarity, as a more likely cause, can also arise from valuable information that makes investors comfortable with local stocks. Therefore, information content is the key to understanding portfolio locality.

This paper tries to identify an important source of information — business exposure, which should help investors to gain familiarity and information about a firm's business. For each firm, its sales in the brokerage city are used as the proxy for business exposure. This paper finds that firm sales are highly correlated with the distance to customer locations when firm size and industries are controlled for. This implies that the relationship between geographical proximity and portfolio local bias can be in part driven by business exposure. In the regression with a sample of both local and nonlocal firms, the effect of business exposure on stock holdings is significantly positive. Specifically, a rise in sales per capita by⁴ \$2.75 leads to a 32 percent increase in the portfolio share relative to the mean. Moreover, the introduction of business exposure reduces the effect of distance by one third. This suggests the importance of business exposure in determining portfolio locality. If local firms are removed from the sample, the distance effect completely vanishes and the effect of business exposure also becomes insignificant. However, for small investors, the exposure to a firm's business has a persistently significant effect for mid-range and remote firms. To examine whether business exposure is only a familiarity breeder, several indicators of business exposure in nonlocal areas are included in a regression. The result suggests that if a nonlocal firm's business is concentrated in other areas, local investors tend to shy away from this stock. However, these coefficients are not statistically significant, so we still cannot reach the conclusion that a firm's sales business has significant amount of information content on stock returns.

¹Local stocks are defined as the stocks for which firms are headquartered within 200 kilometers of the brokerage city.

²For example, see [Hong, Kubik, and Stein \(2008\)](#).

³For a literature review, see Section 2.

⁴\$2.75 is equal to one standard deviation of sales per capita in the brokerage city.

There are few existing papers that examine how portfolio choice relates to business relationship. One exception is [Keloharju, Knüpfer, and Linnainmaa \(2012\)](#), which find that in the case of the automotive industry, buyers of a given make are 51% to 83% more likely than buyers of other makes to own shares in the respective car company. My paper also contributes to finding a source of initial information advantage which is important to explain the scale economy of information acquisition.⁵ The relationship between trade and equity investment also sheds light on home equity bias in international portfolio investment. If a motive of risk sharing with home consumption bias is not adequate to explain home equity bias,⁶ information flow with goods trade may be one potential reason. To investigate portfolios of domestic stocks⁷ may not be informative to draw conclusions for international portfolio holdings, but it also has several research advantages. First, because economies are well integrated across regions, regional shocks are highly correlated. Second, the use of a single currency excludes the need to consider hedging against fluctuations of exchange rates. Finally, to study portfolio decisions at the firm level allows us to incorporate information to the analysis directly from the relationship between firms and investors. It is difficult to evaluate how information aggregates at the region level.

This paper is organized as follows. Section 2 reviews the literature this paper relates to. Section 3 provides descriptions to the data of individual portfolios and firms. Section 4 presents two measures of portfolio locality. Section 5 discusses the empirical framework and results for the relationship between business exposure and portfolio choice. Section 6 concludes.

3.2 Related Literature

This paper relates to five strands of literature. The first studies the effect of geographical proximity on portfolio choice. [Coval and Moskowitz \(1999\)](#) show that the preference for investing close to home applies to portfolios of domestic stocks. They show that fund managers invest in stocks that are 9.32% to 11.20% closer to them than the average stock in their benchmark portfolio. They find that U.S. fund managers exhibit a strong preference particularly for small, highly levered firms that produce non-traded goods. The authors claim that asymmetric information between local and nonlocal investors may drive the preference for portfolio locality. [Huberman \(2001\)](#) documents that the shareholders of a Regional Bell Operating Company (RBOC) tend to live in the region served by the company, and a RBOC's customers tend to hold its shares rather than other RBOCs' stock. The author shows that investment account are typically between \$10,000 and \$20,000. He interprets this bias as "familiarity breeds investment": familiarity may

⁵See [Van Nieuwerburgh and Veldkamp \(2009\)](#)

⁶For details, see Chapter 2.

⁷In China, individuals cannot purchase foreign equities in person, but they can hold internationally diversified mutual funds.

represent information available to the investor, but not yet to the market (information advantage), or the investor's illusion that he has superior information (overconfidence), or the investor's belief that he will have superior information (feeling safe). [Grinblatt and Keloharju \(2001\)](#) document that Finnish investors are 81% more likely to hold local stocks than domestic stocks at large. They find that Finnish investors are more likely to hold, buy, and sell the stocks of firms that are located close to them, that communicate in the native tongue, and that have chief executives of the same cultural background. [Ivković and Weisbenner \(2005\)](#) use the data on individual holdings from a U.S. discount brokerage firm and find that individual investors exhibit a strong preference for local investments — the average share of local investments in companies headquartered within 250 miles from the investor is around 30%. Using the same data, [Hong et al. \(2008\)](#) report that across the entire sample in December 1995, a given investor is 116% more likely to hold a local stock than an average stock. [Cohen \(2009\)](#) finds that conglomerate employees will invest 10 percentage points (75%) less in their company stock than stand-alone employees. He argues that this is a pattern of loyalty-based portfolio choice and superior information or perceived information cannot explain the observed differences between stand-alone and conglomerate employee investment. My paper studies a sample of Chinese individual investors located in the same city. I find the average investor holds stocks that are 3.34% to 4.66% closer to them. For nonlocal stocks more distant than 200 kilometers, investors do not exhibit a preference of proximity.

This paper also adds to the ongoing debate whether local investors have superior information over nonlocal investors. [Cumby and Glen \(1990\)](#) examine fifteen U.S.-based internationally diversified mutual funds between 1982 and 1988, and find no evidence that these funds, either individually or as a whole, provide investors with performance that surpasses a broad, international equity index over the sample period. In contrast, [Coval and Moskowitz \(2001\)](#) find that U.S. fund managers earn an additional return of 2.65% per year in nearby investments. They suggest that investors trade local securities at some sort of information advantage. [Dvořák \(2005\)](#) shows that during 1998-2001 Indonesian domestic investors have short-term higher profits than foreign investors. The difference is about 4% of the market capitalization of the 30 stocks in the sample, which amounts to about 400 million dollars. He also suggests that local information matters. [Ivković and Weisbenner \(2005\)](#) finds that the average household generates an additional annualized return of 3.2% from its local holdings to its nonlocal holdings, suggesting that local investors can exploit local knowledge. [Malloy \(2005\)](#) use a panel of analyst data and find that local analysts covering small stocks in remote areas are approximately \$0.141 per share more accurate than distant analysts, which suggests that local analysts are significantly more accurate than other analysts. [Choe, Kho, and Stulz \(2005\)](#) use Korean data to show that the trade-weighted disadvantage of foreign money managers is 21 basis points for purchases and 16 basis points for sales, which suggests that Korean investors have an edge over foreign investors. [Bae, Stulz, and Tan \(2008\)](#) use a sample of 32 non-US countries to examine the accuracy of earning forecast for local and nonlocal analysts, measured by the price-scaled absolute forecast error of an analyst minus the average price-

scaled absolute forecast error across analysts. They find that after controlling for firm and analyst characteristics, analyst local advantage is still economically and statistically significant, amounting to 2.3 cents per share and 7.8% of the average price-scaled forecast error. [Seasholes and Zhu \(2010\)](#) use the same data as [Ivković and Weisbenner \(2005\)](#), but obtain different results. They find that the “alphas” of local portfolios held by individual investors are not statistically different from zero. In this paper I find indirect, weak evidence that other than familiarity, a firm’s business presence affects individual portfolio choice because it contains information content.

Several papers investigate the consequence of locally concentrated ownership on corporate governance and stock returns. [Gaspar and Massa \(2007\)](#) study the relations among informed local shareholders, corporate governance, and stock liquidity. They find that locally held firms are associated with high quality of corporate governance but more illiquid shares. [Kang and Kim \(2008\)](#) use a sample of partial block acquisitions to examine the importance of geographic proximity in corporate governance and target returns. They find that geographically proximate block acquirers are more likely to be involved in post-acquisition governance activities in targets than are remote block acquirers. In addition, targets of in-state acquirers and those of local acquirers experience both higher abnormal announcement returns and better post-acquisition operating performance than those of other acquirers. [Baik, Kang, and Kim \(2010\)](#) examine whether the effect of stock trading on future stock returns is different across local and nonlocal institutional investors. They find that informed trading by local institutional investors is a strong predictor of future returns.

The paper also relates the strand of literature that investigate the role of attention in individual portfolio decisions. [Odean \(1998\)](#) suggests that many investors limit their search to stocks that have recently captured their attention, with contrarians buying previous losers and trend chasers buying previous winners. [Barber and Odean \(2008\)](#) test whether individual investors are more likely to buy rather than sell those stocks that catch their attention. They confirm this proposition and find that individual investors make nearly twice as many purchases as sales of stocks experiencing unusually high trading volume and nearly twice as many purchases as sales of stocks with an extremely poor return the previous day while the buying behavior of the professionals is barely influenced by attention. In my paper, attention to a firm’s business is one explanation for the effect of business exposure on portfolio choice.

This paper is closely related to [Keloharju et al. \(2012\)](#), which find a strong positive relation between customer relationship, ownership of a company, and size of the ownership stake. A wealth of literature examines the relationship between international trade and international portfolios. International diversification is first discussed in [Grubel \(1968\)](#), [Levy and Sarnat \(1970\)](#), and [Solnik \(1974\)](#). [French and Poterba \(1991\)](#) document equity portfolio shares for major OECD countries and is probably the most prominent among the numerous empirical studies that demonstrate the tendency of incomplete international diversification. For excellent surveys, see [Huberman \(2001\)](#). Attempts to explain home equity bias usually consider either transaction costs or hedging needs. The former include

outright capital controls, taxes, and higher transaction costs associated with international investments. But [Tesar and Werner \(1995\)](#) suggest these costs pose no material challenge to cross-border investments among developed countries. Different hedging needs may arise because residents of different countries consume bundles that are subject to stochastic real exchange rates, or because they produce and consume different nontraded goods, or because they own assets that do not trade. For a thorough survey on recent literature with macroeconomic perspectives, see Chapter 2.

3.3 Data

3.3.1 Individual portfolios

The data of individual portfolios are obtained from a regional brokerage firm located in Ningbo, a medium-sized city of eastern China. Most of the individual investors in this brokerage reside in the city. To be concrete, Ningbo is about one hundred miles away from Shanghai and this area is called the Yangtze River Delta, a relatively developed region in China. The per capita annual income in Ningbo is about \$3,000, which ranks 5th among all cities over the country.

The portfolio data record end-of-month stock holdings of all investors for three months during the period between March 2009 and May 2009. The number of investors holding at least one common stock is about 14,000. For each stock in one investor's portfolio, the data also contain some information about the investor's trading history of the stock during the holding period. For example, we know the starting date of the holding period, the last trading date, and the amount of total shares and value for which an investor purchased and sold during the holding period. Due to privacy protection, the data do not contain demographic information, such as age, gender, and personal income. Bond and mutual fund holdings are excluded in my analyzed sample. In this research, I focus on common stock investments.

Table 3.1 presents the descriptive statistics of the data. Individual stock portfolios are considerably under-diversified. The mean and median numbers of stocks in one's portfolio are three and two respectively. Although the confidence of having information advantage is one candidate explanation, we cannot exclude the possibility that investors have constraint on funds available for investment and the possibility that investors may have a limited understanding of the advantages of diversification.⁸ The median amount of individual stock investment is \$3,809, which is quite close to the per capita annual income in the region. We cannot observe the total balance of one's investment account, but from these relatively small stock investment, it is likely that investors find it hard to allocate investment money efficiently. [Barber and Odean \(2000\)](#) show that the median US households holds 2.61 stocks worth \$16,210. This is similar to the case in China.

The size of the brokerage portfolio is 202 million dollars, which accounts for about

⁸The latter explanation is received from my communication with Terrance Odean.

0.02 percent of China's stock market. Brokerage investors in total held 1,579 different stocks. The brokerage portfolio has only several stocks shy of total stocks traded in the market. In China's stock market, because of high uncertainty on trading conditionality for individual stocks, it is not easy to define a market portfolio for a time period. In this paper, I simply construct the market portfolio with the stocks held by the brokerage investors.

Figure 3.1 shows an interesting portfolio pattern of individual investors. The numbers of shares an investor tends to hold are integers that are easy to remember, like 100 and 500. About 1.15 percent of stock holdings have only one share left. My guess is that these one-share holdings may arise when investors sell stocks and still want to keep attentions to those stocks, whether it may be because investors want to buy them again when prices fall into target zones of reinvesting or because investors want to compare the performance of their current portfolio holdings with the performance of the stocks already sold.

Since a time window of three months is quite short for an analysis of individual portfolios, small stock holdings have special implications. Investors may have made in the past or will make transactions on these stocks in the future. This in turn implies that we can find meaningful results to investigate individual portfolios with reasonable weights on small holdings.

3.3.2 Listed firms

The data of listed firms are obtained from the Wind financial database (WindDB). The WindDB organizes a series of statistics and information from quarterly and annual reports filed by listed firms in the Shanghai Exchange and the Shenzhen Exchange, the two stock exchanges in mainland China. The structure of the WindDB is similar to Compustat, a popular database of U.S. listed firms.

The WindDB almost includes all the useful information reported by firms. The data can be further categorized into basic information, stock information, and balance-sheets information. For example, the basic information includes detailed descriptions of a firm's business or products. Each firm reports its incorporation address and headquarter address. Most of the firms have these two addresses located in the same city.

3.3.2.1 Sales revenue distribution

One key segment in annual reports is sales revenue divided by regions, which nonetheless is absent in the WindDB. Aside from a few of national companies, most of the firms vary in sales revenue across different regions. This is the advantage of studying individuals and firms in a large country. With this type of variation, we can learn how a firm's business exposure to customers affects its stock holder distribution. Moreover, regional sales are required to be disclosed by China's listed firms. This requirement cannot be found in most of other countries, which makes an analysis of China's investors special. Regional variation of sales leads to different business exposure of investors. Business exposure

enhances an investor’s familiarity to a firm and attracts attention. There are also two sources of information asymmetry relevant to sales-based exposure. One is consumption-revealed information. The other is insider information from local employees hired by listed firms.

I collect the data of regional sales directly from annual reports. Because no guide line is specified on how to divide regions in China, some discrepancies exist. Some firms simply divide the whole country into two parts, inner province and outer province, while some other firms report sales for each province.⁹ Therefore, one consistent format must be chosen for all the firms on how their sales should be allocated across regions. I specify a series of criteria to sort out all the information. For details, refer to Appendix C.1.

3.3.2.2 Location and distance

Each firm’s location is identified with its incorporation address. Headquarter cities of most firms are same as their incorporation cities. Every city can be matched with a longitude and a latitude of the city’s centroid. Then we can calculate the arc length between every firm and the home city following the standard procedure (Coval and Moskowitz, 1999 and Ivković and Weisbenner, 2005). The standard formula for computing the distance $d_j = d(i, j)$ between the brokerage city i and the corporate headquarter of stock j is given by

$$d(i, j) = \arccos\{\cos(lat_i) \cos(lon_i) \cos(lat_j) \cos(lon_j) + \cos(lat_i) \sin(lon_i) \cos(lat_j) \sin(lon_j) + \sin(lat_i) \sin(lat_j)\}2\pi r/360,$$

where lat_i and lon_i (lat_j and lon_j) are latitude and longitude degrees for the brokerage city (the corporate city), and r is the radius of the earth (approximately 6,378 kilometers). In my case, all the individual investors must open their investment accounts in a nearby brokerage, so individual distance is represented by the distance between the brokerage and listed firms.

3.4 Local Bias Measured

3.4.1 Average portfolio distance and local bias statistics

Table 3.2 presents the results for Coval and Moskowitz (CM)’s tests of local stock preference.¹⁰ The first panel on the top shows the results for all stocks as a portfolio base. Formally, let $h_{i,j}$ represent the actual weight that investor i places on stock j and m_j represent the portfolio weight on stock j in the benchmark portfolio which investor i ’s portfolio

⁹There are thirty-one provinces in China, including directly-controlled municipalities and ethnicity municipalities. Figure 3.2 shows a map of China with each province with solid boundaries. Provinces with a same color are comprised of one traditional census region.

¹⁰For details, see Appendix B

is compared to. Denote the number of investors by I and the number of stocks by J . I consider four tests which differ in terms of investor weights, ω_i , and portfolio weights, $h_{i,j}$. When investors are equally weighted, $\omega_i = 1/I$, and when investors are value weighted, ω_i is investor i 's share of the total brokerage investment in common stocks. When portfolios are equally weighted, $h_{i,j}$ is the inverse of the number of investor i 's holding stocks, and when portfolios are value weighted, $h_{i,j}$ is the ratio of investor i 's investment in stock j to i 's total investment. In a similar vein, for the benchmark portfolio, when it is equally weighted, $m_j = 1/J$, and when it is value weighted as the market portfolio, m_j is stock j 's fraction of total market capitalization. Since all investors reside in the same area, investor weights do not affect the calculation of the average distance from the benchmark portfolio.

Local bias (LB) statistics measure how large the the average distance of the brokerage portfolio deviates from the average distance of the benchmark portfolio. Table 3.2 also reports the components that comprise LB statistics. Column 4 reports the average distance the brokerage is from the stocks that the brokerage investors hold. Column 5 reports the average distance the brokerage is from the stocks in the benchmark portfolio. Column 6 reports the difference between column 4 and 5. Finally, column 7 and 8 reports LB statistics and t -stats from mean tests.

Table 3.2 shows that, on average, investors are 910 to 923 kilometers away from the stocks they choose to hold, and 950 to 954 kilometers away from the benchmark portfolio. In percentage terms, investors hold stocks that are 3.34 percent to 4.66 percent closer to them than the stocks in the benchmark portfolio. Because of the large sample size, t -stats are all high and the null hypothesis of no local bias is rejected.

The economic significance of local bias seems smaller than the evidence in existing studies. Coval and Moskowitz (1999) find an approximately 10 percent bias from the holdings of U.S. investment managers at the end of 1996. Zhu (2003) uses a U.S. brokerage dataset between 1991 and 1996 and finds an approximately 13 percent bias for individual investors. All of my sample investors are located in the same city, so my result of 4 percent bias may not be representative for the average individual investor in China, if geography plays an important role in the analysis of investor behavior from a large country. However, China's listed firms are not as dispersed as those in the U.S.; a majority of them are located in eastern China. Although the results to quantify it are different, the pattern of individual investment is similar across countries.

Distance is related to portfolio choice. Information advantage has been thought of as one explanation of local equity bias if it is related to geographical proximity. However, information dispersion does not diminish linearly with distance. It is therefore important to see whether the effect of distance on local bias is linear. I divide all holding firms into two groups: local firms within 200 kilometers from the brokerage and nonlocal firms out of this range. The second and third panel in Table 3.2 show LB statistics based on these two groups of firms. Surprisingly, for nonlocal firms on average, the statistics are from -0.03 percent to -3.72 percent. Distance-based local bias completely vanishes for nonlocal firms. In contrast, the results for local firms show a strong bias: for local firms

within 200 kilometers, investors hold stocks that are 8.69 percent to 18.79 percent closer to them. These findings indicate that distance-based bias is simply a pattern of locality, so distance may not be a good measure of geographical proximity that affects portfolio choice. Nonetheless, this sharp decline of the distance effect measured for nonlocal firms is in accord with the non-linear relationship between information dispersion and distance.

3.4.2 Composition of investor portfolios by locality

Table 3.3 shows descriptive statistics for portfolio locality. I consider the difference between local and nonlocal firms with the division threshold of 200 kilometers.

The first and second columns correspond to the analysis of local bias statistics with equal weights. Column 1 reports the number of stocks that are held by at least one investor. These stocks comprise the market portfolio. Among the 1,567 stocks in the market portfolio, 18 percent of them are local stocks and 82 percent are nonlocal stocks. For individual holdings, local stocks account for 24 percent of total occurrences, one third higher than their frequencies in the market portfolio.

The third to sixth columns correspond to the analysis of local bias statistics with value weights. Column 3 reports the fraction of market capitalization for local and nonlocal stocks. The fraction of market capitalization for local stocks is 21 percent, close to the fraction measured in the number of stocks. Column 4 reports the fraction of portfolio values for local stock holdings and nonlocal stock holdings. Local stock holdings account for 51 percent of total brokerage holdings. If we consider a bias measure as excess holdings of local stocks, the bias is 143 percent, a tremendous number. Portfolio locality is pronounced in an descriptive analysis because we divide all firms into two groups in terms of distance without adding weights. CM's *LB* statistics treat remote firms with higher distance weights,¹¹ so aggregated statistics are smaller. [Ivković and Weisbenner \(2005\)](#) report a even stronger bias. They find that local stocks account for 12.6 percent of the market portfolio, but for 31.5 percent of individual portfolios, so the bias is 150 percent. My result is actually similar to theirs.

Column 5 and 6 report local stock fractions for investors with large holding values above \$3,000 and \$10,000 respectively. Similar to the results in [Ivković and Weisbenner \(2005\)](#), no significant difference exists for potentially richer investors. The evidence based on the data for 2009 shows clearly that local bias is still a prevailing pattern of individual investment in common stocks.

3.5 Local Bias and Business Exposure

Previous studies use either the dummy of locality or distance to represent proximity in empirical regressions. These proxies contain fundamental factors which are relevant to individual portfolio choice, but differ from each other. For example, loyalty ([Cohen, 2009](#))

¹¹See Appendix B.

and patriotism (Morse and Shive, 2011) can also be implied in the dummy of locality, but these two factors have little to do with information. With business presence, however, investors gain familiarity of firms, which is likely to contain information content. In this section, I use firm reports of sales distribution to calculate the sales revenue in the brokerage city for each listed firm. This variable therefore is used as a proxy for business exposure. I examine whether individual portfolio choice is related to a firm's business exposure.

Table 3.4 shows the determinants of sales per capita for listed firms. This analysis helps us to understand the relationship and difference between business exposure and geographical proximity. The results are obtained from a pooled regression with OLS. Regions with no sales reports are dropped from the regression. A censored regression does not change the results. Column 1 shows the bivariate relationship between business sales and distance. Similar to the evidence in a gravity model of trade, remoteness has a significantly negative effect on trade, thus on a firm's business exposure. My result indicates that a headquarter twice farther from a target region reduces firm sales by 65 percent. However, the R -squared is only 0.05 for the bivariate regression, which implies that business exposure is not only related to distance, so distance cannot capture the entire effect of business exposure. Column 2 confirms that large firms tend to have high sales in the average region, not only sell to more regions. Large firms are more capital intensive and more likely to produce products of high values. It is no surprise that adding market capitalization to the regression raises the R -squared of the regression to 0.31. It is also straightforward to see that the coefficient of market capitalization is 0.92, very close to the unit level. Destination population is also controlled for in column 3 because it affects a firm's scale economy. The result shows that population has a negative effect on sales per capita, but is economically not significant. In column 4, I control for a firm's product type by adding one-digit industry dummies. Different industries have different scales of sales levels, but the coefficients of main variables barely change. The regression of column 5 only considers remote regions more than 1000 kilometers away. With fewer observations, the t -stat of the distance coefficient declines sharply, but the decrease in its magnitude is rather small.

3.5.1 Regression Specification

The dependent variables in the following analysis are deviations of holding positions for a stock in aggregated brokerage portfolios from its positions in benchmark portfolios. Using the same notations as in section 3.4.1, h_j is the portfolio weight of stock j in the brokerage portfolio, and m_j is the portfolio weight of stock j in the benchmark portfolio. The dependent variable can be expressed as

$$y_j = \frac{h_j - m_j}{\bar{m}}, \quad (3.1)$$

or

$$y_i = \frac{h_j - m_j}{m_j}. \quad (3.2)$$

Equation (3.1) defines a dependent variable as the difference between h_j and m_j , a change relative to the mean. Equation (3.2) defines a dependent variable as the ratio of h_j to m_j , which is essentially a percentage change of its own. Only the stock holdings with reported sales distribution are included in the cross-sectional regression. Coval and Moskowitz (1999) use the product of $y_{i,j}$ and the distance between investor i and stock j as the dependent variable. I don't use this framework because distance in this section is specifically used as an explanatory variable in the regression to justify how important proximity is for individual portfolio choice. This regression is run across all stock holdings, where the dependent variable is an $N \times 1$ vector of portfolio deviations, with N being the total number of individual stock holdings ($N = 844$).¹² Since the data contain little information on individual characteristics, I only consider the cross section at the firm level.

The regression equation on individual portfolios is specified as

$$y_j = \alpha + \beta_0 BS_j + X_{1,j}\beta_1 + X_{2,j}\beta_2 + \varepsilon_j, \quad (3.3)$$

where BS is the variable of sales per capita, which is used as a proxy for business exposure, X_1 is a $(N \times k_1)$ vector of a firm's accounting variables from its balance sheet, and X_2 is a $(N \times k_2)$ vector of other information indicators.

Regarding individual portfolio choice, the effect of familiarity is twofold. Whether subjectively or objectively, familiarity strengthens one's belief of having information advantage in the case that market price does not reveal all the private information, and familiarity also gives an investor the belief of some stocks being relatively safe. Business exposure BS can foster one person's belief in both ways. The introduction of this variable alone does not help to distinguish whether business presence contains real information content¹³.

For

$$X_1 = \{\log(MktCap), Leverage, M/B\},$$

three widely used accounting figures are included as independent variables: firm size, leverage, and market-to-book ratios. Firm size is represented by a firm's market capitalization. Kang and Stulz (1997) find that foreign investors tend to overweight large firms.

¹²I drop the stocks labeled as specially-treated (ST) because these firms operate at a loss for at least two consecutive years and many of them seek restructuring. The number of ST stocks in my sample is 131. Stocks with more than .2 percent of total market capitalization are also dropped because most of them are national, large companies. The number of these firms is 84 in my sample. Although it is required to report sales distribution, some firms choose to divide their sales into a domestic part and a foreign part. These firms are dropped as well.

¹³But I can argue that the belief of some stocks being safer also arises from acquisition of some kind of information, for example, a signal that doesn't change expected returns but posterior variance of returns.

Coval and Moskowitz (1999) find that managers' investments in large firms tend to be further away than those in small firms. Large firms, as we show in Table 3.4, are more likely to have business presence in average regions, therefore to lower information asymmetries. Leverage is defined as the ratio of total liabilities to total assets. Coval and Moskowitz (1999) and Zhu (2003) both find that leverage as a distress variable is highly significant and has a positive effect on portfolio locality. Hong et al. (2008) use the market-to-book ratio as the price level of a firm's stock. They argue this ratio is essentially a measure of aggregate stock bias. Coval and Moskowitz (1999) also emphasize the market-to-book ratio as a systematic firm distress factor.

For

$$X_2 = \{\log(\text{Distance}), \text{Concentration}, \text{HHI}, \text{InvstrDensity}\},$$

I construct several variables that may represent market informativeness and do not help individual investors to gain familiarity.

The physical distance, *Distance*, between an investor and a firm is the common measure of investment proximity. Apart from business exposure from sales, distance is related to the information content that transits along the geographical dimension, but fade away with distance.

Sales per capita capture the amount of information and attention an investor directly receives from a firm. For the consideration of portfolio choice, investors tend to think what others think if they are sophisticated enough. If a small group of investors are more informative of a stock, information asymmetry is a big concern for other uninformed investors. On the contrary, for some information that the whole market knows, this piece of information is likely to be revealed in stock price, so information disadvantage might not be an issue for remote investors. Therefore, for the regression not including firms in the home city, a dummy variable of home sales concentration, *Concentration*, is used. I call a firm's sales are concentrated if more than 80 percent of its sales are realized in its headquartered region. In a similar vein, I construct a variable that measures the distribution of a firm's revenue over the country. If business-based information is evenly dispersed, familiarity does not lead to perceived information advantage. The variable follows the formula to calculate the weighted Herfindahl index¹⁴ denoted by HHI_j . If HHI_j reaches its upper bound of one, firm j only sells to one region, so business exposure through sales is limited. If HHI_j becomes low, firm j 's sales are not concentrated in any specific region. Notice that the composition of the whole market's holdings implies that relatively high holdings by local investors can result in relatively low holdings by nonlocal investors. I argue that in a large country, the deviation of holdings by nonlocal investors should be small, and we still can find implications if we obtain significant results. Suppose sophisticated investors consider what information others have, but naive investors

¹⁴The Herfindahl index usually is used to measure market concentration for an industry. The formula for my variable is $HHI_j = \sum_k \left(\frac{R_{j,k}}{R_j} \right)^2 \frac{1}{I_k}$, where R_j is firm j 's total sales, $R_{j,k}$ is firm j 's sales in region k , and I_k is total stock investors located in region k .

only respond to their own attentions, we expect the coefficients of sales concentration in nonlocal areas to be negative.

The more investors in a region, the more informed they are because of information dispersion. Having access to a firm's local business or the word-of-mouth effect enhances a local investor's ability to increasing her comparative information advantage. Therefore, I introduce a measure of investor density in the firm location defined as investors per hectare, *InvstrDensity*. For instance, regions clustered with investors, such as financial centers, have more information pieces circulated on local firms than other areas, so market information is more affluent for firms located around financial centers.

3.5.2 Empirical Results

My baseline regression defines the dependent variable as the difference between the brokerage weight and the weight of the market portfolio as in Equation (3.1). Specifically, the brokerage weight of stock j is equal to the share of the holding value of stock j by all the brokerage investors, and the market weight of stock j is the ratio of market capitalization to total stock market capitalization. Therefore, the definition of h_j in the baseline regression is equivalent to the value-value weighting scheme of local bias in section 3.4.1. Denote this specification as ΔVV . A change in ΔVV is relative to the stock with a mean share in the market (1/1,579).

Table 3.5 presents the results by adding explanatory variables X_1 and a part of X_2 to the regression step by step. The regression used in column 1 only includes the variable of proximity, measured by the logarithm of physical distance. With one percent farther from a business headquarter, an individual investor statistically decreases her portfolio share for that stock by .22 percent of the mean market portfolio share. Since the distance from a remote firm for the brokerage can be as far as 3,800 kilometers, the potential bias arising from proximity is large from this result. This also verifies my findings of local stock bias in section 3.4. Column 2 shows the result with the introduction of business exposure. The effect of business sales is significantly positive. Specifically, a rise in sales per capita by¹⁵ \$2.75 leads to a 32 percent increase in the portfolio share relative to the mean. Compared to the result in column 1, the effect of distance is reduced by one third. This implies that proximity is related to important information about stocks or some source of familiarity that a firm delivers through business presence, so if we sort out this piece of effect by adding a variable of business exposure, the correlation between distance and portfolio locality declines. Column 3 is similar to the framework in existing studies (for example, Coval and Moskowitz, 1999) in which only accounting variables and distance are included to test whether firm characteristics resembles risks that affect individual portfolio choice. Possibly because large firms are not considered in the regression, accounting variables all have insignificant effects. For the signs of their coefficients, the one of market capitalization is negative, same as we expect, but the ones of market-to-book ratios and leverage have opposite effects. Column 4 represents

¹⁵One standard deviation of sales per capita in the brokerage city.

the result by putting all variables together. The effect of market capitalization becomes statistically significant. Meanwhile, the effects of distance and business exposure do not change. Column 5 shows a noticeable change in the result when specially-treated stocks and large-sized firms are included in the regression. The effect of business exposure becomes insignificant, although still positive on portfolio locality. For the firms with high possibility of being restructured, insider information is rather important, so it is usually hard to explain the holdings for these stocks using common firm characteristics. Because the benchmark of dependent variables is the market portfolio share, even the deviation is still highly correlated with the normalizer. That's the reason that the coefficient of market capitalization in this regression becomes much larger and more significant. This observation motivates me to exclude these firms to examine other firms with more similar sizes and business pattern.

The main drawback of using my data is lack of individual characteristics and a long series of stock trading records. Therefore, I examine other weighting strategies to aggregate individual stock holdings together. Specifically, I check the results for eight different dependent variables of my interest. They are denoted by ΔVV , ΔVE , ΔEV , ΔEE , VV , VE , EV , and EE respectively. Δ means a simple difference with fixed normalization. Otherwise, deviations are normalized with each stock's market capitalization. The first identifier, E or V , represents the weight for investors to aggregate individual portfolios: E denotes equal weights and V denotes value weights. The second identifier, also denoted by E and V , explains how stock holdings are weighted for each investor's portfolio: E denotes equal weights and V denotes value weights. As I have discussed in section 3.3.1, small holdings still have implications on the inference of one's portfolio considerations. Because my regressions examine the actual portfolio at the brokerage level, an equally-weighted portfolio helps us to understand better the behavior of small investors.

Table 3.6 shows the main results for this set of dependent variables. For the first four Δ regressions which use difference dependent variables (column 1 to column 4), the coefficients of business exposure and distance are similar. Whether we use equal or value weights for an investor's different stock picks does not change the results. When we put more weights on small investors, the fit of the model becomes better with an increase in R -squared, and the proximity effect declines from 0.13 in column 1 to 0.06 in column 4. This pattern persists when we directly use percentage deviations as dependent variables. These results are reported in column 5 to column 8. In general, the effects of distance are larger than those in the first four columns and the effects of business exposure are smaller and less significant. However, we have seen in Table 3.2 that local bias does not systematically exist for nonlocal firms. Therefore, it is of interest to examine the holdings for nonlocal firms because if the effect of distance remains for nonlocal firms, it implies that distance is a good determinant of stock portfolio choice. Otherwise, if the distance effect cannot be found for nonlocal firms, distance only captures the home-town effect on local stocks. Table 3.7 uses the same specification as in Table 3.6 on the stocks of nonlocal firms, defined as the firms located more than 200 kilometers away from the brokerage city. Not surprisingly, the coefficients of distance are all insignificant from zero and are negative

for the regressions in column 5 to column 8. Hence, distance does not seem to have effect on portfolio decisions about nonlocal firms. We can visualize the distance effect with plots of portfolio deviations by grouping firms headquartered in each province. Figure 3.3 shows the relationship between value-based deviations and firm locations. The brokerage city is located in the place indicated by a golden star. Except for the home province, individual investors in the brokerage do not have a clear pattern of stock investment based on firm locations. For some firms located more than 3,000 kilometers away, some investors still hold a disproportionately large amount of stock shares. Figure 3.4 presents the distribution of shareholder-based deviations. For some firms located in remote areas, the fraction of stock holders in the brokerage is even higher than the fraction of stock holders nationwide. I also cannot confirm whether business presence is a proxy for home-town firms. However, for the brokerage portfolio with equal weights assigned to every individual investor in the regressions with ΔEV (column 3) and ΔEE (column 4), business exposure still shows significantly positive effects. This indicates small investors are more inclined to pay attention to a firm's local business when they pick stocks. Because the information revealed from business presence is related to familiarity and attention, it should be more relevant to the investors with relatively inadequate information capacity. Small investors with difficulties of having access to insider information and reliable analyst reports are more likely to infer information from a firm's business operation. Therefore, the variable of sales per capita is still a good indicator of information dispersion for small individual investors.

Table 3.8 presents the results for nonlocal firms located in four different ranges, with distance lower bounds at 100, 200, 800, 1500 kilometers respectively. The results for two dependent variables ΔVV and ΔEV are both shown for comparison. For the distance variable, its effects are not significant for nonlocal firms with more than 200 kilometers away. The variable of business exposure has consistent effects even for remote firms that are more than 800 kilometers away.

Finally, we add the rest of the variables in X_2 one by one to see if we can find any other clues that a firm's business presence provides valuable information, but not the sense of familiarity to individual investors. Table 3.9 shows the results with the dependent variable ΔEV for the sample of nonlocal firms more than 200 kilometers away. The three measures I create do not provide a better fit for the model, so they are not as important as the variable of business sales. On the other hand, they all exhibit correct signs as we expect. The effect of a firm's sales concentration in other areas is negative on stock portfolio decisions. The variables of revenue HHI and home revenue concentration both measure the extent to which a firm's sales are concentrated in a nonlocal region. If a firm's sales are concentrated in other areas, an investor may feel uncomfortable with this kind of information asymmetry. This implies that a firm's business presence not only helps investor to gain familiarity, but also convey information to investors. The coefficient of investor density is significantly negative at the 5% level. Because of the word-of-mouth effect, this result implies that in a firm's home town, if investor density is high, investors elsewhere may feel more concerned about their information disadvantage.

From these pieces of evidence, I find weak support for the claim that a firm's business presence contains information for individual investors.

3.6 Conclusion

Does trade contain useful information that investors want to utilize when making portfolio decisions? My paper presents some indirect results on information content in a firm's business presence. The evidence is not conclusive, however. Some of the results are not statistically or economically significant, possibly due to inadequacy of the portfolio data.

One important implication of the results is that physical distance between firms and investors is not an appealing measure of geographical proximity that is related to investment behavior. No aggregate proximity bias exists for nonlocal firms outside the home city, nor is the effect of distance on portfolio choice for these firms. The home-town effect is still strong in that investors are more inclined to hold stocks of nearby firms.

Portfolio locality can be driven by familiarity, or perceived information attainment, or both. This source of information is favorable if investors earn abnormal returns from local investment. Some information makes investors feel safe and comfortable when picking a stock, but may not help investors to earn excess returns. This type of risk-related information can be an important concern for individual investors. This paper shows small investors care more about business exposure, which is consistent with their disadvantage of information capacity.

In the case of international equity investment, information or familiarity conveyed by trade can be one important factor for individual portfolio decisions, which in turn have impacts on the portfolios of institutional investors. An explanation based on trade-embodied information helps to shed light on the cause of home equity bias.

Table 3.1. Summary Statistics of Individual Portfolios

The data of individual portfolios are obtained from a regional brokerage firm located in a medium-sized city of eastern China. Most of the individual investors in this brokerage reside in the city. The portfolio data record end-of-month stock holdings of all investors for three months during the period between March 2009 and May 2009. For each stock in one investor's portfolio, the data also contain some information about the investor's trading history of the stock during the holding period. Due to privacy protection, the data do not contain demographic information, such as age, gender, and personal income. Bond and mutual fund holdings are excluded in my analyzed sample since I focus on common stock investments. Local currency denominated in RMB is converted to US dollars with the exchange rate of 6.82 at that time. The top panel presents aggregate statistics. Only investors with positive holdings are observed. The total number of investors holding at least one stock and the total number of different stocks held are calculated for the whole time window of three months. The total value of the brokerage portfolio is a monthly average for the whole period. The middle panel presents statistics for the number of stocks in an individual portfolio. These statistics are calculated for the whole period. The bottom panel presents statistics for individual portfolio size, which are also calculated for the whole period.

Total number of investors holding at least one stock	14,036
Total number of different stocks held	1,579
Total value of all stocks held (000's)	\$202,505
The number of stocks in an individual portfolio	
Mean	3
Median	2
Min	1
Max	115
Individual portfolio size	
Mean	\$15,528
Median	\$3,827
Min	\$0.3
Max	\$4,948,964

Table 3.2. Local Bias of Individual Investors

This table presents local bias statistics in column 7 for three different samples. Panel A shows the results for all stocks. Panel B and C show the results for local and nonlocal stocks separately. Local stocks are the stocks for which firms are within 200 kilometers from the brokerage. The methodology follows [Coval and Moskowitz \(1999\)](#). For details, see Appendix (C.2). Investor weights in column 2 are used to aggregate individual local bias statistics. Value investor weights are stock values held by each investor. Equal investor weights are the inverse of the number of investors. Portfolio weights in column 3 are used to aggregate individual distances. Value portfolio weights are the value of each stock holding. Equal portfolio weights assign individual distances with same weights. An individual distance is the distance from the brokerage city to the headquarter city of the firm whose stock is held. The formula for average distances can be found in Appendix (C.2). The average distance from holdings in column 4 is the average of individual distances weighted by individual portfolio weights. The average distance from the benchmark portfolio in column 5 is the average of individual distances weighted by market portfolio weights. The differences in column 6 are obtained by subtracting column 4 from column 5. Percentage bias in column 7 can be calculated either by aggregating individual local bias statistics or simply dividing column 6 by column 5. Column 8 reports t -stats, obtained from mean tests.

Stocks	Investor weights	Portfolio weights	Average distance from		Difference	Percentage Bias (LB)	t -stat
			Holdings	Benchmark			
Panel A: The sample of all stocks							
All	Value	Value	917.94	950.73	32.79	3.44	13.28
All	Equal	Value	910.90	950.73	39.83	4.18	15.19
All	Value	Equal	923.11	954.98	31.87	3.34	15.08
All	Equal	Equal	910.46	954.98	44.52	4.66	18.37
Panel B: The sample of local stocks (<200km)							
<200km	Value	Value	120.58	143.06	22.48	15.72	59.64
<200km	Equal	Value	116.19	143.06	26.87	18.79	64.52
<200km	Value	Equal	120.95	132.46	11.51	8.69	32.95
<200km	Equal	Equal	116.63	132.46	15.83	11.96	39.33
Panel C: The sample of nonlocal stocks (200km+)							
200km+	Value	Value	1191.92	1164.78	-27.14	-2.33	-12.45
200km+	Equal	Value	1165.10	1164.78	-0.32	-0.03	-0.16
200km+	Value	Equal	1178.64	1136.32	-42.32	-3.72	-21.97
200km+	Equal	Equal	1161.46	1136.32	-25.14	-2.21	-11.55

Table 3.4. Regression of Sales Revenue on Business Distance

This table shows the determinants of sales per capita for listed firms with reports of business presence in a region. The results are obtained from a pooled regression with OLS. The dependent variable is sales per capita in a region. Regions with no sales reports are dropped from the regression. A censored regression does not change the results. Column 1 shows the bivariate relationship between business sales and distance. Column 2 confirms that large firms (measured by market capitalization) tend to have high sales in the average region, not only sell to more regions. Destination population is also controlled for in column 3 because it affects a firm's scale economy. In column 4, I control for a firm's product type by adding one-digit industry dummies. The regression of column 5 only considers remote regions more than 1000 kilometers away.

Dependent variable: Sales <i>per capita</i> in every region					
	1	2	3	4	5
Business Distance	-0.65*** (-17.36)	-0.64*** (-18.98)	-0.66*** (-19.25)	-0.66*** (-19.86)	-0.64*** (-6.78)
Market Capital		0.92*** (17.43)	0.92*** (17.44)	0.97*** (17.35)	0.94*** (15.83)
Destination population			-0.10*** (-10.20)	-0.10*** (-10.28)	-0.09*** (-5.77)
Constant	8.25*** (31.02)	-3.10*** (-4.57)	-2.16*** (-3.08)	-2.55*** (-3.54)	-2.45** (-2.31)
R^2	0.05	0.31	0.31	0.33	0.31
Number of observations	17931	17931	17931	17931	10875

t -stat in parenthesis. Cluster-robust standard errors are calculated for each firm as a group. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 3.5. Regression of Portfolio Deviations (ΔVV) with the Whole Sample

This table presents the baseline regression results for portfolio deviations on business exposure. The regression equation is Equation (3.3). The dependent variable is the difference between the brokerage weight and the weight of the market portfolio as in Equation (3.1). Specifically, the brokerage weight of stock j is equal to the share of the holding value of stock j by all the brokerage investors, and the market weight of stock j is the ratio of market capitalization to total stock market capitalization. Therefore, the definition of h_j in the baseline regression is equivalent to the value-value weighting scheme of local bias in section 3.4.1. Denote this specification as ΔVV . A change of ΔVV_j is the change of portfolio shares for stock j relative to the stock with a mean share in the market (1/1,579). The regression used in column 1 only includes the variable of proximity, measured by the logarithm of physical distance. Column 2 shows the result with the introduction of business exposure, measured by sales per capita in the home city. Column 3 includes only accounting variables and distance, but no business exposure. Column 4 represents the result by putting all variables together. Column 5 shows a noticeable change in the result when specially-treated stocks and large-sized firms are included in the regression.

Dependent variable: Portfolio deviations (ΔVV)					
	1	2	3	4	5
log(Distance)	-0.22*** (-6.19)	-0.14*** (-3.66)	-0.22*** (-6.22)	-0.13*** (-3.60)	-0.21*** (-3.22)
Business exposure		0.02*** (6.67)		0.02*** (6.99)	0.00 (0.69)
log(Market Capitalization)			-0.06 (-1.29)	-0.10** (-2.19)	-0.85*** (-12.66)
Market Cap/Book value			-0.02 (-1.16)	-0.01 (-0.42)	0.00 (0.21)
Leverage			-0.14 (-0.63)	-0.31 (-1.48)	-0.04 (-1.26)
Constant	1.60*** (6.70)	0.99*** (3.94)	3.04*** (2.91)	3.33*** (3.28)	19.31*** (13.18)
R^2	0.04	0.09	0.05	0.10	0.16
Number of observations	844	844	844	844	978

t -stat in parenthesis. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 3.6. Regression of Portfolio Deviations with Different Dependent Variables for All Firms

This table shows the regression results for portfolio deviations on business exposure with a set of dependent variables. The regression equation is Equation (3.3). Dependent variables are defined as the difference between the brokerage weight and the weight of the market portfolio. They are denoted by ΔVV , ΔVE , ΔEV , ΔEE , VV , VE , EV , and EE respectively. Δ means a simple difference with fixed normalization. Otherwise, deviations are normalized with each stock's market capitalization. The first identifier, E or V , represents the weight for investors to aggregate individual portfolios: E denotes equal weights and V denotes value weights. The second identifier, also denoted by E and V , explains how stock holdings are weighted for each investor's portfolio: E denotes equal weights and V denotes value weights. This table does not show the results for other accounting variables. Distance is the physical distance between a firm and the brokerage. Business exposure is measured by sales per capita in the home city.

Dependent variable	1 ΔVV	2 ΔVE	3 ΔEV	4 ΔEE	5 VV	6 VE	7 EV	8 EE
log(Distance)	-0.13*** (-3.60)	-0.11*** (-3.76)	-0.07*** (-3.16)	-0.06*** (-2.73)	-0.26*** (-2.90)	-0.24*** (-3.38)	-0.18*** (-5.13)	-0.17*** (-4.89)
Business exposure	0.02*** (6.99)	0.01*** (6.25)	0.02*** (10.16)	0.02*** (9.18)	0.01* (1.79)	0.01 (1.53)	0.01*** (4.62)	0.01*** (4.24)
R^2	0.10	0.10	0.18	0.16	0.04	0.06	0.16	0.17
Number of observations	844	844	844	844	844	844	844	844

t -stat in parenthesis. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 3.7. Regression of Portfolio Deviations with Different Dependent Variables for Nonlocal Firms (200 km+)

This table shows the regression results for portfolio deviations on business exposure with a set of dependent variables for nonlocal firms only. Nonlocal firms are firms located more than 200 kilometers away. The regression equation is Equation (3.3). Dependent variables are defined as the difference between the brokerage weight and the weight of the market portfolio. They are denoted by ΔVV , ΔVE , ΔEV , ΔEE , VV , VE , EV , and EE respectively. Δ means a simple difference with fixed normalization. Otherwise, deviations are normalized with each stock's market capitalization. The first identifier, E or V , represents the weight for investors to aggregate individual portfolios: E denotes equal weights and V denotes value weights. The second identifier, also denoted by E and V , explains how stock holdings are weighted for each investor's portfolio: E denotes equal weights and V denotes value weights. This table does not show the results for other accounting variables. Distance is the physical distance between a firm and the brokerage. Business exposure is measured by sales per capita in the home city.

Dependent variable	1 ΔVV	2 ΔVE	3 ΔEV	4 ΔEE	5 VV	6 VE	7 EV	8 EE
log(Distance)	0.04 (0.58)	0.03 (0.48)	0.03 (0.66)	0.03 (0.61)	-0.06 (-0.30)	-0.09 (-0.61)	-0.02 (-0.26)	-0.02 (-0.24)
Business exposure	0.00 (1.06)	0.00 (1.23)	0.01*** (2.79)	0.01*** (2.72)	0.00 (0.11)	-0.00 (-0.01)	0.00 (0.67)	0.00 (0.55)
R^2	0.03	0.05	0.05	0.05	0.02	0.05	0.10	0.12
Number of observations	711	711	711	711	711	711	711	711

t -stat in parenthesis. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 3.8. Regression of Portfolio Deviations with Different Dependent Variables for Nonlocal Firms within Different Ranges

This table shows the regression results for portfolio deviations on business exposure with a set of dependent variables for nonlocal firms within different ranges. The regression equation is Equation (3.3). Dependent variables are defined as the difference between the brokerage weight and the weight of the market portfolio. They are denoted by ΔVV and ΔEV respectively. Δ means a simple difference with fixed normalization. The first identifier, E or V , represents the weight for investors to aggregate individual portfolios: E denotes equal weights and V denotes value weights. The second identifier, also denoted by E and V , explains how stock holdings are weighted for each investor's portfolio: E denotes equal weights and V denotes value weights. This table does not show the results for other accounting variables. Distance is the physical distance between a firm and the brokerage. Business exposure is measured by sales per capita in the home city. Column 1 to column 4 (column 5 to column 8) show the regression results with ΔVV (ΔEV) as the dependent variable and with different samples. These samples include nonlocal firms within different ranges specified in the second row.

	1	2	3	4	5	6	7	8
	100km+	200km+	800km+	1500km+	100km+	200km+	800km+	1500km+
Dependent variable	ΔVV	ΔVV	ΔVV	ΔVV	ΔEV	ΔEV	ΔEV	ΔEV
log(Distance)	-0.12*** (-2.63)	0.04 (0.58)	0.10 (0.72)	0.11 (0.44)	-0.04 (-1.64)	0.03 (0.66)	0.13 (1.54)	-0.43** (-2.05)
Business exposure	0.00 (0.49)	0.00 (1.06)	0.00 (0.57)	0.05 (1.11)	0.01*** (2.93)	0.01*** (2.79)	0.02*** (2.89)	0.21*** (5.87)
R^2	0.02	0.03	0.03	0.03	0.05	0.05	0.06	0.21
Number of observations	830	711	556	169	830	711	556	169

t -stat in parenthesis. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 3.9. Regression of Portfolio Deviations on Business Exposure in Other Areas

For the dependent variable ΔEV , Δ means a simple difference with fixed normalization. The first identifier E denotes equal investor weights. The second identifier V denotes value portfolio weights. This table does not show the results for other accounting variables. Distance is the physical distance between a firm and the brokerage. Business exposure is measured by sales per capita in the home city. The Herfindahl revenue index is used to measure sales concentration for a firm. The formula is $HHI_j = \sum_k \left(\frac{R_{j,k}}{R_j} \right)^2 \frac{1}{I_k}$, where R_j is firm j 's total sales, $R_{j,k}$ is firm j 's sales in region k , and I_k is total stock investors located in region k . *Concentration* is a dummy variable of home sales concentration, being 1 if the share of home sales is more than 80 percent. Investor density in the firm location is defined as total stock investors per hectare.

Dependent variable: Portfolio deviations (ΔEV)				
	1	2	3	4
log(Distance)	0.03 (0.66)	0.03 (0.70)	0.03 (0.68)	-0.00 (-0.01)
Business exposure	0.01*** (2.79)	0.01*** (2.69)	0.01*** (2.74)	0.01*** (2.73)
Revenue <i>HHI</i>		-0.05 (-0.83)		
Revenue Concentration			-0.04 (-0.80)	
Investor Density				-0.02** (-2.06)
R^2	0.05	0.05	0.05	0.05
Number of observations	711	711	711	711

t -stat in parenthesis. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Figure 3.1. Shares Distribution for Small Stock Holdings

This figure shows the frequencies for small stock holdings with easy-to-member holding shares in the whole sample. X-axis shows some special picks of stock holding shares. Y-axis shows the frequencies for each share number. Frequencies are rounded arithmetic averages for three months. Investors tend to hold stocks with 1, 10, 50, and 100 shares for small holdings. For example, stock holdings with one share left account for 1.15 percent of total stock holdings. These holdings appear mostly when investor sell stocks and serve as a device of attention commitment. The reason may be because investors want to buy them again when prices fall into target zones of reinvesting or because investors want to compare the performance of their current portfolio holdings with the performance of the stocks already sold.

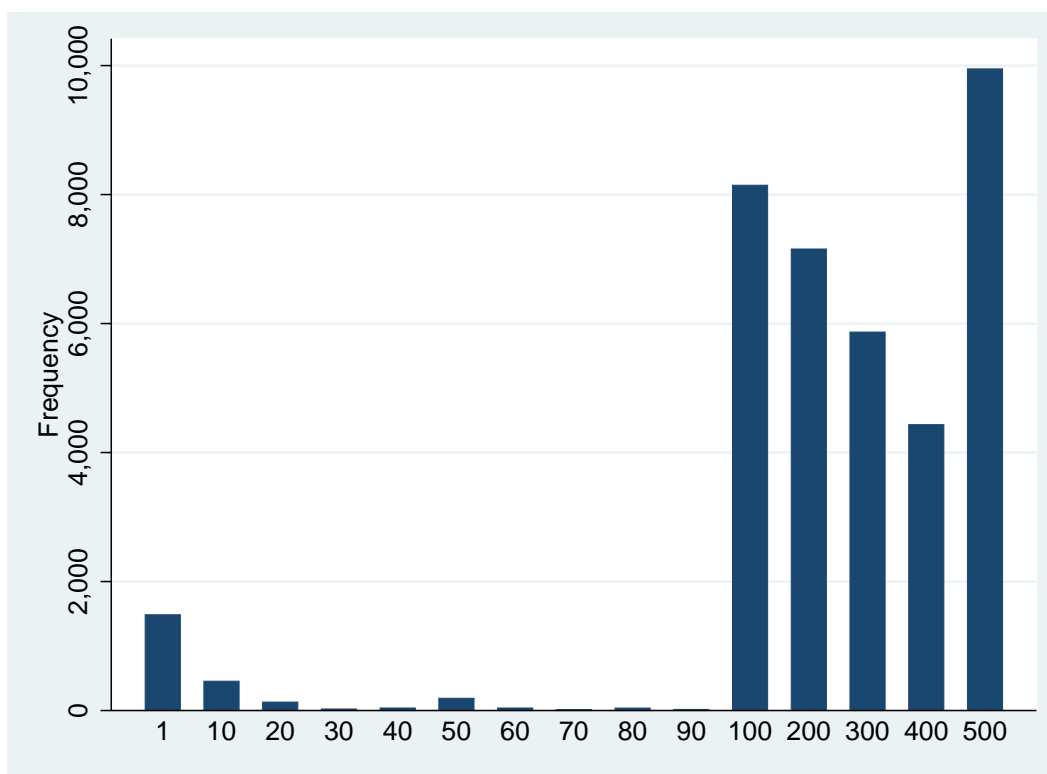


Figure 3.2. Region Division in China

Each area with solid boundaries is one province. Provinces with a same color are comprised of one traditional census region. Red area: Beijing and Blue area: Shanghai.



- Orange: Northeast
- Light Blue: North
- Light Yellow: Northwest
- Pink: East
- Green: Center
- Cyan: South
- Light Pink: Southwest

Figure 3.3. Province Distribution of Portfolio Holding Bias

This figure helps us to visualize the relationship between geographical proximity and portfolio holdings. Each area with solid boundaries is one province. The brokerage city is located in the place indicated by a golden star. For each province j , M_j is the value held by the brokerage; \bar{M}_j is total market capitalization. The ratio $\frac{M_j}{\bar{M}_j} / \frac{\sum_j M_j}{\sum_j \bar{M}_j}$ is plotted for province j following the legend shown on the figure.

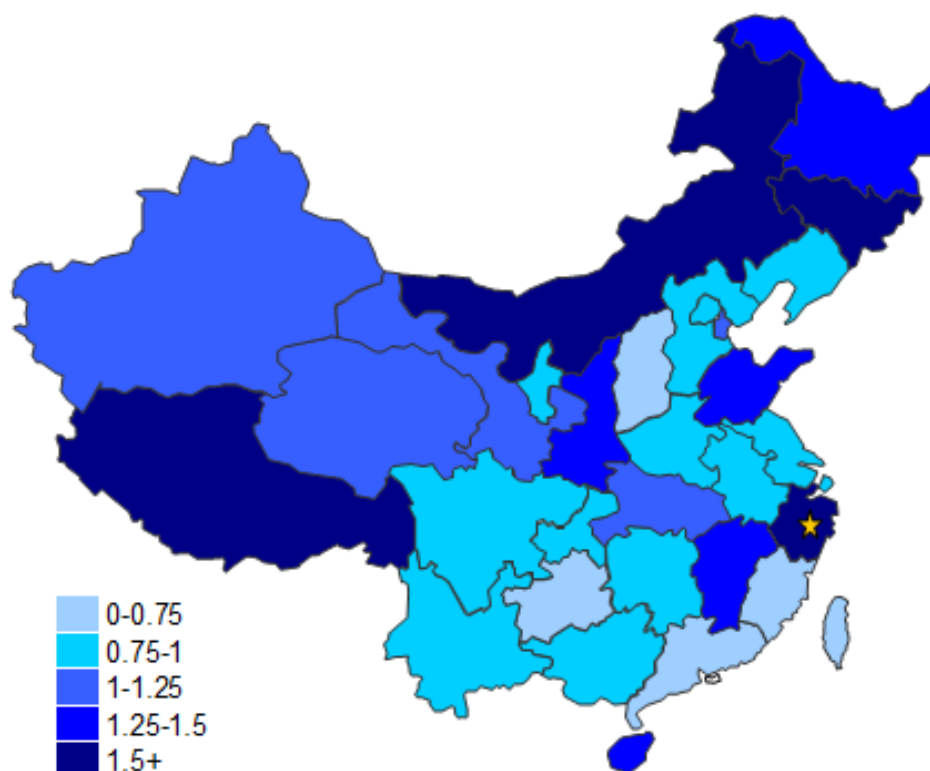
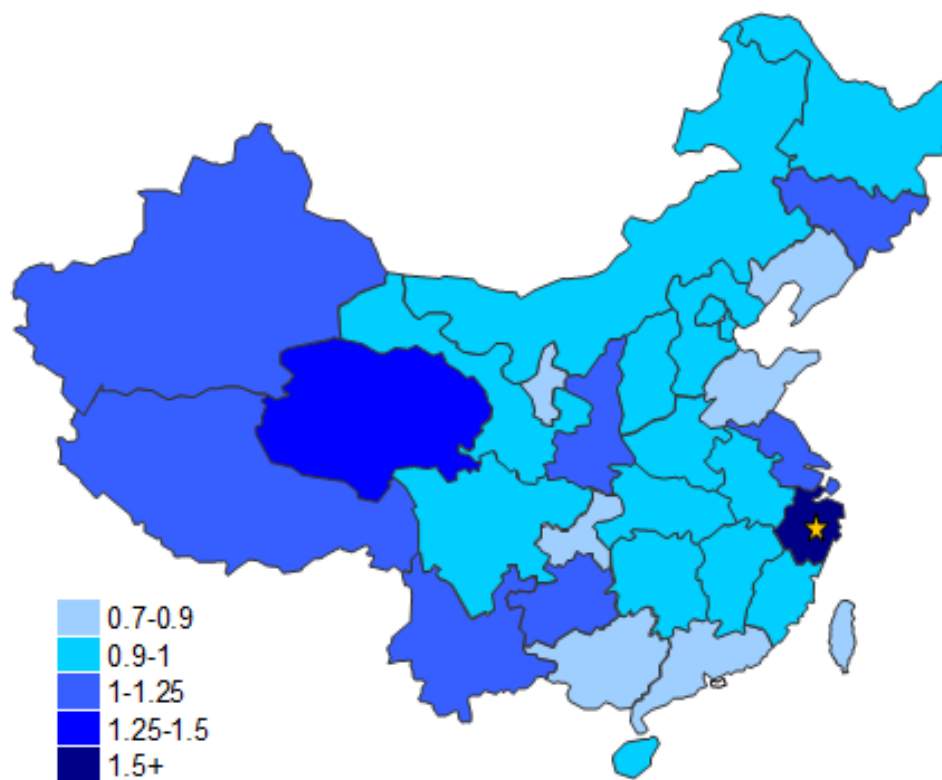


Figure 3.4. Province Distribution of Portfolio Holders Bias

This figure helps us to visualize the relationship between geographical proximity and the number stock holders. Each area with solid boundaries is one province. The brokerage city is located in the place indicated by a golden star. For province j , H_j is the number of brokerage shareholders for all firms in j ; \bar{H}_j is total market shareholders. The ratio $\frac{H_j}{\bar{H}_j} / \frac{\sum_j H_j}{\sum_j \bar{H}_j}$ is plotted for province j following the legend shown on the figure.



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Appendix A

Appendix to Chapter 1

A.1 The baseline model

A.1.1 Household and aggregate resource

The preference in period t of the representative household is given by

$$E_t \sum_{j=0}^{\infty} \beta^j \left(\frac{(C_{t+j} - bC_{t+j-1})^{1-\sigma} - 1}{1-\sigma} - \frac{N_{t+j}^{1+\chi}}{1+\chi} \right), \quad \sigma > 0, \quad \chi > 0,$$

where $0 < \beta < 1$ denotes the discount factor, C_t denotes the index of consumption goods and N_t denotes the number of hours worked in period t . In equilibrium, consumption C_t is equal to gross sales S_t if without investment and government spending. I assume that the parameter b takes a positive value, in order to allow for habit formation in consumption preferences. C_t is the CES aggregator over different varieties

$$C_t = \left(\int_0^1 C_t(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}$$

Define the price index P_t as

$$P_t \equiv \left(\int_0^1 P_t(i)^{1-\theta} di \right)^{\frac{1}{1-\theta}}$$

The budget constraint in period t of the representative household can be therefore written as

$$C_t + E_t D_{t,t+1} \frac{B_{t+1}}{P_{t+1}} = \frac{B_t}{P_t} + \frac{W_t}{P_t} L_t + \Pi_t, \quad (\text{A.1})$$

where B_{t+1} denotes a portfolio of nominal state contingent claims in the complete contingent claims market, $D_{t,t+1}$ denotes the stochastic discount factor for computing the real value in period t of one unit of consumption goods in period $t+1$, W_t denotes aggregate nominal wage, and Π_t denotes real dividend income and transfers. The first order

conditions for consumption and labor supply can be written as

$$\Lambda_t = E_t \left((C_t - bC_{t-1})^{-\sigma} - \beta b (C_{t+1} - bC_t)^{-\sigma} \right),$$

$$N_t^\chi = \Lambda_t \frac{W_t^*}{P_t}, \quad (\text{A.2})$$

where Λ_t is the Lagrange multiplier of the budget constraint (A.1) and W_t^* is the market-clearing wage rate at time t . The optimization condition for bonds holding is

$$D_{t,t+1} = \beta \frac{\Lambda_{t+1}}{\Lambda_t}.$$

Hence, if R_t represents the gross nominal interest rate in period t , absence of arbitrage gives the following Euler equation:

$$E_t \left(D_{t,t+1} R_t \frac{P_t}{P_{t+1}} \right) = 1.$$

The household accumulates capital using the following technology:

$$K_{t+1} = (1 - \delta) K_t + F(I_t, I_{t-1}) + \Delta_t,$$

where the function for adjustment cost is specified by

$$F(I_t, I_{t-1}) = \left(1 - S \left(\frac{I_t}{I_{t-1}} \right) \right) I_t$$

where $S(\cdot)$ is a convex cost function of investment adjustment such that $S(1) = S'(1) = 0$ and $S''(1) > 0$.

The decision of capital accumulation by the household gives us

$$P_{K,t} = \frac{\omega_t}{\Lambda_t}$$

where ω_t is the Lagrangian multiplier on the constraint of capital accumulation. The optimal investment is given by

$$\omega_t \left[1 - S \left(\frac{I_t}{I_{t-1}} \right) - S' \left(\frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} \right] + E_t \beta \omega_{t+1} S' \left(\frac{I_{t+1}}{I_t} \right) \left(\frac{I_{t+1}}{I_t} \right)^2 = \Lambda_t$$

and absence of arbitrage for the capital return leads to

$$E_t D_{t,t+1} \frac{R_{K,t+1} + (1 - \delta_k) P_{K,t+1}}{P_{K,t}} = 1$$

The aggregate resource constraint is given by

$$Y_t = C_t + I_t - S \left(\frac{I_t}{I_{t-1}} \right) I_t$$

A.1.2 A firm's first-order conditions

The first-order conditions for $K_t^*(i)$, $L_t^*(i)$, and $P_t^*(i)$ can be summarized as follows. Firms set prices according to a variant of the mechanism spelled out by Calvo (1983). In each period, a firm faces a constant probability, ξ_p , of not being able to re-optimize its nominal price. Firms that do not re-optimize prices simply follow the indexation rule (see footnote 17). Therefore, the optimal conditions for price are only applied to those firms that re-optimize.

The first-order conditions for capital service and labor in production $K_t^*(i)$ and $L_t^*(i)$ is given by

$$R_{K,t+j} = Q_{t+j}(i) \alpha L_{t+j}^{1-\alpha}(i) K_{t+j}^{\alpha-1}(i) \quad (\text{A.3})$$

and

$$\begin{aligned} & \frac{W_t}{P_t} \left(1 + \Upsilon' \left(\frac{L_t(i)}{L_{t-1}(i)} \right) \frac{L_t(i)}{L_{t-1}(i)} + \Upsilon \left(\frac{L_t(i)}{L_{t-1}(i)} \right) \right) - E_t D_{t,t+1} \frac{W_{t+1}}{P_{t+1}} \Upsilon' \left(\frac{L_{t+1}(i)}{L_t(i)} \right) \left(\frac{L_{t+1}(i)}{L_t(i)} \right)^2 \\ & = Q_{t+j}^{\frac{1}{1-\alpha}}(i) R_{K,t+j}^{-\frac{\alpha}{1-\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} (1 - \alpha) \end{aligned}$$

where the marginal cost from labor input depends on a firm's expected labor input changes in current period and next period.

The first-order condition for price-setting $P_t^*(i)$ is given by

$$E_t^{\bar{p}} \sum_{j=0}^{\infty} \xi_p^j D_{t,t+j} \frac{S_{t+j}(i)}{P_{t+j}(i)} \left(\frac{P_{t+j}(i)}{P_{t+j}} - \frac{\varepsilon}{\varepsilon - 1} Q_{t+j}(i) \right) = 0$$

where marginal cost $Q_{t+j}(i)$ now depends on individual variables.

A.1.3 Parametrization

Parameter	Values	Description and definitions
σ	1	Inverse of inter-temporal substitution
χ	1	Inverse of labor supply elasticity
β	.99	Time discount factor
ϱ	0.7.	Degree of inflation indexation
ϱ_w	0.7	Degree of wage indexation
$1 - \xi_p$	1/2	Frequency of price changes in each quarter
$1 - \xi_l$	1/4	Frequency of wage changes in each quarter
θ	5	Elasticity of substitution across good varieties
ε_w	5	Elasticity of substitution across labor varieties
α	.36	Capital share
δ_k	.025	Quarterly depreciation rate of capital
X	20	Curvature of capital adjustment
σ_a	.3	The rate of capital utilization
b	0.76	Degree of habit persistence
ρ_r	.85	Parameter of interest rate smoothing
ρ_π	1.5	Responsiveness to inflation
ρ_y	0.5/4	Responsiveness to production gap

Appendix B

Appendix to Chapter 2

B.1 Comments on Information Acquisition

Van Nieuwerburgh and Veldkamp (2009) (hereafter VNV) claims that sustaining information asymmetry is possible because investor choose to learn more about risks they have an initial advantage. Because investors prefer an asset they are better informed about, learning more about an asset makes them expect to hold more of it. As expected asset holdings rise, returns to information increase. It is this interaction of the learning and investing decisions that generates increasing returns to specialization. They argue that the effect of an initial information advantage on learning is similar to the effect of a comparative advantage on trade. Does comparative advantage always lead to specialization? No. In international trade, only Ricardian economies with linear technologies specialize. If the production exhibits increasing marginal cost, the case may not be same. In information acquisition, costs still matter. VNV only specifies the amount limit of total information investors can observe, which is called capacity K . The equation (3) in VNV specifies the capacity constraint as:

$$\frac{\prod_i \hat{\Lambda}_i}{\prod_i \Lambda_i} \geq \frac{1}{c(K)},$$

where Λ_i and $\hat{\Lambda}_i$ are prior and posterior variances of asset i . Taking logs for both sides, we have the budget constraint

$$\sum_i \left(\log \frac{\Lambda_i}{\hat{\Lambda}_i} \right) \leq \log c(K).$$

Investors prefer lower $\hat{\Lambda}_i$. This implies the cost function for learning each asset is same and equal to

$$f(x) = \log x,$$

which actually exhibits diminishing marginal cost. That is why VNV obtain a specialization result. Since the information or the capacity is abstract in contrast with the real

information on stock returns, it is nearly impossible to determine what the cost function is necessary to be. If an increasing marginal cost of information acquisition is more plausible, investors will not specialize in acquiring information for one asset.

In fact, specialization is not necessary to generate home equity bias. Given a symmetric cost function of information acquisition, investors will still acquire more information for the asset they have more initial information advantage. Consumption-revealed information supports the idea of information acquisition by two ways. One is the natural information advantage embodied in historical consumption. The other is the asymmetric costs of acquiring consumption-revealed information. One does not have to depend on consumer surveys to forecast future demand, but simply go shopping occasionally.

B.2 Proof of Result 1

Define i 's individual price indexes for home and foreign consumption C_{Hi} and C_{Fi} as

$$P_{Hi} \equiv \left[\int_0^1 \theta_{Hij} p_{Hj}^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}} \quad \text{and} \quad P_{Fi} \equiv \left[\int_0^1 \theta_{Fij} p_{Fj}^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}}.$$

Using the fact that heterogeneity in i 's preferences θ_{ij} is uncorrelated with heterogeneity in marginal cost φ_j , we can rewrite P_{Hi} and P_{Fi} as

$$P_{Hi} = \left[\int_0^1 \theta_{Hij} dj \int_0^1 p_{Hj}^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}} \quad \text{and} \quad P_{Fi} = \left[\int_0^1 \theta_{Fij} dj \int_0^1 p_{Fj}^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}}.$$

Given that $\int_0^1 \theta_{Hij} dj = \int_0^1 \theta_{Fij} dj = 1$, we can define P_H and P_F as

$$P_H \equiv \left[\int_0^1 p_{Hj}^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}} = P_{Hi} \quad \text{and} \quad P_F \equiv \left[\int_0^1 p_{Fj}^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}} = P_{Fi}.$$

Then we have

$$\begin{aligned} y_{Hij} &= \theta_{Hij} C_{Hi} \left(\frac{p_{Hj}}{P_{Hi}} \right)^{-\sigma} = \theta_{Hij} C_{Hi} \left(\frac{p_{Hj}}{P_H} \right)^{-\sigma}, \\ y_{Fij} &= \theta_{Fij} C_{Fi} \left(\frac{p_{Fj}}{P_{Fi}} \right)^{-\sigma} = \theta_{Fij} C_{Fi} \left(\frac{p_{Fj}}{P_F} \right)^{-\sigma}. \end{aligned}$$

B.3 Proof of Result 2

1. C_{Hi} is same for all i and define $C_H \equiv C_{Hi}$.

Price index P_{Hi} is shown to be equal across individuals, so is $P_i = \left[\omega P_{Hi}^{1-\eta} + (1-\omega) P_{Fi}^{1-\eta} \right]^{\frac{1}{1-\eta}}$.

The individual utility $C_i = W_i/P_i = W/P$ is same for all i . Home consumption aggregation $C_{Hi} = \omega C_i (P_H/P)^{-\eta}$ is also same for everyone.

2. Home consumption bias $\gamma \equiv P_H C_H / P_F C_F = \frac{\omega}{1-\omega} (1-\tau)^{1-\eta} > 1$

$\gamma \equiv P_H C_H / P_F C_F = \frac{P_H}{P_F} \frac{\omega C_i (P_H/P)^{-\eta}}{(1-\omega) C_i (P_F/P)^{-\eta}} = \frac{\omega}{1-\omega} \left(\frac{P_H}{P_F}\right)^{1-\eta} = \frac{\omega}{1-\omega} (1-\tau)^{1-\eta}$. Moreover, $P_H^* C_H^* = \frac{1}{\gamma} P_F^* C_F^* = \frac{1}{\gamma} P_H C_H$ by symmetry.

3. Firm j 's profit function $\pi_j = k_j [\gamma \bar{\theta}_{Hj} + \bar{\theta}_{Hj}^*] - l$.

Define firm j 's domestic sale $y_{Hj} \equiv \int_0^1 y_{Hij} di$. It follows that

$$y_{Hj} = \int_0^1 \theta_{Hij} C_{Hi} \left(\frac{p_{Hj}}{P_H}\right)^{-\sigma} di = C_H \left(\frac{p_{Hj}}{P_H}\right)^{-\sigma} \int_0^1 \theta_{Hij} di = \bar{\theta}_{Hj} C_H \left(\frac{p_{Hj}}{P_H}\right)^{-\sigma},$$

where $\bar{\theta}_{Hj} \equiv \int_0^1 \theta_{Hij} di$ is the mean of θ_{Hij} . Then $y_{Hj}^* \equiv \int_0^1 y_{Hij}^* di = \bar{\theta}_{Hj}^* C_H^* \left(\frac{p_{Hj}}{P_H}\right)^{-\sigma}$, where $\bar{\theta}_{Hj}^* \equiv \int_0^1 \theta_{Hij}^* di = \bar{\theta}_{Hj}$ due to the assumption of no preference bias at the product level. So $y_j = y_{Hj} + \frac{P_H^*}{P_H} y_{Hj}^* = \left(\bar{\theta}_{Hj} C_H + \frac{P_H^*}{P_H} \bar{\theta}_{Hj}^* C_H^*\right) \left(\frac{p_{Hj}}{P_H}\right)^{-\sigma}$. The profit of firm j is

$$\begin{aligned} \pi_j &= p_{Hj} y_j - L_j = p_{Hj} y_j - (l + \varphi_j y_j) = \frac{1}{\sigma} p_{Hj} y_j - l \\ &= \frac{1}{\sigma} P_H^\sigma p_{Hj}^{1-\sigma} \left(\bar{\theta}_{Hj} C_H + \frac{P_H^*}{P_H} \bar{\theta}_{Hj}^* C_H^*\right) - l \\ &= k_j [\gamma \bar{\theta}_{Hj} + \bar{\theta}_{Hj}^*] - l, \end{aligned}$$

where $k_j = \frac{1}{\sigma} P_H^* C_H^* \left(\frac{p_{Hj}}{P_H}\right)^{1-\sigma} = \frac{1}{\sigma} P_F C_F \left(\frac{p_{Hj}}{P_H}\right)^{1-\sigma}$.

B.4 Proof of Result 3

Define $\bar{\Sigma}_j = \left[\int_0^1 \Sigma_{ij}^{-1} di\right]^{-1}$

$$\begin{aligned} \int_0^1 q_{Hij} di &= \int_0^1 \frac{m_{ij} - r p_j}{\rho \Sigma_{ij}} di = \int_0^1 \frac{m_{ij}}{\rho \Sigma_{ij}} di - \frac{1}{\rho} \bar{\Sigma}_j^{-1} r p_j \\ &= \int_0^1 \frac{1}{\rho} \Sigma_{ij}^{-1} [k_j [(\gamma + 1) \hat{\mu}_{ij} + \gamma v_j] - l] di - \frac{1}{\rho} \bar{\Sigma}_j^{-1} r p_j \\ &= \frac{1}{\rho} \bar{\Sigma}_j^{-1} (-l - r p_j + k_j \gamma v_j) + k_j \frac{1}{\rho} \int_0^1 \Sigma_{ij}^{-1} \left((\gamma + 1) \frac{\sigma_0^{-2} \mu_j + (\sigma_\varepsilon^{-2} + y_{in} \sigma_f^{-2}) u_j}{\sigma_0^{-2} + \sigma_\varepsilon^{-2} + y_{in} \sigma_f^{-2}} \right) di \end{aligned}$$

Similarly,

$$\begin{aligned} \int_0^1 q_{Hij}^* di &= \int_0^1 \frac{m_{ij}^* - r p_j}{\rho \Sigma_{ij}^*} di \\ &= \frac{1}{\rho} \bar{\Sigma}_j^{*-1} (-l - r p_j + k_j v_j^*) + k_j \frac{1}{\rho} \int_0^1 \Sigma_{ij}^{*-1} \left((\gamma + 1) \frac{\sigma_0^{-2} \mu_j + (\sigma_\varepsilon^{-2} + y_{in}^* \sigma_f^{-2}) u_j}{\sigma_0^{-2} + \sigma_\varepsilon^{-2} + y_{in}^* \sigma_f^{-2}} \right) di \end{aligned}$$

Define $\bar{\Sigma}_j^w = [\bar{\Sigma}_j^{-1} + \bar{\Sigma}_j^{*-1}]^{-1}$. Solve for rp_j from $\int_0^1 q_{Hij} di + \int_0^1 q_{Hij}^* di = x$.

$$rp_j = \pi_j^0 - l + \bar{\Sigma}_j^w \bar{\Sigma}_j^{-1} k_j \gamma v_j - \rho \bar{\Sigma}_j^w x,$$

where

$$\begin{aligned} \pi_j^0 = & \bar{\Sigma}_j^w k_j \left[\int_0^1 \bar{\Sigma}_{ij}^{-1} \left((\gamma + 1) \frac{\sigma_0^{-2} \mu_j + (\sigma_\varepsilon^{-2} + y_{in} \sigma_f^{-2}) u_j}{\sigma_0^{-2} + \sigma_\varepsilon^{-2} + y_{in} \sigma_f^{-2}} \right) di \right] \\ & + \int_0^1 \bar{\Sigma}_{ij}^{*-1} \left((\gamma + 1) \frac{\sigma_0^{-2} \mu_j + (\sigma_\varepsilon^{-2} + y_{in}^* \sigma_f^{-2}) u_j}{\sigma_0^{-2} + \sigma_\varepsilon^{-2} + y_{in}^* \sigma_f^{-2}} \right) di \end{aligned}$$

To make this clear, assume $\mu_j = u_j$.

$$\pi_0 = (\gamma + 1) k_j \bar{\Sigma}_j^w \bar{\Sigma}_j^{-1} = (\gamma + 1) k_j u_j$$

and

$$rp_j = (\gamma + 1) k_j u_j - l + \bar{\Sigma}_j^w \bar{\Sigma}_j^{-1} k_j \gamma v_j + \bar{\Sigma}_j^w \bar{\Sigma}_j^{*-1} k_j v_j^* - \rho \bar{\Sigma}_j^w x$$

Hence

$$\begin{aligned} q_{Hj} &= \int_0^1 q_{Hij} di = \frac{1}{\rho} \bar{\Sigma}_j^{-1} (k_j (\gamma + 1) u_j + k_j \gamma v_j - l - rp_j) \\ &= \frac{1}{\rho} \bar{\Sigma}_j^{-1} (\rho \bar{\Sigma}_j^w x + k_j \gamma v_j - \bar{\Sigma}_j^w \bar{\Sigma}_j^{-1} k_j \gamma v_j - \bar{\Sigma}_j^w \bar{\Sigma}_j^{*-1} k_j v_j^*) \\ &= \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} x + \frac{1}{\rho} \bar{\Sigma}_j^{-1} k_j \gamma \left(1 - \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} \right) v_j - \frac{1}{\rho} \bar{\Sigma}_j^{-1} k_j \bar{\Sigma}_j^w \bar{\Sigma}_j^{*-1} v_j^* \end{aligned}$$

The aggregate domestic holdings of domestic stocks is given by

$$\int_0^1 q_{Hj} dj = \int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} dj + \int_0^1 \frac{1}{\rho} \bar{\Sigma}_j^{-1} k_j \gamma \left(1 - \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} \right) v_j dj - \int_0^1 \frac{1}{\rho} \bar{\Sigma}_j^{-1} k_j \bar{\Sigma}_j^w \bar{\Sigma}_j^{*-1} v_j^* dj$$

When there are enough many domestic and foreign stocks,

$$\int_0^1 q_{Hj} dj \approx \int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} dj$$

The aggregate domestic holdings of foreign stocks is given by

$$\int_0^1 q_{Fj} dj \approx \int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j^*} dj$$

The ratio of domestic stocks in the portfolio then is

$$\frac{\int_0^1 q_{Hj} dj}{\int_0^1 q_{Hj} dj + \int_0^1 q_{Fj} dj} = \frac{\int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} dj}{\int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j} dj + \int_0^1 \frac{\bar{\Sigma}_j^w}{\bar{\Sigma}_j^*} dj}$$

Appendix C

Appendix to Chapter 3

C.1 Construction of sales distribution for listed firms

The variable construction is based on annual reports filed by listed firms. Among the 1,580 firms in the brokerage portfolio, 980 firms reported identifiable regional sales. Because no guide line is specified on dividing regions in China, some discrepancies exist. Some firms simply divide the whole country into inner province and outer province, while some other firms report sales for each province. For most of these firms, the reporting period is 2008, while for some firms the first half of 2008 is used.

The main purpose is to create two variables measuring the information content in business presence. One is home sales and the other is a modified Herfindahl index for sales distribution. The province level is chosen to be the basic unit of sales distribution. In 2008 there are thirty-one provinces including including directly-controlled municipalities and ethnicity municipalities.

The detailed criteria are as follows.

- Firms who don't report regional sales are excluded. For a firm to be used in my analysis, the firm reports at least two sales figures for different regions. For example, some firms have their revenue for the entire country. An even division across all provinces seems too arbitrary.
- Shenzhen has an exchange but is not a directly-controlled municipality like Shanghai. Since Shenzhen is a main financial center in China and the number of stock investors in Shenzhen is relatively large, business in Shenzhen is peculiar for listed firms. In this study, I account for a firm's sales in Shenzhen separately from province Guangdong.
- In a similar vein, a firm's sales in the home city is also taken from the home province.
- A firm's foreign sales are not accounted for.
- If a firm reports sales numbers for more than one city in a province, these numbers are summed up to the sales number for the province except for the home city and

Shenzhen.

- If a firm reports sales numbers for a region containing several provinces, these sales are allocated to each province weighted by populations so that sales per capita are same for all provinces in the region.
- If a firm's sales report includes a number for a region category called "others", this number is divided across all the provinces that are not explicitly included in the report.

C.2 CM's local bias statistics

The measurement of local bias follows the methodology a mean test in [Coval and Moskowitz \(1999\)](#). The null hypothesis is that distance is not related to deviations from the portfolio implied by the Capital Asset Pricing Model (CAPM). In other words, the alpha in the CAPM is uncorrelated with geographic proximity.

Formally, let $h_{i,j}$ represent the actual weight that investor i places on stock j and m_j represent the portfolio weight on stock j in the benchmark portfolio which investor i 's portfolio is compared to. Denote the number of investors by I and the number of stocks by J . The average distance of investor i from all stocks j weighted by holding portfolio weights is denoted by

$$d_i = \sum_{j=1}^J h_{i,j} d_j,$$

and correspondingly, the average distance of investor i from all stocks j weighted by market portfolio weights is denoted by

$$d_i^M = \sum_{j=1}^J m_j d_j.$$

Market portfolio weights implied by the CAPM are represented by fractions of market capitalization. Holding portfolio weights, therefore, should be portfolio values. As we have discussed before, small holdings can have important implications on the long-term portfolio which we cannot observe in the data. It might be interesting to consider equally weighted portfolio weights for individual portfolios and the benchmark portfolio.

CM's test statistic is defined as

$$LB_i = 1 - \frac{d_i}{d_i^M},$$

which measures the percentage deviation of actual portfolio distance from market portfolio distance. LB_i can be rewritten as

$$LB_i = \frac{1}{d_i^M} \sum_{j=1}^J (m_{i,j} - h_{i,j}) d_j.$$

Therefore, if deviations from the benchmark portfolio are unrelated to the distance, the null hypothesis $H_0 : LB_i = 0$ cannot be rejected.

We can test this hypothesis via a mean test on LB_i for all the individual investors. ω_i assigns weights to investors to determine the importance each investor has on the test statistic. Two weighting schemes are also employed for ω_i : equal weights $\omega_i = 1/I$ and value weights $\omega_i = \sum_{j=1}^J h_{i,j}p_j / \sum_{i=1}^I \sum_{j=1}^J h_{i,j}p_j$, where $h_{i,j}p_j$ is the value of i 's stock holding j . I use portfolio values to calculate value weights because that's the only variable in the data to measure the size of individual investment.

The aggregated average distance of individual holdings is given by

$$D = \sum_{i=1}^I \omega_i d_i = \sum_{i=1}^I \omega_i \sum_{j=1}^J h_{i,j} d_j = \sum_{j=1}^J d_j \sum_{i=1}^I \omega_i h_{i,j},$$

which is the average distance weighted by a combination of ω_i and $h_{i,j}$. When both ω_i and $h_{i,j}$ are value weights, $\sum_{i=1}^I \omega_i h_{i,j}$ reduces to the fraction of the brokerage holdings for stock j to the total value of all the brokerage holdings.

The aggregated average distance of the market portfolio

$$D^M = \sum_{i=1}^I \omega_i d_i^M = \sum_{i=1}^I \omega_i \sum_{j=1}^J m_j d_j = d_i^M$$

is same for every investor in the brokerage, which is independent of investor weights.

The mean test statistic is

$$LB \equiv \sum_{i=1}^I \omega_i LB_i = 1 - \frac{D}{D^M},$$

which in my case measures the percentage deviation of the aggregate distance of actual investment for the brokerage from the aggregate distance of the benchmark portfolio.

Then we have

$$\begin{aligned} LB &= \sum_{i=1}^I \omega_i \frac{1}{d_i^M} \sum_{j=1}^J (m_j - h_{i,j}) d_j = \sum_{j=1}^J \frac{d_j}{D^M} \sum_{i=1}^I \omega_i (m_j - h_{i,j}) \\ &= \sum_{j=1}^J \frac{d_j}{D^M} \left[m_j - \sum_{i=1}^I \omega_i h_{i,j} \right] \end{aligned}$$

Therefore, the LB statistics can be viewed from two dimensions. It is a weighted average of individual portfolio deviations. On the other hand, it can be expressed as the deviation of the aggregated brokerage portfolio.