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DEVELOPING A METHODOLOGY FOR ASSESSING THE ECONOMIC IMPACTS OF LARGE SCALE ENVIRONMENTAL REGULATIONS

by

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February 2000

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Abstract

This paper explains the development and implementation of a methodology for assessing the economic impacts of large-scale environmental regulations. The development process began with a literature review surveying channels through which environmental regulations might influence economic performance. Avenues deemed suitable were incorporated into a computable general equilibrium (CGE) model of the California economy. This model is based on the California Department of Finance's Dynamic Revenue Analysis Model (DRAM). Modifications to DRAM for the current project include a revised sectoring scheme that features industries of particular regulatory interest, revamped data matrices that accommodate this new sectoring scheme, a new air pollution module, programming options designed to facilitate the simulation of environmental regulations, and enhanced output reporting that highlights income, production, employment, and price responses to proposed regulatory changes. The new model, E-DRAM, is implemented, policy experiments are run, and their results are interpreted.

A brief time-series exploration of state-product, pollution prevention costs, and pollution follows. In it, vector auto regression (VAR) techniques are used to investigate the relationship between Gross State Product (GSP), pollution prevention expenditures, and levels of pollution. Findings suggests that the cost of holding pollution levels constant increases with GSP and that the cost of pollution control given GSP rise as ambient pollution levels fall. This line inquiry will be more fruitful as more data becomes available.

A Computable General Equilibrium Model for Assessing the Economic Impacts of Large Scale Environmental Regulations

1 Introduction:

Cal/EPA is required by legislative mandate to evaluate the economic effects of its regulations. That agency is currently facile with partial equilibrium techniques which rely on the assumption that parts of the economy not directly subject to the regulation in question are unaffected by that regulation. While suitable for evaluating the economic effects of minor regulations, these techniques are unsuitable for assessing the economic impact of large-scale regulations, such as the State Implementation Plan for the federal Clean Air Act, which can affect the overall size, composition, and competitiveness of the California economy. Therefore, under agreement no. 98-300 investigators at the University of California, Berkeley have developed and demonstrated the implementation of a methodology for assessing the economic impact of large-scale environmental regulations for the Cal EPA/Air Resources Board (ARB).[1]

Computable General Equilibrium (CGE) models are the preferred tools for simultaneously modeling multiple economic relationships and tracing their combined responses to large-scale economic shocks such as broad tax and regulatory changes. Having worked intimately with the California Department of Finance (DOF) to construct the Dynamic Revenue Analysis Model (DRAM), a CGE of the California Economy used for fiscal analysis of pending tax bills, the Berkeley investigators chose this model as the basis for E-DRAM—a CGE suitable for Cal/EPA's use. Like DRAM, this new model is tailor-made for California and extremely refined. It describes the relationships between California producers, California consumers, government, and rest of the world. E-DRAM also features an entirely new air pollution module.

Before modifying DRAM for current purposes, the literature on relationships between environmental regulation and economic performance was studied. One product of this investigation is a literature review that summarizes work considering the influence

[1] The statements and conclusions in this report are those of the University and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

of environmental regulation on phenomena as diverse as technological innovation, investment, trade, and worker as well as firm location decisions. Appendix A provides a summary of this literature review. Insights from the literature also guided construction of E-DRAM and aid interpretation of policy experiment results.

The new model, E-DRAM, is different from DRAM in three respects. First, it features a new industrial aggregation scheme designed to highlight sectors of particular regulatory interest to ARB. More specifically, DRAM's 28 industrial classifications have been expanded to thirty, with new gasoline-powered engine and consumer chemical sectors added at the suggestion of ARB. Second, the model's underlying data matrices that organize production, consumption, and government data have been modified to support the revised industrial aggregation scheme. Third, an air pollution module that enables E-DRAM to track industry-specific emissions of seven critical air pollutants has been added. Copies of the E-DRAM code and associated input files can be found in Appendices B and C1-C4 respectively.

The remainder of this report elaborates on the model development work outlined above. It also gives a detailed account of how to implement various regulatory scenarios in E-DRAM, complete with sample policy experiments and an interpretation of their results.

2 Model Development:

The construction of E-DRAM and an understanding of its policy implications are enlightened by a review of some relevant literature.

2.1 Literature Review:

An investigation of the channels through which environmental regulations may affect the economy was undertaken at the outset of this contract. The product of this research was a literature review.[2] To summarize briefly, there is ongoing debate over the influence of environmental regulations on rates of technological innovation, types and flows of private investment and trade, and the location decisions of workers and firms. Given that evidence concerning the existence and size of such influences is mixed, and considering the challenges posed by fully integrating such effects into a model as

[2]See Appendix A

sophisticated as DRAM, these phenomena have not been explicitly modeled as direct functions of environmental regulation in E-DRAM. A major strength of CGEs, however, is the implicit account they take of such phenomena. In E-DRAM, regulations that directly raise costs of production and/or prices in an industry can indirectly discourage both investment in and exports by that target industry as well as industries that rely on that sector for productive inputs. Investment in affected industries is curtailed via lower returns to capital while exports are discouraged by higher terms of trade (the ratio of domestic to world prices). Additionally, higher costs and prices discourage firms and workers from locating in the regulated area.

2.2 From DRAM to E-DRAM:

E-DRAM is a modified version of DRAM. Following a brief description of the base model, features specific to E-DRAM are discussed below.

2.2.1 DRAM:

DOF and Professor Peter Berck developed DRAM in compliance with California Senate Bill 1837 enacted in August of 1994. DRAM is used for performing dynamic revenue analysis of proposed legislation having significant revenue impacts. The model is dynamic in the sense that it is designed to capture the rational responses of economic agents to policy changes. DRAM is written in GAMS (General Algebraic Modeling System) programming language, publicly available, and currently maintained by the DOF. DOF is responsible for making the model represent conditions in California for the most recent year for which data are available. DRAM, extremely rich and calibrated to beyond the fifth significant digit, is a very powerful tool.

In its first incarnation, DRAM consisted of over 1,000 equations designed to capture the interactions between 28 California industrial groupings (sectors), 10 household types (classified by income level), and 36 government sectors (8 federal, 21 state, and 8 local), and the rest of the world (ROW). Each of the 28 industrial sectors accounts for roughly 4 percent of the firms in the state. Of these 28, 26 are producers; the remaining two are transportation and retail. The productive sectors create value added by combining factors of production: intermediate goods, rented capital, and hired labor. Intermediate goods, in turn, are made by other productive sectors. Households supply capital and labor. The federal, state and local government sectors tax and spend. Trade in factor markets and migration of households link California with the rest of the world. While refinements to the model are ongoing, the structure described here remains basically the same.[3]

2.2.2 E-DRAM:

In order to be used for analyzing the economic impacts of large scale environmental regulations, DRAM has been converted into E-DRAM, an environmentally oriented version of the base model that features a revised industrial sectoring scheme, modified data matrices, and a new industrial air pollution emissions module.

2.2.2.1 Revised Industrial Aggregation Scheme:

DRAM's 28 industrial sectors have been expanded to 30 in E-DRAM. The new sectors, cited by ARB as industries of particular regulatory interest, are producers of consumer chemicals (CONCH) and gasoline powered engines (ENGIN). The former is a subdivision of DRAM's broader chemicals (CHEM) sector, while the latter is composed of pieces from both DRAM's aerospace (AEROS) and other manufacturing (OTHMA) sectors. More specifically, the new CONCH sector is comprised of industries classified by SIC codes 284 and 285 (BEA Industry Numbers 29.0201-30.0000) and includes producers of soaps, detergents, toilet preparations, and surface coatings. The new ENGIN sector is comprised of SIC codes 351-353 (BEA Industry Numbers 43.0100-45.0200) and contains producers of gas-powered engines and machinery, *e.g.* motorcycles and snowmobiles, classified as OTHMA in DRAM. The new ENGIN sector also contains SIC codes 3724 and 3764 (BEA Industrial Number 60.2000) covering aircraft and missile engines respectively, which are both classified as AEROS in DRAM.[4] The revised industrial aggregation scheme outlined here is just one example of how the sectors explicitly tracked by E-DRAM can be manipulated. Any large industry targeted for major new regulation can be isolated in a similar fashion.

2.2.2.2 Modified Data Matrices:

Using a sectoring scheme different from that maintained by DOF requires rebuilding the social accounting matrix (SAM), capital coefficients matrix (CCM), and a few other data matrices (contained in the MSC file) that supply input to the model. Briefly, the SAM organizes data on the relationship between industries, households,

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[3] An example of ongoing refinement is DOF's current work to further disaggregate industrial sectors (toward the 2-digit SIC code level).

[4] See Appendix E for the complete mapping between BEA numbers and E-DRAM sectors.

factors (capital and labor), and government. The CCM contains coefficients governing how investments made by one industry are spent on other industries. Matrices in the MSC file store other key information; e.g. tax data, consumption function parameters, and trade elasticities.[5]

2.2.2.3 New Air Pollution Module:

A major feature of E-DRAM is the incorporation of industry-specific air pollution data. ARB supplied a raw data file of 1998 emissions forecasts based on their 1996 Emissions Inventory Report. The raw data file consisted of 55, 962 records, each containing the average daily emission of a particular air pollutant (TOG, CO, NOx, SOx, or PM)[6] from a particular source listed by emissions inventory code (EIC) and type (stationary point, stationary area, area-wide/non-point, motor vehicles, other mobile, or natural source). A mapping was then created from EICs to E-DRAM sectors.[7] Next, records were aggregated by industry and pollutant. Each industry's emissions of each pollutant were subsequently divided by that industry's base level output. The final result is a matrix of industry-specific emission intensities for each of seven critical air pollutants.[8] The inclusion of this module allows total as well as industry-specific emissions for each critical pollutant to be tracked under various policy scenarios.

2.3 Calibration:

Before using an applied CGE model, calibration must be verified. Specifically, the model should be run to ensure that its solution replicates current conditions. Fortunately, DRAM is very well calibrated – the initial solve replicates the base data beyond the fifth significant digit. With the above modifications made, E-DRAM remains well calibrated.

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[5] See Appendix D for step-by-step instructions on modifying the SAM and other input data matrices for a new sectoring scheme.[For a complete description of how DRAM (and thus E-DRAM) works, the reader is referred to the DOF publication *Dynamic Revenue Analysis for California*, Summer 1996, by P. Berck, E. Golan, and B. Smith with J. Barnhart and A. Dabalen. This publication contains an overview of the model, a description of data requirements and organization, and an equation by equation explanation of the GAMS code. A copy of this comprehensive manual is enclosed and can also be accessed via *www.dof.ca.gov/html/fs_data/dyna-rev/dynrev.html.*]

[6] Additionally, ROG and PM10 emissions are derivable from record-specific information on the fraction of TOG, that is ROG, and PM that is PM10.

[7] Emissions designated as emanating from households and natural sources were not mapped. All emissions from mobile sources were assigned to the transportation sector.

[8] Data handling for this process was done using SAS. Relevant code and intermediate data files are available upon request. See Appendix C4 for the final pollution matrix.

Although some initial solution values differ from the base data at the third and fourth significant digits, no discrepancy is greater than 0.4% and most are much less.

3 Implementing Regulatory Scenarios:

All regulations can be thought of as some combination of price and input requirement changes (generally increases). Given information on how much a proposed regulation is to change price, intermediate, or capital requirements in a target industry, E-DRAM can simulate the effects of this regulation on the CA economy. To facilitate this, new regulatory parameters have been added to the model. Adjusting one set of these new parameters simulates a regulatory price increase, adjusting another set simulates input requirement changes. A third set of parameters address trade considerations and a fourth set handle required investment. Each type of implementation is explained below.

3.1.1 A Price Increase:

One common method of simulating regulations is to model them as price increases. Sales taxes are an obvious example. Regulations predicted to raise product prices by *x*% are also good candidates.

In DRAM, the before-tax price of industry *I* goods are P(I). The after-tax prices are P(I)*(1+TAUQX(I)). In E-DRAM, parameters REG5(I) and REG6(I) have been added such that after-tax, regulation-inclusive prices are expressed as P(I)*(1+TAUQX(I)+REG6(I))*(1+REG5(I)). In the base/no-regulation case, both REG5(I) and REG5(I) are set to zero. To simulate a regulation that increases after-tax prices by *x*%, REG5(I) is set to *x*/100; to simulate a regulation that increases pre-tax prices x%, REG6(I) is set to *x*/100.[9] Such implementations trigger price increases that have the standard (negative) effect on demand, with the caveat that neither producers nor government receive the *x*% markup. Conceptually and operationally, they are equivalent to a sales tax with receipts that do not get spent. See Section 3.2.1.1 for an example.

3.1.2 An Increase in Intermediate Requirements:

A second way to simulate regulations is to model them as increased intermediate requirements. Each industrial sector in E-DRAM is implicitly characterized by a production function that relates output to factor (capital and labor) and intermediate inputs. These relationships can be modified to mimic the effect of regulations requiring increased intermediate input use by target industries in the following manner. Industry *I*'s demand for intermediates from industry *J* per unity of output is governed by parameter-products REG1(I,J)*AD(I,J). AD(I,J) are input-output coefficients calculated from primary data contained in the SAM. In E-DRAM, these coefficients can be scaled directly by changing the new parameter REG1(I,J) from its default setting of unity. Setting REG1(*'industry I label'*, J) = 1.1 for example, simulates a 10% increase in all intermediates required to produce one unit of good *I*. Specifying AD(*'industry I label'*, *'industry J label'*) = 1.1, in contrast, simulates a regulation requiring industry I to use 10% more of industrial good J (*e.g.* pollution control products) only in making a unit of output. See Section 3.2.1.2 for an example.

3.1.3 Required Investment:

Proposed regulations may also be conceived in terms of the investment required by target industries to comply. Investment cannot be forced (since firms can drop out of the industry rather than comply)—only induced via the rate of return on investment. Modeling "required" investment in E-DRAM can be done in two alternate fashions.

First, a regulation requiring investment equivalent to an *x%* increase in capital stock can be modeled as a one-time *x%* reduction in the existing capital stock ("bomb" scenario).[10] This makes sense if the imposition of a regulation is thought of as the immediate elimination of *x%* of the base capital stock by virtue of requiring its dedication to regulatory compliance rather than the production of saleable output. Alternately, a regulation requiring *x%* investment can be modeled a prescription that out of each dollar spent on capital investment (past, present, and future), *x* cents are dedicated to regulatory compliance and 100 minus *x* cents are dedicated to the production of saleable output ("effective capital stock" scenario). This makes sense if you think in terms of ongoing effective (productive) capital stock. The distinction between the "bomb" and "effective capital stock" scenarios can be seen more clearly by referring to the desired capital stock equation in E-DRAM that has been reproduced immediately below.

```
* 4.3 DESIRED CAPITAL STOCK
  KS(I) =E= REG13(I) * KSO(I) * ( R('CAPIT',I) / RO('CAPIT',I) ) ** ETAI(I) -  (1 - REG12(I))* KSO(I);
```

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[9] For example, to simulate in 30% increase the pre-tax price of good *I*, REG5(I) is set to 0.30.

[10] All investment must be stated in percentage of capital stock terms due to data limitations dictating that capital stocks in the model be imputed from payments to capital rather than expressed in actual dollar units.

Requiring x% additional investment translates into setting REG13(I) = (1-x) under "bomb" scenario, or alternately setting REG12(I) = x under the "effective capital stock" scenario. See section 3.2.2.1 for further details.

3.1.4 Trade Considerations:

However regulations are modeled, their implications for trade should be considered. The methods discussed above effectively raise the relative (to world) domestic price of goods produced by the regulated sector. Exports naturally fall as a result – a response captured in E-DRAM by the sensitivity of exports to terms of trade.[11] The response of imports (M(I)) is not so straightforward however. To model this response, two questions must be answered. First, what percentage (REG3(I)) of base imports (M0(I)) will meet the new regulations? Second, will the import price elasticity (ETAM(I)) fall as a result foreign producers having to alter their product for sale in the regulated market? Industry *I* imports are governed in E-DRAM by the following equation:

* 3.02 IMPORT SUPPLY

$$M(I) = REG3(I) * M0(I) * \left[\frac{PD(I)}{PD0(I)}\right]^{ETAM(I)}.$$

REG3(I) and ETAM(I) are set to 1 and 1.5 respectively by default. They can be altered at the policy analyst's discretion. Setting Reg3(I) less than one means that all else (i.e. relative prices) equal, imports drop below their base level M0(I). This is reasonable if goods not meeting the new regulatory requirement(s) are not imported. Dropping ETAM(I) reduces the sensitivity of imports to relative prices. It is plausible that relative domestic price increases triggered by increased regulatory compliance costs will not attract imports to the degree that demand-driven price increases do.

[11] See equation 3.01 in E-DRAM GAMS code. In that equation, exports are sensitive to domestic (CA) price, which is raised by environmental regulation. Implicit in this approach is the assumption that producers in California sell the same product at home and outside the state. Relaxing this assumption would entail changing equation 3.01 such that exports are sensitive to a price other than domestic price (perhaps a somewhat lower price reflecting the lower production cost of non-compliant goods).

3.2 Policy Experiments:

Two policy experiments suggested by ARB were the regulation of architectural coatings and reformulated gasoline. Although specific regulatory proposals were not provided, examples have been generated for illustrative purposes.

3.2.1 Architectural Coatings:

ARB is considering lowering the VOC content limit for the coating category of industrial maintenance. This regulation is projected to raise the cost of architectural coatings by 10-20%. Architectural coatings comprise approximately 37% of paints and allied products (SIC code 285/BEA Industrial Number 30.0000), which in turn comprise roughly 26% of E-DRAM's consumer chemicals (CONCH) sector. The preferred way to model this regulation is as a 1.45%[12] increase in intermediate goods required to produce a unit of consumer chemicals, coupled with a reduction in the sensitivity of imports to domestic consumer chemical prices that essentially leaves the level of imports in that sector unchanged. Modeled in this way, E-DRAM predicts that the VOC regulation under consideration will have a negligible impact on the California economy. Output and employment in the state's consumer chemical sector may drop by roughly $8 million (1%) and 184 jobs (1%) respectively. Statewide, aggregate real personal income may fall by rough $40 million (0.005%) and approximately 300 (0.002% of) jobs could be lost.[13] Additional scenarios have been implemented in order to analyze the sensitivity of these results to various model specifications.

3.2.1.1 Experiment 1: A Straight Price Increase:

This regulation was first modeled as a straight 15% price increase in SIC 285, which translates into a 1.443% increase in the price of consumer chemicals.[14] Based on the GAMS code modifications discussed in Section 3.1.1, a policy experiment designed to analyze the economic impacts of such a price increase is accomplished by inserting the following annotated line of code then resolving E-DRAM.

```
* EXPERIMENT 1: INCREASE PRICE OF CONSUMER CHEMICALS BY 1.443 %
  REG5('CONCH') = (0.37)*(0.26)*(0.15);
```

[12] See footnote 21.

[13] See column seven of Table 7 for further results.

[14] $(0.15)*(0.37)*(0.26) = 0.01443$.

SOLVE EDRAM MINIMIMIZING SPI USING NLP; .[15]

Before discussing the results of experiment 1, a brief discussion of how results for all policy scenarios will be presented throughout this report is in order. For each policy experiment run, E-DRAM is programmed to print the solution values of a standard battery of statewide and industry specific variable in table format. Each column of these tables corresponds to a particular experiment/model run. The first row of each table contains labels for each experiment reported in that table [e.g. the label for experiment 1 is CONCH1]. The second and third rows report model and solver status respectively [entries in these rows should confirm that the model has found a (locally) optimal solution for the experiment in question]. Next come the rows reporting statewide and target industry economic indicators. First to be reported is "CA PERSONAL INCOME", the total real income of all state residents. This and all subsequent variables are reported first in levels then absolute and percentage change from their initial model run (labeled TODAY) values. Next a normalized measure of statewide consumer prices, "CONSUMER PRICE INDEX (BASE=1)" is reported, followed by the number of families residing in the state, "POPULATION (MILLION FAMILIES)". Then comes a normalized indicator of California wage level, "WAGE INDEX (BASE=1)". Millions of jobs in the state, "LABOR DEMAND (MILLIONS)" is listed next. Following these indicators comes a normalized weighted average of the rate of return on investment statewide, "RETURN TO K INDEX (BASE=100)", and an imputation of overall capital stock reported in billions of dollars, "CAPITAL STOCK ($100 BILLION). The last statewide economic indicator reported for each experiment is "GROSS PRIVATE INVESTMENT" which is calculated as the amount required to maintain existing industrial capital stocks in the face of depreciation.

Following statewide indicators, vital statistics for the industry targeted by the experimental regulation are reported. Again, levels are reported first, followed by absolute and percent changes from the initial (TODAY) solutions. The first thing reported is sector output measured in billions of dollars, "OUTPUT ($BILLION)". Next

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[15] Solving the model as a maximization or minimization of any of the variables should yield the same result; minimizing state personal income (SPI) using a non-linear programming algorithm (NLP) is the method employed here. Such solve statement must be invoked after coding each new policy experiment, but will not be referenced explicitly in this report again.

comes imputed capital stock measured in hundreds of billions of dollars, "CAPITAL ($100 BILLION)", followed by millions of jobs in that particular sector, "JOBS (MILLIONS)". A normalized price of that sector's goods is reported next as "PRICE (BASE=1)". Then the value of imports of that sector variety in billions of dollars, "IMPORTS ($BILLION)", is given. Last to be reported is a normalized measure of the cost of capital/return on investment in the target industry, "CAPITAL RENTAL RATE (BASE=100)".

Now full attention can be turned to the results of experiment 1 listed in column 3 (labeled CONCH1) of Table 1.[16] Looking first at the consumer chemical sector, we see that price rises, but by less than the amount implemented. The static increase (1.44%) is militated against by both the downward slope of consumer demand (*i.e.* quantity demanded falls as price rises) and an inward shift in that demand (i.e. quantity demanded falls at every price). This latter effect would be missed in a partial equilibrium analysis, but is picked up in E-DRAM. Notice that statewide real income, employment, the aggregate consumer price index, capital stock, and the return to capital fall slightly – all signs of general economic contraction.[17] Although the price of consumer chemicals rises only slightly in this experiment, output in that sector drops significantly. As a result of the price wedge introduced by regulation, the industry ends up employing roughly 16% less capital and 17% (2,900) fewer workers. Output of consumer chemicals drops by nearly 17% (almost $130 million) as well.[18] The elasticities of consumer chemical employment and output with respect to general equilibrium (static/regulatory) price are both thus nearly –36 (-12).[19] Worker displacement in the consumer chemicals sector

[16] The full output of this and other experiments can be found in the GAMS results (RES) files. This output is captured via a long string of code not included here, but that can be seen in the program code immediately following the annotation * SAVE SOLUTION VALUES which appears after each experimental run.
[17] Not surprisingly the economy-wide changes predicted by the model under this (and subsequent) scenario(s) are very small and well within the error bounds of the model. While quantitative result should not be used to convey a false sense of precision, they are in line with qualitative results consistent with economic theory
[18] These figures as well as all other change and percentage change numbers in the following results tables measure change between current and initial (TODAY) model runs, not changes between current and immediately preceding model runs.
[19] These sector responses are implausibly high. Such results may driven by the relatively small size of the consumer chemical sector relative to other industries in the model, i.e. the regulation in question may be too small to be effectively assessed using E-DRAM. This shortcoming may be corrected in forthcoming versions of DRAM where industrial sectors are disaggregated to roughly the 2-digit SIC level.

creates a bit of slack in the labor market, which slightly deflates economy-wide wages, thus allowing other sectors to hire more labor. Predicted statewide income and employment losses (roughly $160 million and 1,000 jobs respectively) are thus minimal; their implied elasticities with respect to the price of consumer chemicals are negligible as expected.[20]

3.2.1.2 Experiment 2: An Increase in Intermediate Input Requirements:

The regulation simulated immediately above can also be modeled as an approximately 1.45% across-the-board increase in intermediates required for the production of consumer chemicals.[21] This second specification is preferable on the grounds that it incorporates the stimulus of spending induced by regulatory compliance. While target industry costs increase, those additional costs are spent on intermediate inputs supplied by other sectors. Capturing these secondary effects is a particular strength of CGE models such as E-DRAM. As discussed in Section 3.1.2, a policy experiment along these lines is implemented with the code below.

```
* EXPERIMENT 2: INCREASE INTERMED. REQS. IN THE CONCH SECTOR BY 1.443 %
  REG5('CONCH') = 0; 22
  REG1( I, 'CONCH') = 1 + (0.37)*(0.26)*(0.15)/0.922185;
```

Select results of this policy experiment are listed in column 4 (labeled CONCH2) of Table 1. As indicated there, the economic burden of this scenario is somewhat less than that imposed by the straight price hike. In this case, the price of consumer chemicals rises slightly more and output falls a bit less than in experiment 1 because consumer demand shifts back less. That sector's overall elasticity of output and employment with respect to general equilibrium (static/regulatory) price are now –31 (-11) rather than -36. New spending on intermediates mitigates the general economic contraction. Notice how California personal income, aggregate consumer price index, capital stock, return to capital, and statewide employment fall even less than previously.

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[20] Throughout, results should be taken as indication of the rough order of magnitude and direction of effects to be expected. A false sense of precision should not be conveyed, especially where numerical results fall within the error bounds of the model – which they often do (*e.g.* the statewide income and employment numbers cited here).

[21] Intermediates must be increased by 1.44%/0.922185 ≅ 1.45% to trigger a static price increase of 1.44% [the denominator is the share of cost of intermediates in the price of CONCH].

[22] Note: <u>It is necessary to undo model changes by resetting modified parameters to their default setting between policy experiment unless you want such changes to carry over.</u>

Table 1: Architectural Coatings Experiments

model run	TODAY	**CONCH1**	**CONCH2**
Experiment description	initial solve & calibration check	1.443% price increase	increase intermediate requirements
MODEL	LOC OPT	LOC OPT	LOC OPT
SOLVER	OPTIMAL	OPTIMAL	OPTIMAL
CA economy			
CA PERSONAL INCOME ($BILLION)	891.55414	891.395596	891.40875
CHANGE CA PERS. INC.	-0.136282	-0.158545	-0.145391
% CHANGE CA PERS. INC.	-0.000153	-0.000178	-0.000163
CONSUMER PRICE INDEX (BASE=1)	0.999929	0.999736	0.999757
CHANGE AGGREGATE CPI	-0.000071	-0.000194	-0.000173
% CHANGE AGGREGATE CPI	-0.000071	-0.000194	-0.000173
POPULATION (MILLION FAMILIES)	23.140787	23.140307	23.140339
CHANGE POPULATION	-0.000549	-0.00048	-0.000448
% CHANGE POPULATION	-0.000024	-0.000021	-0.000019
WAGE INDEX (BASE = 100)	99.973381	99.919886	99.925055
CHANGE WAGE INDEX	-0.026619	-0.053495	-0.048326
% CHANGE WAGE INDEX	-0.000266	-0.000535	-0.000483
LABOR DEMAND (MILLIONS)	14.045159	14.044133	14.044198
CHANGE LABOR DEMAND	-0.000746	-0.001026	-0.000962
% CHNGE LABOR DEMAND	-0.000053	-0.000073	-0.000068
RETURN TO K INDEX (BASE=100)	99.999198	99.997692	99.997836
CHNAGE RETURN TO CAPITAL INDEX	-0.000802	-0.001506	-0.001362
% CHANGE RETURN TO CAPITAL INDEX	-0.000008	-0.000015	-0.000014
CAPITAL STOCK ($100 BILLION)	14.541822	14.536671	14.53714
CHANGE CAPITAL STOCK	-0.002212	-0.005151	-0.004682
% CHANGE CAPITAL STOCK	-0.000152	-0.000354	-0.000322
GROSS PRIV. INVESTMENT($BILLION)	68.618983	68.594678	68.596891
CHNGE. GROSS PRIV INVESTMENT	-0.01044	-0.024305	-0.022092
% CHANGE GROSS PRIV. INVESTMENT	-0.000152	-0.000354	-0.000322
CONCH sector			
OUTPUT ($BILLION)	0.767794	0.638636	0.64624
CHANGE OUTPUT	-0.000263	-0.129158	-0.121554
% CHANGE OUTPUT	-0.000343	-0.16822	-0.158316
CAPITAL ($100 BILLION)	0.014567	0.012174	0.012313
CHANGE CAPITAL	-0.000007	-0.002393	-0.002254
% CHANGE CAPITAL	-0.000477	-0.164265	-0.154755
JOBS (MILLIONS)	0.017023	0.014122	0.014295
CHANGE JOBS	-0.000005	-0.002901	-0.002729
% CHANGE JOBS	-0.000283	-0.170404	-0.160283
PRICE (BASE=1)	0.999995	1.004733	1.005107
CHANGE PRICE	-0.000005	0.004738	0.005113
% CHANGE PRICE	-0.000005	0.004738	0.005113
IMPORTS ($BILLION)	2.395456	2.488635	2.495128
CHANGE IMPORTS	-0.000088	0.093179	0.099673
% CHANGE IMPORTS	-0.000037	0.038898	0.041609
CAPITAL RENTAL RATE (BASE=100)	0.02122	0.014688	0.015033
CNANGE CAPITAL RENTAL RATE	-0.000021	-0.006531	-0.006186
% CHANGE CAPITAL RENTAL RATE	-0.000977	-0.307786	-0.291542

3.2.1.3 Experiments 3 - 7: Trade Considerations (Import Elasticity):

As discussed in Section 3.1.4, regulators may want to consider trade implications when assessing the economic impact of domestic regulations. There are two ways to do this in E-DRAM. One is to adjust parameter ETAM(I) governing the elasticity of regulated sector *I* imports with respect to the California ("domestic") price of that good. Imports may be less sensitive to regulation [vs. demand] induced California price increases because the cost of producing compliant products is likely to be just as high for out-of-state producers as for in-state ones. Experiments 3 – 6 (labeled CONCH2T1 – to CONCH2T4) in Table 2 are identical to the thus far preferred specification for regulation of architectural coatings (labeled CONCH2), except that the ETAM('CONCH') parameter is progressively ratcheted down from its default of 1.5 to 0.5 in increments of 0.25. In experiment 7 (labeled CONCH2T4.5*), the preferred specification, ETAM('CONCH') is reduced to zero, effectively eliminating any increase in imports due to the new regulation. Results from this scenario suggest that output and employment in the state's consumer chemical sector may drop by roughly $8 billion (1%) and 184 jobs (1%) respectively as a result of the new regulation considered. Statewide, aggregate real personal income may fall by rough $40 million (0.005%) and approximately 300 (0.002% of) jobs could be lost.

Not surprisingly, what we see from this set of experiments is that as ETAM('CONCH') – the elasticity of imports of consumer chemicals with respect to the California price of consumer chemicals – falls, the adverse effects of regulation shrink. Domestic output and employment in the target sector rise toward their initial level, imports in that sector fall back toward their initial level, and prices in that sector creep upward as ETAM is adjusted downward in the face of environmental regulation. E-DRAM suggests elasticities of domestic output (employment) in the consumer chemical sector with respect to ETAM of – 0.19 (-0.21), -0.15 (-0.15), -0.11 (-0.11), and –0.8 (-0.8) at initial values of ETAM of 1.5, 1.25, 1.0, and 0.75 respectively. Looking at statewide indicators, as ETAM drops, personal income, the consumer price index, labor demand, capital stocks, and the return to capital all rises back towards their initial levels.

Table 2: Architectural Coatings Experiments – Sensitivity to Import Elasticity

model run	CONCH2	CONCH2T1	CONCH2T2	CONCH2T3	CONCH2T4	CONCH2T4.5*
description	increase intermediate requirements	CONCH2 & ETAM=1.25	CONCH2 & ETAM=1.0	CONCH2 & ETAM=0.75	CONCH2 & ETAM=0.5	CONCH2 & ETAM=0.0
MODEL	LOC OPT	LOC OPT	LOC OPT	LOC OPT	LOC OPT	LOC OPT
SOLVER	OPTIMAL	OPTIMAL	OPTIMAL	OPTIMAL	OPTIMAL	OPTIMAL
CA PERSONAL INCOME ($BILLION)	891.40875	891.42751	891.44572	891.46344	891.48071	891.51398
CHANGE CA PERS. INC.	-0.145391	-0.126632	-0.108416	-0.090697	-0.073436	-0.040156
% CHANGE CA PERS. INC.	-0.000163	-0.000142	-0.000122	-0.000102	-0.000082	-0.000045
CONSUMER PRICE INDEX (BASE=1)	0.999757	0.999788	0.999818	0.999848	0.999876	0.999931
CHANGE AGGREGATE CPI	-0.000173	-0.000141	-0.000111	-0.000082	-0.000053	0.000002
% CHANGE AGGREGATE CPI	-0.000173	-0.000141	-0.000111	-0.000082	-0.000053	0.000002
POPULATION (MILLION FAMILIES)	23.140339	23.140385	23.140429	23.140471	23.140513	23.140594
CHANGE POPULATION	-0.000448	-0.000402	-0.000358	-0.000316	-0.000274	-0.000194
% CHANGE POPULATION	-0.000019	-0.000017	-0.000015	-0.000014	-0.000012	-0.000008
WAGE INDEX (BASE = 100)	99.925055	99.93292	99.940552	99.947972	99.955196	99.969113
CHANGE WAGE INDEX	-0.048326	-0.040461	-0.032829	-0.025409	-0.018185	-0.004268
% CHANGE WAGE INDEX	-0.000483	-0.000405	-0.000328	-0.000254	-0.000182	-0.000043
LABOR DEMAND (MILLIONS)	14.044198	14.044316	14.04443	14.044542	14.044651	14.04486
CHANGE LABOR DEMAND	-0.000962	-0.000844	-0.000729	-0.000618	-0.000509	-0.000299
% CHNGE LABOR DEMAND	-0.000068	-0.00006	-0.000052	-0.000044	-0.000036	-0.000021
RETURN TO K INDEX (BASE=100)	99.997836	99.998038	99.998236	99.998431	99.998623	99.998998
CHNAGE RETURN TO CAPITAL INDEX	-0.001362	-0.001161	-0.000962	-0.000767	-0.000575	-0.0002
% CHANGE RETURN TO CAPITAL INDEX	-0.000014	-0.000012	-0.00001	-0.000008	-0.000006	-0.000002
CAPITAL STOCK ($100 BILLION)	14.53714	14.53787	14.538578	14.539265	14.539934	14.541223
CHANGE CAPITAL STOCK	-0.004682	-0.003952	-0.003245	-0.002557	-0.001888	-0.0006
% CHANGE CAPITAL STOCK	-0.000322	-0.000272	-0.000223	-0.000176	-0.00013	-0.000041
GROSS PRIV. INVESTMENT($BILLION)	68.596891	68.600333	68.603672	68.606917	68.610074	68.616153
CHNGE. GROSS PRIV INVESTMENT	-0.022092	-0.01865	-0.015311	-0.012066	-0.008909	-0.00283
% CHANGE GROSS PRIV. INVESTMENT	-0.000322	-0.000272	-0.000223	-0.000176	-0.00013	-0.000041
CONCH						
OUTPUT ($BILLION)	0.64624	0.666499	0.686151	0.705248	0.723833	0.759619
CHANGE OUTPUT	-0.121554	-0.101295	-0.081643	-0.062546	-0.043961	-0.008175
% CHANGE OUTPUT	-0.158316	-0.13193	-0.106335	-0.081462	-0.057256	-0.010647
CAPITAL ($100 BILLION)	0.012313	0.012689	0.013054	0.013408	0.013753	0.014416
CHANGE CAPITAL	-0.002254	-0.001878	-0.001513	-0.001159	-0.000814	-0.000151
% CHANGE CAPITAL	-0.154755	-0.128921	-0.103877	-0.079556	-0.055902	-0.010394
JOBS (MILLIONS)	0.014295	0.014749	0.01519	0.015618	0.016036	0.01684
CHANGE JOBS	-0.002729	-0.002274	-0.001833	-0.001405	-0.000987	-0.000184
% CHANGE JOBS	-0.160283	-0.133594	-0.107695	-0.082518	-0.058006	-0.010787
PRICE (BASE=1)	1.005107	1.005227	1.00534	1.005448	1.005552	1.005746
CHANGE PRICE	0.005113	0.005232	0.005345	0.005454	0.005557	0.005751
% CHANGE PRICE	0.005113	0.005232	0.005345	0.005454	0.005557	0.005751
IMPORTS ($BILLION)	2.495128	2.477333	2.46007	2.443297	2.426973	2.395544
CHANGE IMPORTS	0.099673	0.081877	0.064615	0.047841	0.031517	0.000088
% CHANGE IMPORTS	0.041609	0.03418	0.026974	0.019972	0.013157	0.000037
CAPITAL RENTAL RATE (BASE=100)	0.015033	0.01599	0.016947	0.017903	0.018859	0.02077
CNANGE CAPITAL RENTAL RATE	-0.006186	-0.005229	-0.004273	-0.003316	-0.00236	-0.00045
% CHANGE CAPITAL RENTAL RATE	-0.291542	-0.246439	-0.201355	-0.156288	-0.111238	-0.021192

* indicates preferred specification

3.2.1.4 Experiments 8 – 11: Trade Considerations (Base Import Reduction)

The second way to capture trade effects in E-DRAM is by adjusting the parameter REG3(I). As discussed in Section 3.1.4, this parameter effectively curtails the base level of sector *I* imports. A compelling reason to do this when trying to assess the economic impact of domestic environmental regulation is out of consideration that a certain percent of base level imports may not meet the new regulatory requirements. This situation may persist if California is not a significant enough market for out of state producers to bring their product into compliance with California regulations. For experiments 8 – 11 (labeled CONCH2T5 – CONCH2T8) in Table 3, REG3('CONCH') is reduced from its default setting of unity to 0.9, 0.8, 0.6, and 0.4 successively. Results indicate that the elasticities of output and employment in the consumer chemical sector with respect to REG3('CONCH') are roughly -2.8, -1.9, and -0.9 at initial values of REG3 of 0.9, 0.8, and 0.6 respectively.

Comparing results in Table 3 with those in Table 2, it becomes apparent that the model is more sensitive to changes in the initial level of imports brought about by altering parameter REG3 than to changes in import elasticity governed by parameter ETAM. This makes intuitive sense—lowering ETAM discourages imports at the margin, whereas lowering REG3 reduces their base level. Experiments 8 through 11 suggest that if domestic environmental regulations do significantly curtail imports (*e.g.* due to non-compliance), such regulations essentially boil down to domestic content rules which may stimulate the domestic economy in the intermediate run.

Table 3: Architectural Coatings Experiments – Sensitivity to Base Import Reductions

model run	TODAY	CONCH2T5	CONCH2T6	CONCH2T7	CONCH2T8
description		CONCH2 & REG3=0.9	CONCH2 & REG3=0.8	CONCH2 & REG3=0.6	CONCH2 & REG3=0.4
MODEL	LOC OPT	LOC OPT	LOC OPT	LOC OPT	LOC OPT
SOLVER	OPTIMAL	OPTIMAL	OPTIMAL	OPTIMAL	OPTIMAL
CA PERSONAL INCOME ($BILLION)	891.55414	891.68646	891.9611	892.50746	893.05327
CHANGE CA PERS. INC.	-0.136282	0.13232	0.406955	0.953316	1.499132
% CHANGE CA PERS. INC.	-0.000153	0.000148	0.000456	0.001069	0.001681
CONSUMER PRICE INDEX (BASE=1)	0.999929	1.000216	1.000666	1.001554	1.002432
CHANGE AGGREGATE CPI	-0.000071	0.000287	0.000737	0.001624	0.002503
% CHANGE AGGREGATE CPI	-0.000071	0.000287	0.000737	0.001624	0.002503
POPULATION (MILLION FAMILIES)	23.140787	23.141012	23.141684	23.143031	23.144389
CHANGE POPULATION	-0.000549	0.000225	0.000897	0.002244	0.003602
% CHANGE POPULATION	-0.000024	0.00001	0.000039	0.000097	0.000156
WAGE INDEX (BASE = 100)	99.973381	100.04104	100.15501	100.3803	100.60405
CHANGE WAGE INDEX	-0.026619	0.067658	0.181624	0.406916	0.630666
% CHANGE WAGE INDEX	-0.000266	0.000677	0.001817	0.00407	0.006308
LABOR DEMAND (MILLIONS)	14.045159	14.045947	14.047679	14.051126	14.05457
CHANGE LABOR DEMAND	-0.000746	0.000788	0.002519	0.005967	0.009411
% CHNGE LABOR DEMAND	-0.000053	0.000056	0.000179	0.000425	0.00067
RETURN TO K INDEX (BASE=100)	99.999198	100.00104	100.00456	100.0123	100.02071
CHNAGE RETURN TO CAPITAL INDEX	-0.000802	0.001841	0.005366	0.013101	0.021511
% CHANGE RETURN TO CAPITAL INDEX	-0.000008	0.000018	0.000054	0.000131	0.000215
CAPITAL STOCK ($100 BILLION)	14.541822	14.547864	14.558344	14.57894	14.599279
CHANGE CAPITAL STOCK	-0.002212	0.006042	0.016522	0.037118	0.057457
% CHANGE CAPITAL STOCK	-0.000152	0.000416	0.001136	0.002552	0.003951
GROSS PRIV. INVESTMENT($BILLION)	68.618983	68.647495	68.696944	68.794131	68.890106
CHNGE. GROSS PRIV INVESTMENT	-0.01044	0.028512	0.077961	0.175148	0.271122
% CHANGE GROSS PRIV. INVESTMENT	-0.000152	0.000416	0.001136	0.002552	0.003951
CONCH					
OUTPUT ($BILLION)	0.767794	0.944189	1.235532	1.808271	2.373691
CHANGE OUTPUT	-0.000263	0.176395	0.467738	1.040477	1.605897
% CHANGE OUTPUT	-0.000343	0.229742	0.609197	1.355151	2.091574
CAPITAL ($100 BILLION)	0.014567	0.017824	0.023176	0.033625	0.043878
CHANGE CAPITAL	-0.000007	0.003257	0.008609	0.019057	0.029311
% CHANGE CAPITAL	-0.000477	0.223593	0.59096	1.308255	2.012156
JOBS (MILLIONS)	0.017023	0.020992	0.027568	0.040543	0.053395
CHANGE JOBS	-0.000005	0.003969	0.010544	0.02352	0.036372
% CHANGE JOBS	-0.000283	0.233169	0.619416	1.381626	2.136625
PRICE (BASE=1)	0.999995	1.006656	1.007839	1.009533	1.010645
CHANGE PRICE	-0.000005	0.006661	0.007845	0.009538	0.01065
% CHANGE PRICE	-0.000005	0.006661	0.007845	0.009539	0.01065
DOMESTIC PRICE	0.999975	1.023823	1.021241	1.017668	1.015192
IMPORTS ($BILLION)	2.395456	2.23349	1.977819	1.475586	0.980136
CHANGE IMPORTS	-0.000088	-0.161966	-0.417636	-0.91987	-1.41532
% CHANGE IMPORTS	-0.000037	-0.067614	-0.174345	-0.384006	-0.590835
CAPITAL RENTAL RATE (BASE=100)	0.02122	0.032092	0.054972	0.117888	0.203439
CNANGE CAPITAL RENTAL RATE	-0.000021	0.010872	0.033752	0.096668	0.18222
% CHANGE CAPITAL RENTAL RATE	-0.000977	0.512361	1.590608	4.55561	8.587352

3.2.2 Reformulated Gasoline:

ARB is also considering new Phase III regulations for reformulated gasoline. Such regulations will require the petroleum industry to change inputs to production and/or retrofit refineries. Although a preliminary draft of such regulations has been made publicly available, no firm cost estimates have been generated. In the preferred scenario for this regulation, the effective capital stock shrinks by 9.4 percent, operating costs rise (via increased intermediate requirements) by 1.1 percent, and the elasticity of imports with respect to domestic price is falls to zero. Given this parameterization, E-DRAM predicts that Phase III regulations could reduce output and employment in the state's petroleum industry by approximately $274 million (1%) and 231 jobs (1%). For California as a whole, the regulations may reduce real personal income by roughly $404 million (0.05%) and employment by 3,389 jobs (0.02%).

3.2.2.1 Experiments 12 – 14: Increase Investment:

A rough assessment of Phase III regulations might characterize the new standards in terms of increased annual expenditure by the petroleum industry and assume that all these expenditures go toward more intermediate good purchases. Experiment 12 (labeled PETRO1) in Table 4 below takes this basic approach, assuming that compliance with Phase III regulations will require $523 million in before-tax additional annual operating costs by the petroleum industry.[23] Modeling such expenditure as across-the-board increase in intermediates is accomplished by setting REG1('PETRO') to 1.024.[24,25] The code to run this experiment appears immediately below.

```
* EXPERIMENT 12: INCR. ANNUAL OPERATING COSTS (VIA INTERMEDIATES) BY $523M
  REG1(I,'CONCH') = 1.0;
  ETAM('CONCH') = 1.5;
  REG1(I,'PETRO') = 1.024;
```

A second way to model the requirements of Phase III regulations entails distinguishing between compliance investment and operating costs. Assume the regulations require $1 billion of investment by the petroleum industry and an additional $228 million in

[23] Taxes are already incorporated into the model.
[24] See section 3.1.2 for details on how to specify a non-uniform increase in input requirements.
[25] Dollar expenditure increases are translated into percentage increases in intermediate requirements by dividing those dollar increase by the sum of industry *I* purchases over industry *J* goods as recorded in the SAM.

annual operating costs.[26] This can be interpreted as 9.4 percent of existing capital stock being diverted from refining to compliance activity and an across-the-board 1.1 percent increase in spending on intermediate inputs.[27] This approach corresponds to the "bomb" scenario discussed in Section 3.1.3. It is executed using the code below. Corresponding results are reported in column 4 (labeled PETRO2) of Table 4.

```
* EXPERIMENT 13: ELIM. .906 OF PETRO SECTOR K STOCK & INCR. * INTERMEDS. BY 0.011
  REG1(I,'PETRO') = 1.011;
  REG12('PETRO') = 0.906;[28]
```

The third and most appealing method of modeling Phase III regulation also involves distinguishing between compliance investment and operating costs. This approach, corresponding to the "effective capital" rather than the "bomb" interpretation discussed in Section 3.1.3, differs from the previous scenario only in its treatment of the investment component of compliance costs. Rather than thinking required investment as a one-time erosion of the base capital stock, we now model the regulation as diverting 0.094 of every dollar invested from productive to compliance purposes. This interpretation is implemented with the code below. Results are reported in column 5 (labeled PETRO3) of Table 4.

```
* EXPERIMENT 14: MAKE K STOCK OF PETRO SECTOR 0.906 AS EFFECTIVE
*                    & INCR. INTERMEDS. BY 0.011
  REG12('PETRO') = 1;
  REG13('PETRO') = 0.906;
```

[26] $228 million, a pre-tax figure, is used because intermediates are bought at pre-tax prices. Tax credits for purchasers and tax revenue debit for sellers are all handled within the model.

[27] The 9.4 percent figure is derived by dividing $1 million by the capital stock of the CA petroleum industry (this latter number is reported as $10.6 billion in the 1997 Census of Manufacturing as $10.6). Operating costs have been converted to percentage increase in intermediate good expenditures as described in footnote 25.

[28] 1 - 0.906 = 0.094 = 9.4%—See equation 4.3 in Section 3.1.3.

Table 4: Reformulated Gasoline Experiments

model run	TODAY	**PETRO1**	**PETRO2**	**PETRO3**
description		Incr. operating costs by 0.024	Elim. 0.094 of K stock & incr. opp. costs by 0.011	Make K stock only 0.906 as effective & incr. opp. cost by .11
MODEL	LOC OPT	LOC OPT	LOC OPT	LOC OPT
SOLVER	OPTIMAL	OPTIMAL	OPTIMAL	OPTIMAL
CA PERSONAL INCOME ($BILLION)	891.55414	890.66685	891.14265	891.14235
CHANGE CA PERS. INC.	-0.136282	-0.887291	-0.411488	-0.41179
% CHANGE CA PERS. INC.	-0.000153	-0.000995	-0.000462	-0.000462
CONSUMER PRICE INDEX (BASE=1)	0.999929	1.000203	1.000055	1.000055
CHANGE AGGREGATE CPI	-0.000071	0.000274	0.000126	0.000126
% CHANGE AGGREGATE CPI	-0.000071	0.000274	0.000126	0.000126
POPULATION (MILLION FAMILIES)	23.140787	23.135833	23.138491	23.13849
CHANGE POPULATION	-0.000549	-0.004954	-0.002296	-0.002297
% CHANGE POPULATION	-0.000024	-0.000214	-0.000099	-0.000099
WAGE INDEX (BASE = 100)	99.973381	99.90706	99.942502	99.942475
CHANGE WAGE INDEX	-0.026619	-0.066321	-0.030879	-0.030906
% CHANGE WAGE INDEX	-0.000266	-0.000663	-0.000309	-0.000309
LABOR DEMAND (MILLIONS)	14.045159	14.037822	14.04176	14.041757
CHANGE LABOR DEMAND	-0.000746	-0.007337	-0.0034	-0.003402
% CHNGE LABOR DEMAND	-0.000053	-0.000522	-0.000242	-0.000242
RETURN TO K INDEX (BASE=100)	99.999198	99.995493	99.997963	99.998002
CHNAGE RETURN TO CAPITAL INDEX	-0.000802	-0.003706	-0.001235	-0.001196
% CHANGE RETURN TO CAPITAL INDEX	-0.000008	-0.000037	-0.000012	-0.000012
CAPITAL STOCK ($100 BILLION)	14.541822	14.528717	14.535616	14.535601
CHANGE CAPITAL STOCK	-0.002212	-0.013105	-0.006207	-0.006221
% CHANGE CAPITAL STOCK	-0.000152	-0.000901	-0.000427	-0.000428
GROSS PRIV. INVESTMENT($BILLION)	68.618983	68.557143	68.589696	68.589626
CHNGE. GROSS PRIV INVESTMENT	-0.01044	-0.06184	-0.029287	-0.029357
% CHANGE GROSS PRIV. INVESTMENT	-0.000152	-0.000901	-0.000427	-0.000428
PETRO				
OUTPUT ($BILLION)	23.979113	23.374819	23.695619	23.695405
CHANGE OUTPUT	-0.001325	-0.604294	-0.283494	-0.283708
% CHANGE OUTPUT	-0.000055	-0.025201	-0.011823	-0.011831
CAPITAL ($100 BILLION)	0.026176	0.025526	0.025801	0.025795
CHANGE CAPITAL	-0.000006	-0.00065	-0.000375	-0.000381
% CHANGE CAPITAL	-0.000218	-0.024833	-0.014333	-0.014565
JOBS (MILLIONS)	0.021983	0.021426	0.021741	0.021743
CHANGE JOBS	0	-0.000557	-0.000241	-0.00024
% CHANGE JOBS	-0.000014	-0.025321	-0.010984	-0.010918
PRICE (BASE=1)	0.999955	1.023045	1.01063	1.010637
CHANGE PRICE	-0.000045	0.02309	0.010675	0.010682
% CHANGE PRICE	-0.000045	0.023091	0.010675	0.010683
IMPORTS ($BILLION)	0.562809	0.583314	0.572248	0.572254
CHANGE IMPORTS	-0.00004	0.020505	0.009438	0.009445
% CHANGE IMPORTS	-0.00007	0.036433	0.01677	0.016782
CAPITAL RENTAL RATE (BASE=100)	0.068517	0.065075	0.066823	0.066816
CNANGE CAPITAL RENTAL RATE	-0.000031	-0.003443	-0.001694	-0.001701
% CHANGE CAPITAL RENTAL RATE	-0.000447	-0.050245	-0.024728	-0.024829

Comparing and contrasting results from policy simulations 12 through 14 yield the following insights. First, comparing the outcome of experiment 12 (PETRO1) with those of experiment 13 (PETRO2), it appears that regulations raising annual operating costs are more detrimental to the economy than those requiring capital investment. Second, comparing experiments 13 and 14 (PETRO3) implies that if capital investments are to be made, it may be better to require that they be made all at once rather than on a continual, incremental basis.

Looking more closely at results from experiments 12 and 13, we see that nearly all the increase in operating costs are passed through to increases in the final price of petroleum (both costs and price rise nearly 2.4% and 1.1% in experiments 12 and 13 respectively.) Experiment 12 suggests elasticities of output and employment in the petroleum industry with respect to price (and the cost of intermediates) of roughly –1.[29] Changes in statewide economic indicators with respect to price change in the petroleum sector are insignificant.

Experiment 14 lends itself to the intuitive interpretation that 9.4% each dollar invested in the petroleum industry is dedicated to regulatory compliance, leaving 90.6% for the production of saleable output. This "effective capital" setup is preferable to the one-time investment/"bomb" setup because in the former, dollars spent on compliance scale up (or down) with industry size and are an ongoing concern.

Using this specification, E-DRAM predicts that Phase III reformulated gasoline regulations as currently parameterized can be expected to reduce output and employment in the California petroleum industry by approximately 1% each. This translates into roughly $284 million less product and 240 fewer jobs. Regulation will lower the rate of return on capital invested in that industry by about 2.5%, which in turn will lead to about a 1.5% reduction in the industry's capital stock. Prices in the sector can be expected to rise roughly 1%. Statewide, the consumer price index may rise, real personal income may fall, and some jobs may be lost, but the relative size of these changes will be miniscule. Overall, the

[29] These results are much more plausible than the elasticities derived in experiments 1 and 2 in Sections 3.2.1.1 and 3.2.1.2 respectively, both involving the relatively tiny consumer chemicals sector. Note: the petroleum industry is much more similar in size to other industrial sectors in the model than the consumer chemical sector is.

impacts of Phase III reformulated gas regulations on the California economy will be negligible.

3.2.2.2 Experiments 15 – 19: Trade Considerations Again

One final battery of tests are run to determine how sensitive results from the preferred specification of Phase III reformulated gas experiment (PETRO3) are to trade considerations. As in Section 3.2.1.3, the import elasticity of the sector being regulated is progressively reduced from its default setting of 1.5 to 0.5 in increments of 0.25—then finally to zero.[30] Looking at the results listed in Table 5, it is obvious that such considerations mitigate the adverse economic impacts of regulation, but only slight, due to the low base level of imports in that sector. Experiment 19, labeled PETRO3T4.5* is the preferred scenario for modeling Phase III reformulated gasoline regulations. It combines the appealing features of experiment 14 (PETRO3) with an import elasticity parameterization [ETAM('PETRO')=0.0] that keeps imports right around pre-regulation levels. Under this scenario, E-DRAM predicts that Phase III regulations could reduce output and employment in the state's petroleum industry by approximately $274 billion (1%) and 231 jobs (1%). For California as a whole, the regulations may reduce real personal income by roughly $404 million (0.05%) and employment by 3,389 jobs (0.02%).

[30] Experiments testing the sensitivity of results with respect to changes in parameter REG3 governing the base level of imports are not conducted because petroleum is largely refined in state. What are imported are raw inputs, which do not change significantly with regulation.

Table 5: Reformulated Gasoline Experiments – Sensitivity to Import Elasticity

model run	PETRO3	PETRO3T1	PETRO3T2	PETRO3T3	PETRO3T4	PETRO3T4.5*
description	Make K stock only 0.906 as effective & incr. opp. cost by .11	ETAM=1.25	ETAM=1	ETAM=0.75	ETAM=0.5	ETAM=0.0
MODEL	LOC OPT	LOC OPT	LOC OPT	LOC OPT	LOC OPT	LOC OPT
SOLVER	OPTIMAL	OPTIMAL	OPTIMAL	OPTIMAL	OPTIMAL	OPTIMAL
CA PERSONAL INCOME ($BILLION)	891.14235	891.14368	891.145	891.14631	891.14763	891.15025
CHANGE CA PERS. INC.	-0.41179	-0.410465	-0.409144	-0.407826	-0.406512	-0.403893
% CHANGE CA PERS. INC.	-0.000462	-0.00046	-0.000459	-0.000457	-0.000456	-0.000453
CONSUMER PRICE INDEX (BASE=1)	1.000055	1.000056	1.000057	1.000058	1.000059	1.000061
CHANGE AGGREGATE CPI	0.000126	0.000127	0.000128	0.000129	0.00013	0.000132
% CHANGE AGGREGATE CPI	0.000126	0.000127	0.000128	0.000129	0.00013	0.000132
POPULATION (MILLION FAMILIES)	23.13849	23.138494	23.138499	23.138504	23.138508	23.138518
CHANGE POPULATION	-0.002297	-0.002293	-0.002288	-0.002283	-0.002279	-0.002269
% CHANGE POPULATION	-0.000099	-0.000099	-0.000099	-0.000099	-0.000098	-0.000098
WAGE INDEX (BASE = 100)	99.942475	99.942733	99.94299	99.943247	99.943503	99.944012
CHANGE WAGE INDEX	-0.030906	-0.030648	-0.030391	-0.030135	-0.029879	-0.029369
% CHANGE WAGE INDEX	-0.000309	-0.000307	-0.000304	-0.000301	-0.000299	-0.000294
LABOR DEMAND (MILLIONS)	14.041757	14.041759	14.041762	14.041764	14.041766	14.041771
CHANGE LABOR DEMAND	-0.003402	-0.0034	-0.003398	-0.003395	-0.003393	-0.003389
% CHNGE LABOR DEMAND	-0.000242	-0.000242	-0.000242	-0.000242	-0.000242	-0.000241
RETURN TO K INDEX (BASE=100)	99.998002	99.998015	99.998028	99.99804	99.998053	99.998078
CHNAGE RETURN TO CAPITAL INDEX	-0.001196	-0.001183	-0.00117	-0.001158	-0.001145	-0.00112
% CHANGE RETURN TO CAPITAL INDEX	-0.000012	-0.000012	-0.000012	-0.000012	-0.000011	-0.000011
CAPITAL STOCK ($100 BILLION)	14.535601	14.535645	14.535689	14.535733	14.535776	14.535863
CHANGE CAPITAL STOCK	-0.006221	-0.006177	-0.006133	-0.00609	-0.006046	-0.005959
% CHANGE CAPITAL STOCK	-0.000428	-0.000425	-0.000422	-0.000419	-0.000416	-0.00041
GROSS PRIV. INVESTMENT($BILLION)	68.589626	68.589834	68.590041	68.590248	68.590454	68.590865
CHNGE. GROSS PRIV INVESTMENT	-0.029357	-0.029149	-0.028942	-0.028735	-0.028529	-0.028118
% CHANGE GROSS PRIV. INVESTMENT	-0.000428	-0.000425	-0.000422	-0.000419	-0.000416	-0.00041
PETRO						
OUTPUT ($BILLION)	23.695405	23.697064	23.698719	23.70037	23.702017	23.705298
CHANGE OUTPUT	-0.283708	-0.282049	-0.280393	-0.278742	-0.277096	-0.273815
% CHANGE OUTPUT	-0.011831	-0.011762	-0.011693	-0.011624	-0.011556	-0.011419
CAPITAL ($100 BILLION)	0.025795	0.025797	0.025798	0.0258	0.025802	0.025805
CHANGE CAPITAL	-0.000381	-0.000379	-0.000378	-0.000376	-0.000374	-0.000371
% CHANGE CAPITAL	-0.014565	-0.014497	-0.014428	-0.01436	-0.014292	-0.014157
JOBS (MILLIONS)	0.021743	0.021744	0.021746	0.021747	0.021749	0.021752
CHANGE JOBS	-0.00024	-0.000238	-0.000237	-0.000235	-0.000234	-0.000231
% CHANGE JOBS	-0.010918	-0.010849	-0.010779	-0.01071	-0.010641	-0.010504
PRICE (BASE=1)	1.010637	1.01064	1.010642	1.010644	1.010647	1.010651
CHANGE PRICE	0.010682	0.010685	0.010687	0.010689	0.010692	0.010696
% CHANGE PRICE	0.010683	0.010685	0.010687	0.01069	0.010692	0.010697
IMPORTS ($BILLION)	0.572254	0.570677	0.569103	0.567534	0.565968	0.562849
CHANGE IMPORTS	0.009445	0.007867	0.006294	0.004724	0.003159	0.00004
% CHANGE IMPORTS	0.016782	0.013979	0.011183	0.008394	0.005612	0.00007
CAPITAL RENTAL RATE (BASE=100)	0.066816	0.066826	0.066835	0.066845	0.066854	0.066873
CNANGE CAPITAL RENTAL RATE	-0.001701	-0.001692	-0.001682	-0.001673	-0.001663	-0.001644
% CHANGE CAPITAL RENTAL RATE	-0.024829	-0.02469	-0.024552	-0.024413	-0.024276	-0.024001

* indicates preferred scenario

3.2.3 A Comparison of Architectural Coating and Reformulated Gasoline Experiments

E-DRAM predicts that new reformulated gasoline regulations will have a larger impact on the California economy than proposals to lower the VOC content limit for certain architectural coatings. A comparison of preferred scenarios CONCH2T4.5* in Table 2 and PETRO3T4.5* in Table 5 suggests that the former will have roughly ten times the adverse effect on California personal income and employment as the latter. This makes intuitive sense when one considers that the petroleum industry is much larger that the consumer chemical industry statewide. Industry specific results, in contrast, indicate that lowering VOC limits and Phase III gasoline standards can be expected to reduce output and employment in their respective regulated sectors by roughly 1%. Contrasting results across experiments CONCH2T1-CONCH2T4.5* vs. PETRO2T1-PETRO2T4.5* highlights the importance of trade considerations. Imports account for a much larger share of output in the consumer chemical industry than the in petroleum refining industry (roughly 76% and 2% respectively). Regulations that simply raise the cost of domestic vs. foreign production have larger adverse impacts on more trade intensive sectors. As discussed in Sections 3.1.4 and 3.2.1.3 however, domestic regulation may reduce imports as a result of compliance issues. E-DRAM is thus behaving logically when it predicts that trade considerations (*i.e.* reducing the elasticity of imports with respect to domestic relative to world price from 1.5 to 0.5) dampen the adverse economic impacts of regulations aimed at the import laden consumer chemical sector much more than they mitigate the predicted negative economic effects of regulations targeting the domestically dominated petroleum refining industry.

4 Conclusions:

In Accordance with Agreement 98-300, investigators at the University of California, Berkeley have developed and demonstrated the implementation of E-DRAM—a computable general equilibrium model suitable for Cal EPA/Air Resources Board's use in assessing the economic impacts of large-scale environmental regulations. This paper outlines features of that model developed to allow policy analysts to parameterize regulations as some combination of price, cost, and investment requirements for target industries. It also demonstrates the implementation of several such policy experiments and suggests how to interpret their results.

As a refined, well-calibrated CGE, E-DRAM is able to impart some sense of the economy-wide implications of proposed environmental regulations missed by partial-equilibrium analyses. In most cases, general equilibrium adjustments dampen the sector-specific impacts of proposed regulations and the types of policies being considered seldom significantly affect the California economy as a whole. Those using E-DRAM should keep in mind, however, that the model reports equilibrium results. Initial reactions to regulation and adjustment to a new equilibrium take time. During that time, sector-specific change may not seem trivial to those directly involved.

Two lines of research for improving E-DRAM are worth special mention. First, the extent to which trade flows react to environmental regulation has not been well studied. Results of such research will shed light on how much adjustment of trade-related parameters [REG3 – base import reduction, and ETAM – import elasticity with respect to domestic price in E-DRAM] is appropriate when attempting to assess the economic impacts of domestic environmental regulation. Second, the new air pollution module could be more fully integrated into the model. This can be done quite easily by further parameterizing regulations in terms of the pollution (intensity) reduction they are expected to bring about.

A Time Series Exploration of State Product, Pollution Prevention Costs, and Pollution

Introduction

In both theory and in the data there is a relationship between Gross State Product (GSP), the expenditures on pollution prevention capital (CAP), the operating costs of pollution prevention equipment (OP) and the level of pollution present (OZONE). The theoretical nature of the relationship is that of a restricted cost function. The cost of preventing pollution is a function of the level of output and the amount of pollution, as well as the prices of the major inputs, labor and capital. The data are as yet too sparse to support this level of generality, though some conclusions can be supported.

Data

There are three sources for this study. The Gross State Product is from the Department of Finance. The operating and capital costs are from current industrial reports, Pollution Abatement Costs and Expenditures, series MA200. These data only go back to 1973 and data for 1987 was not collected. In the regressions, the 1987 value is linearly interpolated from the adjacent years. The regressions use total cost (COST) which is the sum of real operating costs plus 11% of the value of the capital stock. The capital stock variable was formed by estimating the initial capital stock of pollution control equipment to be 20 times the 1973 investment and assuming a depreciation rate of 5%. Pollution data is from ARB and is the days above 1 hour ozone NAAQS. The data is from South Coast. An alternative, but shorter series for ozone is described below. Though there is not a perfect match between the pollution data and the economic data, the need for a long consistent series dictates the use of South Coast, rather than statewide data. The data were all used after a natural log transformation and the monetary data was deflated by the GDP deflator with a 1992=100 base. The number of data points available is too few to estimate a very general model with any confidence. The passage of time will obviously change this situation.

Estimation

The model is estimated with cointegrated vector auto regression (VAR). Cointegrated VARs are regressions of the first difference of the variables on their levels and lagged value of the first differences. The estimation process limits the inclusion of the lagged values of variables to particular linear combinations of the variables. Those linear combinations are cointegrating relationships and define the long run relationships among the variables. Tests involving these cointegrating relationships provide evidence on the relations among pollution, pollution abatement costs and GSP.

Following Engle and Granger (1987) the VAR model is written in error correction form as:

$$(1) \qquad \Delta \mathbf{y}_t = \phi + \Gamma_1 \Delta \mathbf{y}_{t-1} + \cdots + \Gamma_{k-1} \Delta \mathbf{y}_{t-k+1} + \Pi \mathbf{y}_{t-1} + \varepsilon_t,$$

where $\mathbf{y}_t$ is a column three-vector of the variables included in the study at time t, $\mathbf{y}_t' =$ (COST, GSP, OZONE). Δ indicates the first difference of variables (e.g., $\Delta \mathbf{y}_t = \mathbf{y}_t - \mathbf{y}_{t-1}$). The Γ_t are matrices of parameters of the t-times lagged difference of $\mathbf{y}$. Ψ are the corresponding parameters. ϕ is a vector of constant terms. ε is a vector of mean zero errors. And Π is a parameter matrix containing information about the cointegrating vectors.

The parameters of (1) are estimated in a three-step statistical analysis. First, the number of lagged difference terms to be included in the estimated equation is determined. One lagged difference (the minimum) was included because each lagged difference uses 3 degrees of freedom and there are only 22 observations on each variable.

Second, the rank of the cointegrating spaces in the models was determined. Preliminary testing using augmented Dickey-Fuller tests strongly suggested that all the time series are integrated of order one. There are two ways in which multiple I(1) variables can be made stationary. First differencing all variables will make them stationary. It is also possible that some linear combination or combinations of the variables will be stationary. For instance, if pollution is proportional to GSP, at least in the long run, then pollution less the constant of proportionality times GSP would be stationary. That is, the two variables do not drift apart over time. Linear combinations of I(1) variables that are stationary are called cointegrating relationships. The number of linearly independent cointegrating relationships, r, is found by cointegration tests. Following Johansen and Juselius (1990), the hypothesis of cointegration of rank r among the p (in this case three) series is the hypothesis that the rank of Π is r:

(2) $$H_1(r): \Pi = \alpha\beta'$$

where α and β are pxr (and rxp) matrices of full rank. The elements of $\mathbf{y}_t$ are cointegrated when the rank r of the matrix Π is greater than zero but less than the number of endogenous variables, p. In this formulation β is the matrix of coefficients for r stationary cointegrating relationships $\beta'\mathbf{y}_t$, which are interpreted as stationary relations among nonstationary variables. It is known that $\mathbf{y}(t)$ tends toward the cointegrating space; as t becomes large, $\mathbf{y}(t)$ satisfies each of the cointegrating relationships $0= \beta'\mathbf{y}_t$. This is the sense in which cointegration gives long run relationships among variables. The rates at which the variables y adjust toward the cointegrating space is given by α. Some variables may adjust quickly while others may not change at all.

Johansen and Juselius (1990)derive two useful tests for the hypothesis of r cointegrating vectors. The first is a likelihood ratio test for the reduced rank of Π hypothesis called the Trace statistic. The null hypothesis is: H_0: rank $(\Pi) \leq r$ (or, equivalently, that the system has p-r unit roots) versus the alternative that the rank is greater than r. An alternative, called the maximum eigenvalue test, computes the λ_{max} statistic, and is based on the ratio of the likelihood of $H_1(r)$ to $H_1(r+1)$. The null hypothesis is that the rank of Π is r or less while the alternate is r+1 or less.. The asymptotic distributions of the rank and trace test statistics are nonstandard, and depend on deterministic components included in the model. Practically, determination of the cointegration rank is an iterative process where one starts with the hypothesis of r=0 cointegrating vectors. If this test is rejected by either test at the .90 significance level, the test is repeated for r =1, 2, ..., p-1 cointegrating vectors. Otherwise the first accepted rank was the reported estimate.

A coinegrating rank of zero was rejected in favor of a rank of one, while a rank of one was not rejected in favor of a rank of two. The L-Max test rejects a cointegrating rank of zero in favor of a greater rank while the Trace test is close to rejection. Both tests reject a cointegrating rank greater than one. Therefore we analyzed the system with the cointegrating rank set to one.

A rank of one means that there is one long run relationship among the variables. That relationship is expected because output increases pollution while expenditure decreases it. The relationship is

(3) $$\ln(COST) = .490 \ln(GSP) - 0.242 \ln(OZONE).$$

The signs in this relationship are as expected. An increase in State product, pollution constant, increases the cost of pollution control. A one percent increase in GSP increases pollution control costs by only ½ percent. An increase in pollution, GSP constant, decreases the cost of pollution control. A reduction of the ozone level from .16 ppm to .12 ppm, for instance (a 25% decrease) would increase control costs by about 7%. While there is certainly a relationship of this type in the data, long run exclusion tests show that it is not possible to reject, at the 10% level, the exclusion of either pollution or GSP from the relationship. The relation between OZONE and the other two variables is known with particularly little precision.

Third, the nature of the adjustment was investigated by running a test for weak exogeneity. The test was for GSP to be weakly exogenous, which would mean that the other two variables in the system would do all the adjusting to equilibrium. That was rejected. Therefore OZONE and COST help determine the GSP.

For completeness, the Π matrix was:

Π Matrix	COSTR	GSPR	OZONE
COST	-0.734*	0.360*	-0.178*
GSP	-0.339*	0.166*	-0.082*
OZONE	-0.586	0.287	-0.142

where an * indicates the coefficient is asymptotically different from zero at the 95% level and yR is a model of the single lagged dependent variable matrix, Γ_1 and a constant term.

Lagged Variables	COST	GSP	OZONE
COST	0.250	0.712	-0.016
GSP	0.243	0.437	0.062
OZONE	1.317	-1.186	-0.246

(none significant)

The constant terms were.

OP	1.734*
GSP	.817*
OZONE	1.377

An Alternative Series

We also carried out the analysis using a shorter, but consistently measured time series. The series used was the mean of the highest 20 of the basinwide daily maximum ozone concentrations in each year. The series is only used from 1978 to 1994 for two reasons. First, the earlier years did not use the standard ultra-violet absorbtion method, which is superior to the older Potassium Iodide colorimetric method. The older method is biased compared to the UV method. Second, some key sites did not begin operation until 1978. Examples include Azusa, Burbank, and Reseda. Glendora, a major site throughout the 1980's did not begin operations until 1981. Nevertheless, the 1978 to 1998 period is appropriate.

Using the 1978-1994 sample, the trace and L-max tests both reject no cointegration and fail to reject 1 (1 or more) cointegrating relationship, so the rank of π is set to 1. The cointegrating vector is:

Cointegrating Vector

Variable	COSTR	GSPR	LOZONE
Coefficient	1.000	-0.719	-0.630
asymptotic t	.8	3.4'	3.3

This estimated equation has no significance for the variable for cost and the wrong sign for the variable ozone. Increasing ozone concentrations should be associated with lower, not higher costs. In this equation the higher quality of the ozone data seems to have been overcome by the sensitivity of the analysis to a shorter series length. It is also possible that the 3 year moving average form of the ozone variable is superior as a predictor of cost.

This completes the description of the model

Conclusion

This paper demonstrates that it is (just barely) feasible to estimate a time series model including pollution, the costs of pollution control, and GSP. There is certainly a cointegrating relation among these three series, though it is difficult to estimate the contribution of pollution to that relation with any precision. Similarly, the short-run dynamics, particularly those determining OZONE, are not known with precision. Since OZONE is a decision variable, this last point is not disturbing.

The equations do not allow for drift in the cointegrating space. Drift would account for a switch from pollution intensive to "green" activities in GSP. The choice of GSP is also arbitrary. It excludes the benefits of cleaner air. A broader measure of welfare including air quality could lead to standards increasing welfare, rather than standards decreasing GSP.

As the data series available for time series modeling becomes longer, these techniques will provide increasingly accurate measurements of the effect of regulation on GSP and other variables of interest, like employment.

APPENDIX A: LITERATURE REVIEW

for

A Methodology for Assessing the Economic Impacts of Large Scale Environmental Regulations

1 Introduction

The nature of the relationship between environmental regulation and economic welfare is inherently complex. The popular notion that environmental protection and economic health are fundamentally incompatible goals is widely regarded as overly simplistic. While it is true that environmental regulations impose static costs on regulated firms, this is not the whole story. The dynamic effects and broader welfare implications of environmental regulation must also be considered. What are the benefits stricter environmental regulations? How do environmental regulations influence innovation and the investment decisions of firms? How much of a factor is the stringency of environmental regulation/quality in firms'/people's location decisions? How are these relationships changing over time? The investigation of these and related questions in several strands of the professional economic literature is reviewed below.

1.1 National models

Many studies investigate the aggregate relationship between environmental regulation and economy performance. A good example of such work is Boyd and Uri (1990) which provides a useful estimate of clean air costs at the national level. It uses a Shoven and Whalley calibration-type computable general equilibrium model (CGE) to estimate the cost of complying with President George Bush's Clean Air Plan proposal of 1989.[31] The proposal included cutting SO_2 emissions by 50%, attaining existing health standards for ozone and carbon monoxide nationwide, and cutting the release of suspected carcinogenic toxic compounds by 75-90%. The model consists of twelve production sectors, thirteen consuming sectors, six household categories classified by income, a government sector, and rest of world (ROW). Experimental runs based on government-generated estimates of the various price and tax hikes necessary to induce compliance compare costs under both command-and-control and tax inducement scenarios. Under the regulation scheme, they estimate production dropping by .096 percent, consumer prices rising by .244 percent, and an aggregate utility loss of 0.347 percent. Under the market tax scenario, output falls by 0.075 percent and aggregate utility losses totaling 0.12 percent are "almost completely offset by increases in government revenue." (*Ibid.*, p. 1177)

Jorgenson and Wilcoxen (1990) investigates the coincidence of laggard economic growth and the "advent of environmental regulation" in the U.S. over the period 1973 to 1985. As motivation, they cite that the average annual growth rate over that period was 2.5 percent as compared to 3.7 percent from 1947 to 1973.[32] To facilitate their analysis, the authors construct a simulation model with 35 industries (one being government) and a consumer sector. Production equations utilize econometrically estimated input-substitution parameters to allow regulation-induced substitution between inputs to occur as realistically as possible. Consumers have perfect foresight. Estimates of the cost of environmental regulation are computed via simulations that subtract out industry-reported operating and investment costs of compliance as well as motor vehicle emissions control costs. The elimination of such costs frees up capital for productive investments. Not surprisingly, the relatively capital intensive, "dirty" industries benefit most in these simulations. Results of the study indicate that between 1973 and 1985 environmental regulations created an annual growth rate drag of .191% that reduced the level of GNP by 2.59%.[33] The authors up front admonition that they "have not accounted for consumption benefits resulting from environmental cleanup or production benefits associated with pollution abatement" (*Ibid.*, p. 314) should be kept in mind.

Hazilla and Kopp (1990) stresses the importance of using social welfare measures rather than private compliance costs and dynamic general equilibrium models rather than static

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[31]At the time, this proposal was serving as the basis for draft amendments to the Clean Air Act.
[32]Not only does the more recent period coincide with increased oil prices that the authors fairly point out, but their basis of comparison includes the post war boom years.
[33]The overall growth drag estimate breaks down as follows: operating costs slowed annual growth by .034%, start-up plant investment requirements dragged it down another .074%, investments required to retrofit existing plants cut an additional .026%, and motor vehicle emissions regulations slowed it another .051%.

partial equilibrium ones when conducting cost benefit analysis. Using a Hudson-Jorgenson econometric (vs. Shoven and Whalley calibration) type general equilibrium model Hazilla and Kopp estimate the compensating variation of federal air and water pollution control regulations in 1975 to be $6.8 billion vs. EPA's private cost estimate of $14.1 billion. The authors cumulative cost estimate for 1981to 1990 is $977 billion as compared to EPA's $648 billion. Their results demonstrate that general equilibrium social costs can be below or *above* private costs. They also highlight that the former increases relative to the latter over time because regulation-induced price increases raise the cost of consumption relative to leisure. This in turn slows the rates of savings and thus investment and growth. Capital intensive and relatively "dirty" industries, i.e. electric utilities, motor vehicles, crude petroleum and natural gas, primary metals, and chemicals and allied products suffer direct productivity losses, price increases, and output reductions. These effects ripple through to other industries in the form of higher factor prices. Hazilla and Kopp end with the suggestion that the intertemporal general equilibrium framework be expanded to incorporate benefit estimation.

Boyd, Krutilla and Viscusi (1995) explicitly incorporates the benefit side of CO_2 reductions in a computable general equilibrium model of energy taxation. Drawing on cost-benefit and regulatory analyses coordinated by the U.S. Environmental Protection Agency (EPA), the authors estimate average total damage per unit of pollution. These estimates assume a linear damage function and include harm from auto emissions, particulate matter, sulfur oxides, ozone depletion, and visibility loss caused by coal, oil and natural gas energy sources. Upon aggregation, these estimates produce low, medium, and high estimates of total environmental damages from fossil fuel consumption in the U.S. of 0.2, 2.0, and 4.0 percent of GNP respectively. These exogenous estimates of damage by source are then used in conjunction with a policy simulation taxing fuels (domestic and imported) in proportion to their carbon content. The simulation framework is a CGE model with fourteen production, six household, a government and foreign sectors.[34] The model is run twice with alternate assumptions about the degree of substitutability (low vs. high) between intermediate goods (including energy) and the three primary factors of production (land,

[34] The authors make a strong case for using general over partial equilibrium analyses. The former capture market/price impacts that latter, often in the form of "bottoms up" engineering cost estimates, ignore.

labor, and capital). Throughout, the authors maintain the assumption that carbon tax revenues will not be used to lower other taxes.

The upshot of Boyd, Krutilla and Viscusi (1995) is that once associated damages are taken into account, energy is underpriced. The degree to which this is the case is more sensitive to damage than substitution estimates although the latter markedly reduce the non-linearity of the welfare cost of compliance curve. Assuming low substitution, the optimal (no-regrets, i.e. zero welfare change) reductions in CO_2 emissions are about 5 (8), 12 (20), and 15 (27) percent for low, medium, and high damage estimates respectively; corresponding tax rates are 20 (33), 46 (75), and 57 (97) on coal.[35] Imposing optimal taxes under the LS scenario, welfare levels rise by $1.1billion, $8.8 billion (0.2 percent), and $21.1 billion (0.47 percent), again depending on which damage estimates are used. Under the high substitution (HS) scenario, costs of achieving any given reduction are lower and the benefits are higher due to substitution away from coal. The optimal (no-regrets) use reductions are 11 (21), 29, 38 (64) percent with corresponding tax rates between 24 (37) and 70 (117) percent. Depending on the damage estimates used, optimal taxes under the HS scenario increase welfare by $2.1billion, $24.1 billion (0.54 percent), and $59.3 billion (1.32 percent). According to the latter (HS) simulation, the cost of reducing CO_2 emissions by 50 percent is approximately $62 billion, or 1.4 percent of national welfare. According to the authors, previous models incorporating market effects commonly put costs of the same at 1 to 3 percent of GNP and the mean welfare cost across nine studies completed as of 1991 was around 3.5 percent.

1.2 Competitiveness Considerations

Concerns about domestic economic growth are inextricably tied to those about international competitiveness. Jaffe *et. al.* (1995) provides a good summary of the links between environmental regulation and the competitiveness of U.S. manufacturing industries. Reviewing the relevant literatures, they find that environmental regulation has no significant effect on net exports. Although international trade patterns suggest the migration of "dirty" industries to less developed countries, there is little evidence that this

[35] Corresponding tax levels for oil and natural gas are set in proportion to their carbon content relative to coal, amounting to 53 and 26 percent of the coal tax level respectively.

can be attributed to their relatively lax regulatory regimes rather than their progression through standard stages of development. Similarly, data on foreign direct investment does not indicate significant capital flight due to environmental regulation. Labor costs, market access and presence of established industrial bases are overriding considerations for companies investing abroad.

Studies reviewed in Jaffe *et. al.* (1995) do, however, tend to suggest that excessive environmental regulation can have negative productivity effects.[36] It is within this context that the comparative cost-effectiveness of market based incentives vise-a-vise performance or technology standards is stressed. Concerning the Porter hypothesis, which posits that environmental regulation may actually spur growth via innovation, Jaffe *et. al.* feel that speculation and anecdotal support outweighs hard empirical evidence to date. Among its overall conclusions, Jaffe *et. al.* (1995) states that, "Overall there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness, however that elusive term is defined." (*Ibid.*, p. 157) The authors, like most of those cited in Section 2.1 above also admit they have not considered the welfare benefits of environmental regulation and point out that "pollution control can reduce labor costs and enhance competitiveness in some locations under certain conditions." (*Ibid.*, p. 158)

Stephan (1995) apparently captures just such a competitiveness effect by building dynamic CCE in with vertically aggregated production. What this feature does is make capital stocks evolves incrementally rather adjust instantaneously. Technology change is thus sluggish and path dependent. Other aspects of the model are sparser; there are three regions (Northern Europe, Southern Europe and ROW including the U.S. and Japan) each of which uses labor along with capital and environmental services to produce its own distinct commodity for production and/or trade. The model begins in 1973 and has six periods. The initial period is seven years; the rest are five years each. Baseline assumes no change in environmental regulations and annual growth rates for ROW/Northern Europe/Southern Europe of approximate 4.5/3.0/1.5 percent. A second scenario requires that from 1980 on, end-of-pipe emissions be cut 95 percent.

[36] Biorn et. al. (1998) cites additional studies with similar conclusions.

Without specifying further how the three regions' economies differ, Stephan reports that under the emissions reduction scenario, Northern Europe's GNP grows faster while GNP in the other two regions grows slightly slower than in the base case. He explains as follows. In the short run, Northern Europe imports inputs and goods, (de facto exporting emissions) because they can't meet environmental regulations quick enough otherwise. In the medium-to-long run, as investment in abatement technology (that is more efficient that end of pipe reduction) comes on line, environmental compliance costs actually fall below what they are in the base case. The results of this study hinging on the relative

2 Mechanisms by which Environmental Regulations Effect the Economy and Competitiveness

2.1 Innovation

As discussed above, what has become know as the Porter hypothesis [Porter 1991, Porter and van der Linde (1995)] asserts that stricter environmental regulation induces firms to innovate, i.e. come up with new, cleaner and perhaps even cheaper methods of production. By extension, countries with stricter regulations can become net exporters of the induced environmental technologies. Porter and van der Linde (1995) like Jaffe et. al. (1995), stress the attractiveness of market incentives over emissions targets over technology standards.

Jaffe and Palmer (1997) criticize the ambiguity of the Porter hypothesis, showing how it is open to alternately "narrow", "weak", and "strong" interpretations. According to Jaffe and Palmer, the narrow interpretation is simply that particular types of environmental regulation, i.e. those that emphasize outcomes over processes induce innovation. The weak interpretation is that firms constrained by environmental regulation must do things differently and therefore innovate. The strong interpretation is that such innovation leads to increased profits. [Jaffe and Palmer point out the theoretical impossibility of a constrained optimum being greater than an unconstrained one; referencing Schmalensee (1994), they stress that the true opportunity cost of R&D funds dedicated to environmental compliance may be their diversion from more profitable R&D projects.]

Implying that the Porter hypothesis is too vague to test formally, Jaffe and Palmer (1997) sets out to summarize statistical evidence concerning the relationship between pollution control expenditure and innovative activity in U.S. The study's conclusions are mixed: it finds a positive, statistically significant relationship between relevant compliance costs and R&D expenditure but no statistically significant relationship between the former and patents issued.[37] In light of: i) its own results, ii) those of Lanjouw and Mody (1993) indicating a positive relationship between environmental compliance costs and related patents internationally, and iii) those of other studies indicating that environmental regulations are detrimental to productivity, Jaffe and Palmer (1997) leaves the definitive relationship between productivity and (R&D inducing) environmental regulations an open question.[38]

Heavily influenced by the engineering literature's recognition that the best hope for pollution reduction is improved technology, Carraro and Galeotti (1997) investigate the effects of subsidizing R&D versus technology adoption. Relevant policy simulations are run using WARM (world assessment of resource management), an econometric general equilibrium model for the European Union and its member countries. Two noteworthy features of WARM are that it explicitly models technological progress and the amount of emissions generated by various economic activities (predominantly production and consumption involving fossil fuels). The results of Carraro and Galeotti's simulations indicate that subsidizing environmentally friendly R&D or technology adoption — both policies designed to stimulate technological progress directly — can achieve environmental protection while improving economic growth and competitiveness over the base case.[39]

2.2 Investment

Gray and Shadbegian (1998) investigates possible linkages between environmental regulation and firms' investment decisions. Using data on the U.S. paper industry from 1972 to 1990, the authors find three things. First, plants in states with tougher

[37] Scott (1997) presents corroborating evidence of the first point, finding that Title III of the Clean Air Act, by signaling the government's commitment to evolving standards, induced increases related R&D expenditures by large firms engage in Schumpeterian R&D rivalry.
[38] In related work, Jaffe and Stavins (1995) develops a framework for measuring the degree to which alternate environmental policy instruments induce technology dispersion. In empirical application, they find that subsidizing technology adoption is superior to both Pigouvian taxes and regulatory standards.
[39] In the simulations, it mattered little whether revenues to fund the subsidies raised through direct or indirect taxation.

environmental standards use cleaner technologies. Further, mills in states with tougher air (water) regulations avoid the most air (water) polluting technologies. Second, there is small, marginally significant negative correlation between state's environmental regulatory stringency and investment in mills in that state. Third, abatement investment crowds out productive investment. Although mill investment is lumpy overall, i.e. abatement investment and productive investment tend to be made together to minimize production stoppage, the former significantly 'crowds out' the latter. This effect is strongest within firms, indicating that companies with multiple mills tend to shift investment toward 'low-abatement-cost' plants.[40] Beladi and Frasca (1996) presents a corroborating model in which foreign capital flows out of the country that tightens environmental standard.

2.3 Location Decisions

According to Jaffe *et. al.* (1995) the bulk of research on *domestic* firms echoes the findings of work international firms discussed above, indicating that the relative stringency of states' environmental regulations has little to no significant influence of on plant location decisions. Studies not covered in Jaffe et. al. (1995) present more mixed results. Deily and Gray (1991) reports that U.S. steel mills facing stricter air pollution enforcement are more likely to close.[41] Henderson (1996) indicates that polluting industries in the U.S. tend to migrate from nonattainment (polluted) to attainment (initially less polluted) areas in attempts to avoid regulatory scrutiny. Gray (1997) finds a significant negative relationship between the stringency of a state's environmental regulations and the opening of new plants in that state. In contrast, the results of Biorn et. al. (1998) show that Swedish establishments under strict environmental regulation are one-third less likely to close than establishments that are not. Unable to explain their results, Biorn et. al. suggest the Porter hypothesis as partial rationalization.

As mentioned in Jaffe *et. al.* (1995) there are plausible links between environmental quality and lower labor costs and/or higher firm productivity. Arguments along the latter line, i.e.

[40] Regressing productive investment on abatement investment with (without) firm dummies indicates 188-(99) percent crowding out. Regressing total investment on abatement investment also indicate that abatement spending lowers productive spending more than one-for-one.
[41] The same study also contends that regulatory enforcement action is less probable against mills that are likely to close and/or are major local employers

that environmental quality may be a direct, positive input to production, have been largely confined to theoretical discussion [see Roback (1982), Mather and Stein (1993)] and are generally overshadowed by empirical studies of the negative correlation between environmental regulation and productivity discussed in greater detail above. There is strong theoretical and empirical evidence, however, that people are willing to accept lower wages in order to live in "nicer", healthier environments — they may even be drawn to such areas [see Roback (1982), Henderson (1982)]. Firms seeking to attract such workers and capitalize on lower labor costs may be drawn to high amenity areas as well [see Knapp and Graves (1989), Gottlieb (1995)].

3 Policy and Modelling Issues

3.1 Choice of Policy Instruments

Much of the literature on the economic costs of environmental protection stresses the need for flexible regulation. Market-based incentives like a pollution tax are preferred to rigid emissions or technology standards on strict efficiency grounds. Taxes spur cleanup firms that can do so cheaply while allowing emissions (at a price) by firms for which cleanup is too costly. The main deficiency of price-based environmental regulations, however, are that they cannot guarantee given quantities of emissions (reductions). Standards provide more precise quantity regulation, but inefficiently require uniform compliance by all firms, regardless of cost structure. If regulators have little information about firms and compliance costs are likely to be variable and/or highly nonlinear [as suggested by Boyd, Krutilla and Viscusi 1995)], price based regulation is preferred. When pollution damages are more uncertain and likely to exhibit severe threshold effects [as suggested in Stephan (1995)], quantity standards look more attractive.[42] Theoretically, tradable permit schemes offer an attractive mix of quantity control and price flexibility; in practice, though, they can be tricky to implement.

There are other policy instruments to consider as well. Although the literature on direct technology subsidies is relatively scant to date, the work of Carraro and Galeotti (1997)

[42] See Weitzman (1974) for the classic presentation of price vs. quantity theory.

discussed above looks promising. There also seems to be a growing interest in information based compliance schemes. U.S. EPA programs such as the toxic release inventory (TRI) that simply requires firms to make their polluting activities publicly known seem to be inducing at least some firms to clean up their acts [see Cohen (1997)].

3.2 The double dividend question

In most policy simulations of environmental regulation, some form of pollution tax is the policy instrument of choice. This immediately raises the issue of what is to be done with the revenues raised from such a tax. Boyd, Krutilla and Viscusi (1995) explicitly assumes that revenue generated from carbon taxation is just added to the government's budget. The authors acknowledge that this simplification makes their benefit estimates conservative. Boyd and Uri (1990), like most other studies, makes the same assumption implicitly and without similar acknowledgement. Overlooking the so-called *double dividend* of eco-taxes misses one of their most attractive properties though — that revenues raised by addressing one market failure can be used to reduce distortionary taxes (or subsidies) elsewhere. This point is discussed most recently by de Mooij and Bovenberg (1998) and Mabey and Nixon (1997). Edwards (1996) provides an empirical example. His simulation predicting that cutting CO_2 emissions by 20 percent in Japan could cost as little as 0.1 percent of GNP hinges critically on new carbon taxes replacing current subsidies to domestic coal. Pireddu and Dufournaud (1996) entertains the possibility of incorporating eco-taxes in Italy that could reduce energy consumption without raising taxes overall.

3.3 Substitution effects

Another important consideration in modeling the economic impacts of environmental regulations is the degree of flexibility in production and consumption. On the production side, the ease with which regulated inputs (e.g. carbon heavy energy or "dirty" intermediate goods) can be replaced with additional labor and/or other forms of capital will largely determine how costly regulations turn out to be. This is precisely why Boyd, Krutilla and Viscusi (1995) run alternate simulations based on low and high degrees of input substitution. On the consumption side, the degree to which people are willing to substitute relatively "clean" goods and services for regulated ones will influence the composition of aggregate output as noted by Boyd and Uri (1990).

Thinking hard about substitutability in production and consumption naturally leads to consideration of dynamics and adjustment cost. Substitutability in production processes is a function of technology. Substitutability in consumption is a matter of taste. Both technology and tastes change over time; assumptions (implicit or explicit) about the speed at which they do so will have large impacts on calculations of the money and welfare costs of environmental regulation.

4 Conclusions

The literature on the relationship between environmental regulation and economic welfare is long and diverse. What we have attempted here is a summary of its major conclusions and an explanation of the considerations that tend do drive these results. That environmental regulations impose direct costs on firms in a static context is intuitive and well understood. The benefits of environmental regulation are harder to systematically catalogue and quantify. Dynamic and indirect relationships between environmental regulation and economic performance are even more difficult to capture fully. Linkages between environmental regulation and innovation, investment, and location decisions appear critical. How and how quickly production technology and consumer tastes change are fundamentally relevant policy questions with few solid answers. Those attempting to systematically model the long-term effects of major environmental regulations should keep all of these issues in mind.

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