Assessing the Economic Impacts of Large Scale Environmental Regulations in California

By*

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1 Introduction:

The California Environmental Protection Agency (Cal/EPA) is required by legislative mandate to evaluate the economic effects of its regulations. While facile with partial equilibrium techniques suitable for evaluating the effects of minor regulations, the agency needs capability in assessing the economic impact of large-scale regulations that may affect the overall size, composition, and competitiveness of the California economy. This paper explains the development and implementation of such capability by investigators at the University of California, Berkeley for the Cal/EPA's Air Resources Board (ARB).

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, Berkeley investigators chose this model as the basis for E-DRAM – a CGE suitable for Cal/EPA's use.

Like DRAM, E-DRAM is tailor-made for California and extremely refined in its description of the relationships between California producers, California consumers, government, and rest of the world. Unlike DRAM, the new model features an industrial aggregation scheme designed to highlight sectors of particular regulatory interest to ARB. It also contains an air pollution module able to track industry-specific emissions of five critical air pollutants.

The remainder of the paper is organized as follows. Section 2 briefly describes DRAM and its evolution into E-DRAM. Section 3 discusses data. Section 4 outlines the mechanisms through which regulatory scenarios are implemented in the model. Sections 5 and 6 presents select results from various policy assessments performed to date.

2 Model:

DOF and Professor Peter Berck developed the Dynamic Revenue Analysis Model (DRAM) in compliance with California Senate Bill 1837 enacted in August of 1994. The model is used for performing dynamic revenue analysis of proposed legislation having significant revenue impacts. DRAM is dynamic in the sense that it is designed to capture the rational responses of economic agents to policy changes. It 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.

The original DRAM had 1,100 modeling equation specifying the relationships between 75 distinct sectors: 28 industrial sectors, two factor sectors (labor and capital), one investment sector, seven household sectors (classified by income level) 36 government (federal, state, and local) sectors, and one sector representing the rest of the world (ROW).[1] Subsequent refinements have added an additional (high-income) household sector, nine government sectors, and a system of household demand for nine aggregate consumer good sectors (corresponding to U.S. Bureau of Labor Statistics' Consumer Price Index categories) estimated from ten years of western region Consumer Expenditure Survey data.[2,3]

E-DRAM is a modified version of DRAM. The new model delineates two new industrial sectors ARB's request – producers of consumer chemicals and manufacturers of gasoline powered engines. It also folds the previously distinct (small, but tax laden) alcohol, tobacco, and horseracing sector into the foods sector.[4] This revised industrial aggregation scheme, in conjunction with the refinements mentioned above, makes E-DRAM a 95 sectors model.

All versions of the California CGE work essentially the same way. Industrial sectors create value added by combining factors of production: intermediate goods (bought from industrial sectors), rented capital, and hired labor. Each industrial sector is modeled as a perfectly competitive firm with a Constant Elasticity of Substitution (CES) production function. Households supply capital and labor, also taking prices as given. 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. These myriad relationships are illustrated by the "circular flow" diagram in Figure 1 below.

3 Data:

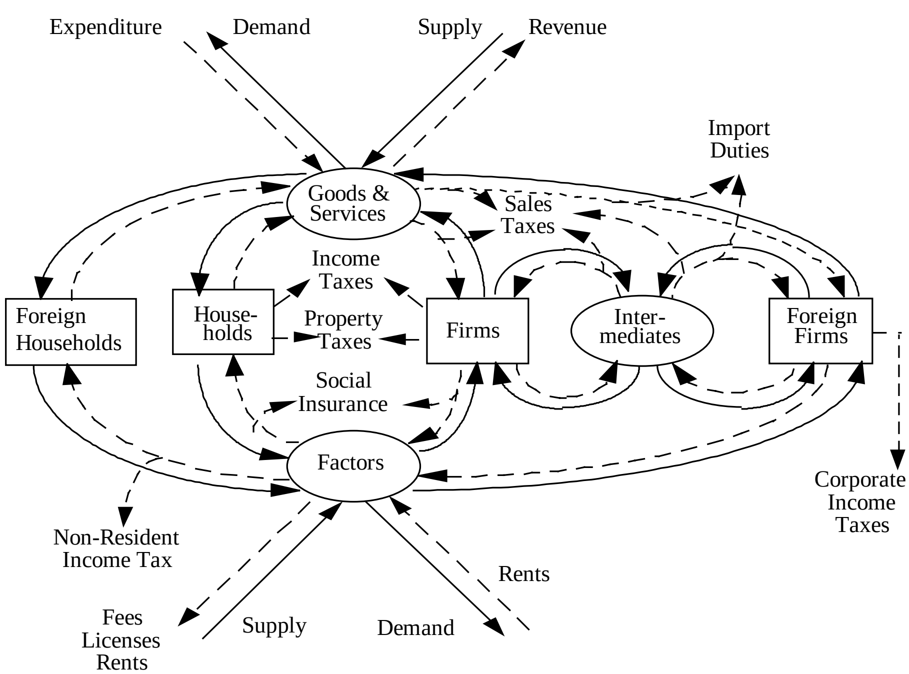
Data on the relationships described above is organized in a Social Accounting Matrix (SAM). The SAM is a square matrix consisting of a row and column for each sector of the economy. Each entry in the matrix identifies an exchange of goods and services between (or within) sectors. Entries along a SAM row record payments received by that particular row sector from each column sector. Summing across the row gives total payments made to that row sector by all (column) sectors. Entries down a SAM column record expenditures made by that particular column sector to all (row) sectors. Summing down a column gives total expenditures by that column sector to all row sectors. For accounting purposes, a SAM must "balance," *i.e.*, the each sector's row sum must equal its corresponding column sum. This

[1] For a full description of the original DRAM, see Berck, *et. al.* (Summer 1996), available online at www.dof.ca.gov/HTML/FS_DATA/dyna-rev/dynrev.htm.
[2] For a full description of the demand system work, see Berck, Hess, and Smith (September 1997), currently available online at www.are.berkeley.edu/~phess/demand.pdf.
[3] DOF is currently working to further disaggregate industrial sectors (toward the 2-digit SIC code level).
[4] This revised industrial aggregation scheme is just one example of how sectors explicitly tracked by the model can be manipulated - any large industry targeted for major new regulation can be isolated in a similar fashion.

balancing ensures that no money "leaks" out of the economy, *i.e.*, that all money received by firms (row sum) is spent by them (column sum).

SAM data sources are as follows. Industrial sector data originates from the Census of Business conducted by the U.S. Department of Commerce's Bureau of Economic Analysis (BEA).[5] National figures are scaled to California from state employment data and updated using DOF's growth estimates. Household income data come from the California Franchise Tax Board's Personal Income Tax "sanitized" sample, while household spending patterns are derived from the Consumer Expenditure Survey. Government transaction data is culled from published federal, state, and local government reports. E-DRAM's air pollution module, a matrix of industry-specific emission-intensities for five critical air pollutants, is derived from raw data on average daily organic gas (ozone precursors), carbon monoxide, nitrogen oxides, sulfur oxides, and particulate matter emissions by source furnished by ARB. It allows total as well as industry-specific emissions for each critical pollutant to be tracked under various policy scenarios.

Figure 1: Circular Flow Diagram of the California CGE



[5] The survey is conducted in years ending in 2 and 7 and data is released after processing. DRAM, and hence E-DRAM, use data from the 1997 release, which contains processed 1992 survey data.

4 Modeling Regulation:

For modeling purposes, regulations are distilled to some combination of price and/or production process changes. The following code enables analysts furnished with estimates of regulations' direct effects on prices, inputs, capital requirements, and/or trade flows in target industries to model these effects then rerun E-DRAM to assess their economy-wide impacts.

4.1 Price Change:

One method of modeling regulation is as price change(s). In DRAM, the before-tax price of industry *I* goods is P(I) and the after-tax price is P(I)*(1+TAUQX(I)). In E-DRAM, parameters REG5(I) and REG6(I) are added such that after-tax price is P(I)*(1+TAUQX(I)+REG6(I))*(1+REG5(I)). In the base/no-regulation case, both REG5(I) and REG6(I) are set to zero (and the original DRAM expression is returned). To simulate a regulation that increases after-tax prices *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.[6] These 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.

4.2 Modified Input Requirements:

A second way to of modeling regulation is as changes in input requirements for production and/or consumption.

Each industrial sector in DRAM is implicitly characterized by a production function that relates output to factor and intermediate inputs. Industry *J*'s demand for industry *I* intermediates per unity of output is governed by input-output coefficient AD(I,J).[7] In E-DRAM, the AD(I,J) coefficients are scaled by regulatory parameters REG1(I,J). Modifying REG(I,J) mimics the effect regulations requiring different intermediate usage by target industries. Changing REG1(I, '*industry J label'*) from its default setting of unity to 1.1, for example, simulates a regulation requiring industrial good *J* production to use 110% of the intermediate inputs (from all 29 industries) previously required. Setting AD('*industry I label'*, '*industry J label'*) to 1.1 simulates a regulatory change requiring good *J* production to use 110% of the inputs from industry *I* previously required (with inputs from the 28 other industries unchanged). These types of implementation trigger *J* good price increases indirectly, via increased production costs. E-DRAM then tracks the effect of both the price and intermediate expenditure increases.

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

[7] These input-output coefficients are calculated from primary SAM data.

Household consumption in DRAM is channeled through nine consumer good sectors. Parameters PHI(I,C) regulate the distribution of household spending on consumer goods *C* across industries *I*. In E-DRAM, PHI(I,C) is multiplied by parameter REG16(I,C) to allow for regulation-induced changes in consumption technology. Changing REG16(*I*, *'consumer good C label'*) from its default setting of unity to 0.8, for example, simulates a technological change enabling one unit of consumer good *C* to be enjoyed using only 80% of the inputs (from all 29 industries) previously required. Specifying REG16*('industry I label', 'consumer good C label'*) simulates a technological change enabling one unit of consumer good *C* to be enjoyed using 80% of the industry *I* inputs previously required (while leaving inputs from the other 28 industries unchanged).

4.3 Required Investment:

A third way of modeling regulation is as required investment. Capital expenditure dedicated to regulatory compliance can be handled two ways in E-DRAM. One is to model required investment as a one-time reduction in existing capital stock. This "bomb" scenario is appealing insofar as regulation means a one-time shift in some fraction of existing capital from the production (of sellable output) to compliance purposes. Alternately, required investment can be modeled as prescribing that some fraction of each capital dollar spent – past, present, and future – be dedicated to regulatory compliance. This "effective capital stock" scenario is appealing insofar as regulation continuously diverts some portion of capital spending toward compliance. The distinction between the "bomb" and "effective capital stock" scenarios is seen more clearly by referring to E-DRAM's capital stock equation;

KS(I) =E= REG13(I) * KS0(I) * (R('CAPIT',I) / R0('CAPIT',I)) ** ETAI(I) - (1 - REG12(I))* KS0(I),

Where KS(I) are industry I capital stock variables, KS0(I) are initial capital stocks (calculated from base data), R('CAPIT', I) are industry I rates of returns to capital, R0('CAPIT', I) are initial returns to capital, and ETAI(I) are investment supply elasticities.[8] Regulation requiring *x*% additional investment is modeled by setting REG12(I) = (1-*x*/100) for the bomb scenario, or REG13(I) = *x* for the effective capital stock scenario.[9]

4.4 Trade Considerations:

However regulations are modeled, their implications for trade should be considered. Environmental regulations effectively raise the domestic price PD(I) of goods produced by the targeted sector(s) above their initial levels PD0(I). Exports naturally decline as a result – a response captured in E-DRAM by the

[8] ETAI(I) are set at 20.
[9] 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.

sensitivity of exports to terms of trade.[10] The response of imports (M(I)) is not so straightforward however. First, the import price elasticity (ETAM(I)) may fall as a result of foreign producers having to alter their product for sale in the regulated market. Second, only some percentage (REG3(I)) of base imports (M0(I)) may satisfy the new regulatory requirements. Industry *I* imports are governed in E-DRAM by the following equation:

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

ETAM(I) and REG3(I) and are set to 1.5 and 1.0 respectively by default, but can be altered at the policy analyst's discretion. Dropping ETAM(I) reduces the sensitivity of imports to relative domestic prices; doing so is appropriate to the extent that price increases triggered by regulation compliance costs will not attract imports to the degree that demand-driven price increases do. Lowering REG3(I) from unity drops imports below their base level M0(I); this is reasonable to the extent that newly non-compliant are not imported.

5 Policy Analyses:

E-DRAM is designed to help Cal/EPA assess the economic impacts of large-scale environmental regulations. Preliminary work using the model to evaluate the State Implementation Plan (SIP) of the federal Clean Air Act for ARB is presented in Section 5.1.[11] Section 5.2 presents fuel efficiency scenarios run for the ARB and California Energy Commission's (CEC's) joint effort to develop strategies for reducing California's petroleum dependency – a task mandated by Assembly Bill 2076.[12]

5.1 Clean Air:

While particular SIP related proposals have not been provided to date, scenarios related to lowering volatile organic compound (VOC) content in industrial architectural coatings and formulating cleaner burning gasoline – run at ARB's request – are discussed in Sections 5.1 and 5.2 respectively, then compared and contrasted in Section 5.1.3.

5.1.1 Industrial Architectural Coatings Policy Scenarios:

ARB is considering lowering the VOC content limit for industrial architectural coatings. This regulation is projected to raise the cost of such coatings – which comprise approximately 37% of paints

[10] 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).

[11] For a full report of this work, see Berck and Hess (February 2000).

[12] For a full report of this work, see Hess and Berck (March 2002).

and allied products, which in turn comprise roughly 26% of E-DRAM's consumer chemicals (CONCH) sector – by 15%. These costs are modeled several ways.

The regulation is first modeled as a 15% price increase in architectural coatings, which translates into a 1.44% increase in the price of consumer chemicals, implemented by setting REG5('CONCH') = 0.0144.[13] Select results of this scenario (CONCH1) are listed in the third column of Table 1.[14] They indicate that the price of consumer chemicals rises, but by less than 1.44%. The static increase (1.44%) is militated against by both the downward slope of consumer demand and an inward shift in that demand (this latter effect would be missed in a partial equilibrium analysis, but is picked up in E-DRAM). Although the price of consumer chemicals rises only slightly, the sector shrinks significantly, employing roughly 16% ($239 million) less capital, employing 17% (2,900) fewer workers, and producing nearly 17% (almost $130 million) less output.[15] Statewide real personal income, employment, the consumer price index, the capital stock, and the return to capital all fall slightly – signs of general economic contraction.[16]

Next the regulation was modeled as a 1.56% increase in all intermediate inputs to the consumer chemical production process, implemented by setting REG1(I, 'CONCH') = 1 + 0.0156.[17] This specification is preferable to the straight price hike because it captures the stimulus of spending induced by regulatory compliance. Select results of this scenario (CONCH2) are listed in the fourth column of Table 1. Intuitively, the economic burden of this scenario is lighter than that imposed by the previous one. The price of consumer chemicals rises slightly more and output falls a bit less than in the straight price hike scenario because consumer demand now shifts in less as increased spending on intermediates mitigates the general economic contraction. California real personal income, employment, the consumer price index, the capital stock, and the return to capital all fall less than in CONCH1.

Scenarios 3 (CONCH3) and 4 (CONCH4) are CONCH2 plus trade considerations. Scenario 3 reduces ETAM('CONCH') from its default of 1.5 to zero, thus effectively freezing imports at pre-regulation levels. Not surprisingly, this modification dampens the adverse impacts of the regulation.

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[13] $0.15*0.37*0.26 \cong 0.0144$

[14] The second column reports select results for a base (no regulatory modeling) solve of E-DRAM. Level and percentage changes of the variables are as compared to the base data and indicate that the model remains well calibrated, *i.e.*, solution values of the variables match the base data to within a few hundredths of one percent.

[15] These sector responses are implausibly high and may be 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 the model where industrial sectors are disaggregated to roughly the 2-digit SIC level.

[16] 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

[17] Intermediates must be increased by $1.44\%/0.9222 \cong 1.56\%$ to trigger a static price increase of 1.44% because intermediate costs are 0.9222 of the price of CONCH.

Domestic output and employment rise toward their initial level, imports fall back toward their initial level, and prices creep back up. Alternately, Scenario 4 lowers REG3('CONCH') from its default of unity to 0.9, thus imposing a (static) 10% reduction in regulated sector imports. This formulation is expansionary. Results suggest that if domestic environmental regulations significantly curtail imports (*e.g.* due to non-compliance), they may stimulate the state economy in the intermediate run. Comparing results across scenarios three and four indicates that the model is logically more sensitive to changes in REG3 than ETAM – lowering ETAM discourages imports at the margin, whereas lowering REG3 reduces their base level.

Table 1: Architectural Coatings Policy Scenarios

Scenario	TODAY	CONCH1	CONCH2	CONCH3	CONCH4
Scenario description	initial solve & calibration check	1.443% price increase	1.56% increase in intermediate requirements	CONCH2 & ETAM=0.0	CONCH2 & REG3=0.9
CA economy					
CA PERSONAL INCOME ($BILLION)	891.55414	891.395596	891.40875	891.51398	891.68646
CHANGE CA PERS. INC.	-0.136282	-0.158545	-0.145391	-0.040156	0.13232
% CHANGE CA PERS. INC.	-0.0153%	-0.0178%	-0.0163%	-0.0045%	0.0148%
CONSUMER PRICE INDEX (BASE=1)	0.999929	0.999736	0.999757	0.999931	1.000216
CHANGE AGGREGATE CPI	-0.000071	-0.000194	-0.000173	0.000002	0.000287
% CHANGE AGGREGATE CPI	-0.0071%	-0.0194%	-0.0173%	0.0002%	0.0287%
LABOR DEMAND (MILLIONS)	14.045159	14.044133	14.044198	14.04486	14.045947
CHANGE LABOR DEMAND	-0.000746	-0.001026	-0.000962	-0.000299	0.000788
% CHNGE LABOR DEMAND	-0.0053%	-0.0073%	-0.0068%	-0.0021%	0.0056%
CONCH sector					
OUTPUT ($BILLION)	0.767794	0.638636	0.64624	0.759619	0.944189
CHANGE OUTPUT	-0.000263	-0.129158	-0.121554	-0.008175	0.176395
% CHANGE OUTPUT	-0.0343%	-16.8220%	-15.8316%	-1.0647%	22.9742%
CAPITAL STOCK($100 BILLION)	0.014567	0.012174	0.012313	0.014416	0.017824
CHANGE CAPITAL STOCK	-0.000007	-0.002393	-0.002254	-0.000151	0.003257
% CHANGE CAPITAL	-0.0477%	-16.4265%	-15.4755%	-10.394%	22.3593%
JOBS (MILLIONS)	0.017023	0.014122	0.014295	0.01684	0.020992
CHANGE JOBS	-0.000005	-0.002901	-0.002729	-0.000184	0.003969
% CHANGE JOBS	-0.0283%	-17.0404%	-16.0283%	-1.0787	23.3169%
PRICE (BASE=1)	0.999995	1.004733	1.005107	1.005746	1.006656
CHANGE PRICE	-0.000005	0.004738	0.005113	0.005751	0.006661
% CHANGE PRICE	-0.0005%	0.4738%	0.5113%	0.5751%	0.6661%
IMPORTS ($BILLION)	2.395456	2.488635	2.495128	2.395544	2.23349
CHANGE IMPORTS	-0.000088	0.093179	0.099673	0.000088	-0.161966
% CHANGE IMPORTS	-0.0037%	3.8898%	4.1609%	0.0037%	-6.7614%

Overall, Scenario 3 – a 1.44% price increase via a 1.56% across the board increase in intermediate requirements, coupled with a zero elasticity of imports with respect to domestic price change – is the preferred implementation. 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 personal income and employment may fall slightly.[18]

5.1.2 Reformulated Gasoline Policy Experiments:

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. The following scenarios with preliminary cost estimates were run for ARB in Spring 2001.

Petroleum Policy Experiment 1 (PETRO1) characterizes the new Phase III standards as requiring the petroleum industry to spend an additional $523 million on inputs. Modeling this expenditure as an across-the-board increase in intermediates is implemented by setting REG1('PETRO') to 1.024.[19] Results of this experiment are reported in the third column of Table 2.

Other ways to model Phase III regulations entail distinguishing between compliance investment and operating costs. Petroleum Policy Experiments 2 (PETRO2) and 3 (PETRO3) assume that the regulations require the petroleum industry to make $1 billion of additional investment and spend $228 million more on annual operating costs. The required investment translates into 9.4% of petroleum sector capital stock being diverted from refining to compliance activity, while the operating cost figure means a 1.1% increase in spending on all intermediates.[20] PETRO2 models the investment requirement as a one-time reallocation of 9.4% of the sector's existing capital from production to compliance – the "bomb" scenario discussed in Section 4.3, implemented by setting REG12('PETRO') to 0.906. PETRO3 models the required investment as diverting 9.4% of every dollar spend on refining capital from productive to compliance purposes – the "effective capital" scenario discussed in Section 4.3, implemented by setting REG13('PETRO') to 0.906.[21] In both PETRO2 and PETRO3, the 1.1% increase in intermediate expenditures is modeled by setting REG1(I,'PETRO') = 1.011. The final petroleum policy experiment (PETRO4) differs from PETRO3 only in that ETAM('PETRO'), the elasticity of petroleum imports with respect to relative domestic price, is lowered from its default of 1.5 to zero. Select results of PETRO2-4 are also reported in Table 2.

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[18] While E-DRAM predicts state personal income and employment falling by rough $40 million (0.005%) and 300 jobs (0.002% of) respectively, these figures are well within the calibration limits of the model.

[19] 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.

[20] The 9.4% 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 the previous footnote.

[21] The "effective capital" interpretation is preferable to the one-time investment/"bomb" scenario insofar as in the former, dollars spent on compliance scale up (or down) with industry size and are an ongoing concern.

Table 2: Reformulated Gasoline Policy Experiments

Scenario	TODAY	PETRO1	PETRO2	PETRO3	PETRO4
Scenario 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	PETRO3 & ETAM=0.0
CA Economy					
CA PERSONAL INCOME ($BILLION)	891.55414	890.66685	891.14265	891.14235	891.15025
CHANGE CA PERS. INC.	-0.136282	-0.887291	-0.411488	-0.41179	-0.403893
% CHANGE CA PERS. INC.	-0.000153	-0.000995	-0.000462	-0.000462	-0.000453
CONSUMER PRICE INDEX (BASE=1)	0.999929	1.000203	1.000055	1.000055	1.000061
CHANGE AGGREGATE CPI	-0.000071	0.000274	0.000126	0.000126	0.000132
% CHANGE AGGREGATE CPI	-0.000071	0.000274	0.000126	0.000126	0.000132
LABOR DEMAND (MILLIONS)	14.045159	14.037822	14.04176	14.041757	14.041771
CHANGE LABOR DEMAND	-0.000746	-0.007337	-0.0034	-0.003402	-0.003389
% CHNGE LABOR DEMAND	-0.000053	-0.000522	-0.000242	-0.000242	-0.000241
RETURN TO K INDEX (BASE=100)	99.999198	99.995493	99.997963	99.998002	99.998078
CHNAGE RETURN TO CAPITAL INDEX	-0.000802	-0.003706	-0.001235	-0.001196	-0.00112
% CHANGE RETURN TO CAPITAL INDEX	-0.000008	-0.000037	-0.000012	-0.000012	-0.000011
CAPITAL STOCK ($100 BILLION)	14.541822	14.528717	14.535616	14.535601	14.535863
CHANGE CAPITAL STOCK	-0.002212	-0.013105	-0.006207	-0.006221	-0.005959
% CHANGE CAPITAL STOCK	-0.000152	-0.000901	-0.000427	-0.000428	-0.00041
PETRO sector					
OUTPUT ($BILLION)	23.979113	23.374819	23.695619	23.695405	23.705298
CHANGE OUTPUT	-0.001325	-0.604294	-0.283494	-0.283708	-0.273815
% CHANGE OUTPUT	-0.000055	-0.025201	-0.011823	-0.011831	-0.011419
CAPITAL ($100 BILLION)	0.026176	0.025526	0.025801	0.025795	0.025805
CHANGE CAPITAL	-0.000006	-0.00065	-0.000375	-0.000381	-0.000371
% CHANGE CAPITAL	-0.000218	-0.024833	-0.014333	-0.014565	-0.014157
JOBS (MILLIONS)	0.021983	0.021426	0.021741	0.021743	0.021752
CAPITAL RENTAL RATE (BASE=100)	0.068517	0.065075	0.066823	0.066816	0.066873
CNANGE CAPITAL RENTAL RATE	-0.000031	-0.003443	-0.001694	-0.001701	-0.001644
% CHANGE CAPITAL RENTAL RATE	-0.000447	-0.050245	-0.024728	-0.024829	-0.024001
CHANGE JOBS	0	-0.000557	-0.000241	-0.00024	-0.000231
% CHANGE JOBS	-0.000014	-0.025321	-0.010984	-0.010918	-0.010504
PRICE (BASE=1)	0.999955	1.023045	1.01063	1.010637	1.010651
CHANGE PRICE	-0.000045	0.02309	0.010675	0.010682	0.010696
% CHANGE PRICE	-0.000045	0.023091	0.010675	0.010683	0.010697
IMPORTS ($BILLION)	0.562809	0.583314	0.572248	0.572254	0.562849
CHANGE IMPORTS	-0.00004	0.020505	0.009438	0.009445	0.00004
% CHANGE IMPORTS	-0.00007	0.036433	0.01677	0.016782	0.00007

Comparing and contrasting results across PETRO1-4 yields the following insights. First, it appears that regulations raising annual operating costs are more detrimental to the economy than those requiring capital investment. PETRO1 has a significantly larger negative economic impact than the other gasoline experiments. Second, nearly all increases in operating costs are passed through to final prices. Petroleum sector costs and price both rise nearly 2.4% in PETRO1 and 1.1% in PETRO2-4. Third, comparing results from PETRO3 and PETRO4 suggests that if capital investments are required, it may be better to make them all at once rather than on a continual, incremental basis. Fourth, all four experiments suggest elasticities of petroleum sector output and employment with respect to petroleum price of roughly –1.[22] Fifth, trade considerations may dampen the adverse effects of domestic environmental regulation. Sixth, changes in statewide economic indicators with respect to Phase III measures being considered are insignificant.

Results of PETRO4, the preferred specification, suggest that Phase III reformulated gasoline regulations can be expected to reduce output and employment in the California petroleum industry by approximately 1% each, meaning roughly $274 million less product and 231 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 minuscule. Overall, the impacts of Phase III reformulated gas regulations on the California economy will be negligible.

5.1.3 Summary of Clean Air Analyses:

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 CONCH3 in Table 1 and PETRO4 in Table 2 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%.

5.2 Petroleum Dependence

E-DRAM is also being used in ARB and CEC's joint task of examining petroleum dependency issues. Enhancements to the model for this purpose are briefly discussed in Section 5.2.1. Related policy experiments presented in Section 5.2.2.

[22] These results are much more plausible than the elasticities derived in the industrial architectural coating experiments. The petroleum industry is much more similar in size to other industrial sectors in the model than the consumer chemical sector is.

5.2.1 Model Enhancements

For the joint ARB/CEC project, E-DRAM is enhanced in two ways. First, the model's base petroleum data are reconciled with figures provided by Arthur D. Little (ADL) in consultation with the ARB and CEC – see Table 3 below.[23] Second, the 1998/1999 base year model is extrapolated to 2020 and 2050 based on state personal income, population, and industry-specific forecasts. Monetary flows recorded in the 1998/1999 SAM, except as indicated below, are assumed to grow at rates based on the University of California, Los Angeles (UCLA) business forecast – 2.84% annually from 2000 to 2020, and 2.58% from 2020 to 2050.[24] Population and employment are assumed to grow at DOF's projected annual rate of 1.36%.[25] Monetary flows for the petroleum refining (PETRO) and crude oil production (ENMIN) sectors are assumed to follow the trajectory outlined by ADL in Table 3 below, which indicates a growing dependence on imports.[26] Once all these modifications are made, the SAMs are re-balanced so that the each sector's row (receipt) total equals its column (expenditure) total. This re-balancing is done using a program written by Sherman Robinson and Moataz El-Said in November 2000.[27]

Table 3: Estimates of Supply and Demand Balance for California Refineries

Description	1999 $ million*	2020 $ million**	2050 $ million**
CA refined petroleum supply	32,413	52,413	52,483
Demand for CA refined petro.	35,136	68,137	116,922
California	28,649	56,553	98,876
Export to Arizona, Nevada	4,048	8,164	14,626
Export from refineries	2,439	3,420	3,420
CA refined petro. imports	2,723	15,725	64,438
California crude oil supply	4,900	2,000	0
California crude oil demand	10,071	11,683	15,710
CA crude oil imports	6,971	13,683	15,710

***** Based on finished motor gas and crude oil prices of $1.30/gal. and $17.81/bbl respectively.
***** Based on finished motor gas and crude oil prices of $1.65/gal. and $22.50/bbl respectively.

[23] ADL estimated California refinery flows based on data from Petroleum Supply Annual 1999 (EIA, June 2000).
[24] These growth rates translate into scale factors of 2.2515 for 1999 to 2020 and 2.2520 for 2020 to 2050.
[25] Compounding this rate delivered scale factors of 1.3 and 1.5 for projecting 1999 employment to 2020 and 2050 levels respectively.
[26] Again, 1999 figures are based on EIA data. Estimates of 2020 and 2050 demand (CA, AZ, and NV) are based on the following CEC projected annual growth rates of demand (CEC, 2001): 1.6% for gasoline, 2.4% for diesel, 3.4% for jet fuel, 2.0% for residuals, and 1% for liquid propane gas and other miscellaneous products. Supply estimates are based on the assumption that California refining capacity increases 0.5% annually through 2020 (Stillwater), then remains fixed, and that California crude production declines according to a linear extrapolation of either historical production or reserves. Net imports equate supply and demand.
[27] The method is described in Robinson, *et. al.* (March/June 2001).

Table 4 displays selected input data and corresponding model output for the 1999, 2020, and 2050 base-case models. Comparing the columns labeled "DATA" and " BASE MODEL" for any given year indicates that the model is well calibrated, *i.e.*, it produces model solutions that match the input data to within tenths or hundredths of one percent. Achieving such calibration is essential for policy analysis, as policy scenario results that differ from the base model by less than calibration error are quantitatively insignificant. Comparing across year columns demonstrates how the modeled economy grows by roughly the growth rates/scale factors discussed above. State output and personal income each increase by factors of roughly 2.25 from 1999 to 2020 and 2.15 from 2020 to 2050, while state population and employment each grow by factors of roughly 1.3 from 1999 to 2020 and 1.5 from 2020 to 2050. The petroleum (PETRO) and energy and mining (ENMIN) sectors both also grow by roughly the scale factors implemented.[28]

5.2.2 Policy Scenarios:

Four alternate strategies for reducing California's petroleum dependence have been developed in a collaborative process between ARB, CEC, and ADL. Each scenario is built around two elements: (1) reduced gasoline demand from improved light-duty vehicle fuel economy, and (2) diesel fuel displacement from gas-to-liquid (GTL) or Fischer Tropsch diesel (FTD) fuels. Scenarios 1 and 4 are presented as bounds on the possible impacts to the California economy. Scenario 1 combines off-the-shelf fuel efficiency improvements in light-duty vehicles with a 33% blend of FTD in diesel, while scenarios four incorporate more aggressive and therefore more costly fuel efficiency/displacement options.

Both scenarios are modeled and coded as some combination of increased transportation costs and decreased fuel costs for industries and households; the rationale is that more efficient transportation is costlier to produce, but saves fuel. In E-DRAM, industries buy vehicle engines and fuel directly, while households buy them indirectly via the consumer goods sectors. Industrial purchases from the engine (ENGIN) and petroleum (PETRO) sectors are recorded in SAM cells ('ENGIN', I) and ('PETRO', I) respectively. Household purchases from the consumer transportation sector (CTRANS) and consumer fuel sector (CFUEL) are recorded in the SAM cells (I, 'CTRANS') and (I, 'CFUEL') respectively. Following the explanation of regulatory parameters in Section 4, increases in industrial and consumer transportation costs are modeled using parameters REG1('ENGIN',I) and REG16(I, 'CTRNS') respectively. Decreases in industrial and consumer fuel costs are modeled using parameters REG1('PETRO', I) and REG16('PETRO', 'CFUEL') respectively.[29]

[28] Small divergence between scaling input to the model and output from the model occur due to SAM balancing.
[29] The CEC estimates that residential use accounts for roughly 90% of gasoline consumption in the state. Hence, 90% of projected increases in engine costs are apportioned to household and 10% are apportioned to industries. Likewise, 90% of projected fuel savings are apportioned to households and 10% are apportioned to industries.

Table 4: Select Output for E-DRAM 1999, 2020, and 2050 Base Models

	1999		2020		2050	
	DATA	BASE MODEL	DATA	BASE MODEL	DATA	BASE MODEL
CA OUTPUT ($BILLION)	1377.0067	1378.0905	3075.0665	3078.0223	6561.4202	6568.5732
% CHANGE CA OUTPUT		0.08%		0.10%		0.11%
CA PERSONAL INCOME ($BILLION)	891.6942	892.4894	2007.3821	2009.5373	4319.8863	4325.2331
% CHANGE CA PERS. INC.		0.09%		0.11%		0.12%
CONSUMER PRICE INDEX (BASE=1)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0001
% CHANGE AGGREGATE CPI		0.00%		0.00%		0.01%
POPULATION (MILLION FAMILIES)	23.1413	23.1431	30.7317	30.7362	46.0883	46.0978
% CHANGE POPULATION		0.01%		0.01%		0.02%
WAGE INDEX (BASE = 100)	100.0000	100.0517	100.0000	100.0688	100.0000	100.0880
% CHANGE WAGE INDEX		0.05%		0.07%		0.09%
LABOR DEMAND (MILLIONS)	14.0459	14.0483	18.6552	18.6605	27.9572	27.9673
% CHANGE LABOR DEMAND		0.02%		0.03%		0.04%
RETURN TO K INDEX (BASE=100)	100.0000	100.0060	100.0000	100.0067	100.0000	100.0075
% CHANGE RETURN TO K INDEX		0.01%		0.01%		0.01%
CAPITAL STOCK ($100 BILLION)	14.5720	14.5863	32.7161	32.7557	70.3030	70.4023
% CHANGE CAPITAL STOCK		0.10%		0.12%		0.14%
ENMIN						
OUTPUT ($BILLION)	5.8738	5.8789	6.2035	6.2086	7.6830	7.6887
% CHANGE OUTPUT		0.09%		0.08%		0.07%
JOBS (MILLIONS)	0.0178	0.0178	0.0182	0.0182	0.0216	0.0216
% CHANGE JOBS		0.16%		0.15%		0.14%
PRICE (BASE=1)	1.0000	1.0001	1.0000	1.0001	1.0000	1.0000
% CHANGE PRICE		0.01%		0.01%		0.00%
IMPORTS ($BILLION)	17.5309	17.5404	35.9865	36.0105	57.3622	57.4093
% CHANGE IMPORTS		0.05%		0.07%		0.08%
PETRO						
OUTPUT ($BILLION)	24.8013	24.8156	39.2783	39.3048	39.2124	39.2540
% CHANGE OUTPUT		0.06%		0.07%		0.11%
JOBS (MILLIONS)	0.0220	0.0220	0.0292	0.0292	0.0294	0.0295
% CHANGE JOBS		0.09%		0.10%		0.15%
PRICE (BASE=1)	1.0000	1.0001	1.0000	1.0001	1.0000	1.0000
% CHANGE PRICE		0.01%		0.01%		0.00%
IMPORTS ($BILLION)	2.8054	2.8058	15.6811	15.6834	63.6238	63.6368
% CHANGE IMPORTS		0.01%		0.01%		0.02%

Strategy 1 (SCNRIO1) is a combination of fuel efficiency measures applied to light-duty vehicles starting in 2008 and FTD blended with other diesel feedstocks at 33% to meet ARB's future ULSD specification. Its cost/benefit estimates, summarized in Table 5, are implemented as follows (see footnotes for actual GAMS code).[30] First, the cost of consumer transportation (CTRNS) increases by 90% of projected consumer cost. These additional costs are inserted such that the new, higher amount of consumer transportation spending is expressed as the appropriate multiple of old spending.[31] Second, the cost of industrial engines increases by 10% of the projected consumer cost, plus the commercial costs.

[30] Numbers in the illustrative scenario coding correspond to 2020 cost/benefit projections.

These additional costs are inserted such that the new, higher amount of industrial spending on engines is expressed as the appropriate multiple of old spending.[32] Third, 90% of the projected savings from increased fuel efficiency accrue to consumers. These savings are inserted such that the new, lower amount of consumer fuel spending is expressed as the appropriate fraction of old spending.[33] Fourth, 10% of the projected savings from increased fuel efficiency accrue to industry. These savings are inserted such that the new, lower amount of industrial spending on fuel is expressed as the appropriate multiple of old spending.[34]

Table 5: Estimated Economic Inputs for Scenario 1 – EEA/Duleep Fuel Economy Improvements

Changes in Consumer Expenditures	Million 2002 $		Changes in Sector Revenue	Million 2002 $	
	2020	2050		2020	2050
Cost			Benefit		
Household (inc. vehicle cost)	1,460	4,900	Vehicle Mfg. (inc. vehicle revenue)	1,460	4,900
Household (inc. PZEV cost)	501	812	Vehicle Mfg. (inc. PZEV revenue)	501	812
Commercial (inc. GTL-diesel cost)	125	146	Foreign GTL Producer (inc. revenue)	125	146
Total Cost	2,087	5,858	Total Benefits	2,087	5,858
Benefits			Cost		
Household (dec. gasoline expenditure	3,264	14,617	Refiners (decrease in revenue)	2,547	11,409
			California Excise Tax (dec. revenue)	358	1,604
			Federal Excise Tax (dec. revenue)	358	1,604
Total Benefits	3,264	14,617	Total Costs	3,264	14,617

Scenario 4 is more aggressive, featuring the introduction of all hybrid technologies starting in all light-duty vehicles in 2008. This case is based on ACEEE - full hybrid technologies and costs; it also includes FTD blends. Its costs/benefits estimates, summarized in Table 6, are implemented as follows. Scenario 4 code is structurally identical to Scenario 1 code, but the cost and benefit figures are higher.[35] First, the cost of consumer transportation (CTRNS) increases by 90% of projected consumer cost. These additional costs are inserted such that the new, higher amount of consumer transportation spending is

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[31] REG16(I,’CTRNS’) = (SUM(J, SAM(J,’CTRNS’)) + 0.9*1.961)/SUM(J, SAM(J,’CTRNS’));
[32] REG1(’ENGIN’,I) = (SUM(J,SAM(’ENGIN’,J)) + .1*1.961 + .125)/SUM(J,SAM(’ENGIN’,J));
[33] REG16(I,’CFUEL’) = (SUM(J, SAM(J,’CFUEL’)) - .9*3.264)/SUM(J, SAM(J,’CFUEL’));
[34] REG1(’PETRO’,I) = (SUM(J,SAM(’PETRO’,J)) - .1*3.264)/SUM(J,SAM(’PETRO’,J));
[35] Again, numbers in the illustrative scenario coding correspond to 2020 cost/benefit projections.

expressed as the appropriate multiple of old spending.[36] Second, the cost of industrial engines increases by 10% of the projected consumer cost, plus the commercial costs. These additional costs are inserted such that the new, higher amount of industrial spending on engines is expressed as the appropriate multiple of old spending.[37] Third, 90% of the projected savings from increased fuel efficiency accrue to consumers. These savings are inserted such that the new, lower amount of consumer fuel spending is expressed as the appropriate fraction of old spending.[38] Fourth, 10% of the projected savings from increased fuel efficiency accrue to industry. These savings are inserted such that the new, lower amount of industrial spending on fuel is expressed as the appropriate multiple of old spending.[39]

Table 6: Estimated Economic Inputs for Scenario 4: ACEEE-Full Hybrid Vehicles

Changes in Consumer Expenditures	Million 2002 $		Changes in Sector Revenue	Million 2002 $	
	2020	2050		2020	2050
Cost			Benefit		
Household (inc. vehicle cost)	13,033	21,096	Vehicle Mfg. (inc. vehicle revenue)	13,033	21,096
Household (inc. PZEV cost)	501	812	Vehicle Mfg. (inc. PZEV revenue)	501	812
Commercial (inc. GTL-diesel cost)	125	146	Foreign GTL Producer (inc. revenue)	125	146
Total Cost	13,660	22,054	Total Benefits	13,660	22,054
Benefits			Cost		
Consumer (dec. gasoline expenditure	12,533	29,896	Refiners (decrease in revenue)	9,782	23,333
			California Excise Tax (dec. revenue)	1,376	3,281
			Federal Excise Tax (dec. revenue)	1,376	3,281
Total Benefits	12,533	29,896	Total Costs	12,533	29,896

Select results for Strategy 1 and 4 are reported in Table 7. As expected Strategy 1's economic impacts are more benign than Strategy 4's.

[36] REG16(I,'CTRNS') = (SUM(J, SAM(J,'CTRNS')) + .9*13.534)/SUM(J, SAM(J,'CTRNS'));
[37] REG1('ENGIN',I) = (SUM(J,SAM('ENGIN',J)) + .1*13.534 + .125)/SUM(J,SAM('ENGIN',J));
[38] REG16(I,'CFUEL') = (SUM(J, SAM(J,'CFUEL')) - .9*12.533)/SUM(J, SAM(J,'CFUEL'));
[39] REG1('PETRO',I) = (SUM(J,SAM('PETRO',J)) - .1*12.533)/SUM(J,SAM('PETRO',J));

Table 7: Modeling Results for Petroleum Dependence Reduction Strategies

	2020			2050		
	BASE MODEL	SCNRIO1	SCNRIO4	BASE MODEL	SCNRIO1	SCNRIO4
CA Economy						
CA OUTPUT ($BILLION)	3078.0223	3074.9243	3062.4866	6568.5732	6557.2797	6538.4894
% CHANGE CA OUTPUT	0.10%	-0.10%	-0.50%	0.11%	-0.17%	-0.46%
CA PERSONAL INCOME ($BILLION)	2009.5373	2009.5213	2001.0251	4325.2331	4329.6794	4318.1160
% CHANGE CA PERS. INC.	0.11%	0.00%	-0.42%	0.12%	0.10%	-0.16%
LABOR DEMAND (MILLIONS)	18.6605	18.6767	18.6726	27.9673	28.0326	28.0382
% CHNGE LABOR DEMAND	0.03%	0.09%	0.06%	0.04%	0.23%	0.25%
PRICE OF CFOOD	1.0001	1.0001	1.0026	1.0001	1.0000	1.0018
PRICE OF CHOME	1.0000	1.0000	1.0018	1.0001	0.9999	1.0012
PRICE OF CFUEL	1.0000	0.9687	0.8818	1.0000	0.9324	0.8636
PRICE OF CFURN	1.0001	1.0001	1.0022	1.0001	1.0000	1.0015
PRICE OF CCLOTH	1.0001	1.0001	1.0023	1.0001	1.0000	1.0016
PRICE OF CTRANS	1.0000	1.0072	1.0513	1.0001	1.0095	1.0382
PRICE OF CMED	1.0001	1.0002	1.0038	1.0001	1.0003	1.0029
PRICE OF CAMUS	1.0000	1.0001	1.0027	1.0001	0.9999	1.0018
PRICE OF COTHR	1.0000	1.0000	1.0017	1.0001	0.9999	1.0012
ENMIN sector						
OUTPUT ($BILLION)	6.2086	6.0575	5.6084	7.6887	7.2328	6.7220
% CHANGE OUTPUT	0.08%	-2.43%	-9.67%	0.07%	-5.93%	-12.57%
IMPORTS ($BILLION)	36.0105	34.8290	31.8337	57.4093	52.2725	47.5359
% CHANGE IMPORTS	0.07%	-3.28%	-11.60%	0.08%	-8.95%	-17.20%
EXPORTS ($BILLION)	1.0965	1.1122	1.1542	2.6396	2.7452	2.8549
% CHANGE EXPORTS	-0.07%	1.43%	5.27%	-0.09%	4.00%	8.16%
PETRO sector						
OUTPUT ($BILLION)	39.3048	37.6902	33.5161	39.2540	32.6620	26.4558
% CHANGE OUTPUT	0.07%	-4.11%	-14.73%	0.11%	-16.79%	-32.60%
IMPORTS ($BILLION)	15.6834	15.5646	15.2814	63.6368	62.1426	60.7897
% CHANGE IMPORTS	0.01%	-0.76%	-2.56%	0.02%	-2.35%	-4.47%
EXPORTS ($BILLION)	11.9979	12.0739	12.2582	19.1419	19.5219	19.8796
% CHANGE EXPORTS	-0.02%	0.63%	2.17%	-0.02%	1.99%	3.85%
ENGIN sector						
OUTPUT ($BILLION)	40.4675	40.5818	40.8046	87.0335	87.2217	87.4671
% CHANGE OUTPUT	0.05%	0.28%	0.83%	0.05%	0.22%	0.50%
IMPORTS ($BILLION)	9.0494	9.0815	9.2482	19.4495	19.5153	19.7580
% CHANGE IMPORTS	0.02%	0.35%	2.20%	0.04%	0.34%	1.59%
EXPORTS ($BILLION)	13.8359	13.7822	13.5091	29.7408	29.6307	29.2304
% CHANGE EXPORTS	-0.03%	-0.39%	-2.36%	-0.05%	-0.37%	-1.72%
FOODS sector						
OUTPUT ($BILLION)	92.9579	95.1127	101.3527	200.2299	210.4874	221.4745
% CHANGE OUTPUT	0.14%	2.32%	9.03%	0.17%	5.12%	10.61%
APPAR sector						
OUTPUT ($BILLION)	25.9513	26.4969	27.5086	55.8814	58.7842	60.8908
% CHANGE OUTPUT	0.20%	2.10%	6.00%	0.25%	5.19%	8.96%
MOTOR sector						
OUTPUT ($BILLION)	18.2243	18.1613	17.8553	39.3478	39.1508	38.6851

SCNRIO1 reduces state output – by 0.10% in 2020 and 0.17% in 2050 – while slightly increasing state personal income – by 0.1% in 2050. *Real* personal income (what's reported in the table) rises while output falls because of increased consumer purchasing power due to improved fuel efficiency. The price of consumer fuel (CFUEL)– interpreted as the price of vehicle miles traveled – drops roughly 3 % in 2020 and 7% in. Increased fuel efficiency reduces the demand for refined petroleum (PETRO) products by 4% in 2020 and 16% in 2050. Decreased petroleum sector output adversely affects upstream crude oil suppliers. Energy and mining (ENMIN) sector output is down 4% in 2020 and 16% in 2050. Meanwhile, money freed from fuel expenditure is spent in other sectors. Both food (FOODS) and apparel (APPAR) sector output are up roughly 2% in 2020 and 5% in 2050. Sectors that rely heavily on combustion engine inputs, such as motor vehicle manufacturing (MOTOR), see costs rise – thus their prices rise and output falls. In 2020, the price of consumer transportation (CTRANS) is up 0.72% while MOTOR output is down 0.35%. In 2050, the price of CTRANS is up 0.95% while MOTOR output is down 0.50%.

Impacts of Scenario 4 are greater. It reduces state output by 0.50% in 2020 and 0.46% in 2050; real income falls by 0.42% in 2020 and 0.16% in 2050. The price of consumer fuel – again, interpreted as the price of vehicle miles traveled – drops 12% in 2020 and 14% in 2050. Increased fuel efficiency reduces the demand for refined petroleum products; petroleum sector output is 15% lower in 2020 and 33% lower in 2050. Decreased petroleum sector output adversely affects upstream crude oil suppliers. ENMIN is down 10% in 2020 and 13% in 2050. Money freed from fuel expenditure is spent in other sectors. Food sector output is up 9% in 2020 and 11% in 2050, while apparel sector output is up 6% and 9% in those same years respectively. Costs rise in sectors that rely heavily on combustion engine inputs. In 2020, the price of consumer transportation (CTRANS) is up 0.72% while MOTOR output is down 0.35%. In 2050, the price of CTRANS is up roughly 5% while MOTOR output is down 2%. In 2050, the price of CTRANS is up about 4% while MOTOR output is nearly 2%.

5.2.3 Higher World Energy Prices

A primary motivation for decreasing petroleum dependency is limiting vulnerability to supply shocks that cause price spikes. Examining how E-DRAM assesses the impact of such spikes on the state economy – and predicting the extent to which the scenarios under consideration these impacts – is thus critical.

Table 8 compares runs given 20% higher world ENMIN and PETRO prices (gray columns) with runs at original world prices (white columns) . Comparing "NEW MODEL" to "BASE MODEL" columns shows that E-DRAM predicts 2020 California state product being roughly $21 billion (0.7%) lower and state personal income being $22 billion (1.1%) lower when both world PETRO and ENMIN prices are 20% higher. These higher world prices nudge the price of consumer fuel (CFUEL) up 6.2%,

Table 8: Results for Petroleum Dependence Reduction Strategies with High World Energy Prices

2020	BASE MODEL	NEW MODEL	SCNRIO1	SCNRIO1	SCNRIO4	SCNRIO4
CA economy						
CA OUTPUT ($BIL.)	3078.022	3057.149	3074.924	3055.703	3062.487	3046.364
% CHNGE OUTPUT	0.10%	-0.58%	-0.10%	-0.05%	-0.50%	-0.35%
PERS. INC. ($BIL.)	2009.537	1987.684	2009.521	1989.172	2001.025	1984.108
% CHNGE PERS. INC.	0.11%	-0.98%	0.00%	0.07%	-0.42%	-0.18%
JOBS (MIL.)	18.661	18.536	18.677	18.558	18.673	18.571
% CHNGE JOBS	0.03%	-0.64%	0.09%	0.12%	0.06%	0.19%
PRICE OF CFOOD	1.000	1.000	1.000	1.000	1.003	1.002
PRICE OF CHOME	1.000	1.000	1.000	1.000	1.002	1.001
PRICE OF CFUEL	1.000	1.062	0.969	1.030	0.882	0.938
PRICE OF CFURN	1.000	1.000	1.000	1.000	1.002	1.002
PRICE OF CCLOTH	1.000	1.000	1.000	1.000	1.002	1.002
PRICE OF CTRANS	1.000	1.000	1.007	1.008	1.051	1.052
PRICE OF CMED	1.000	0.998	1.000	0.998	1.004	1.002
PRICE OF CAMUS	1.000	0.999	1.000	0.999	1.003	1.002
PRICE OF COTHR	1.000	0.999	1.000	0.999	1.002	1.001
ENMIN sector						
OUTPUT ($BILLION)	6.209	8.394	6.058	8.477	5.608	8.027
% CHANGE OUTPUT	0.08%	35.31%	-2.43%	0.99%	-9.67%	-4.37%
IMPORTS ($BILLION)	36.011	34.875	34.829	33.762	31.834	30.946
% CHANGE IMPORTS	0.07%	-3.09%	-3.28%	-3.19%	-11.60%	-11.27%
EXPORTS ($BILLION)	1.096	1.136	1.112	1.127	1.154	1.168
% CHANGE EXPORTS	-0.07%	3.51%	1.43%	-0.82%	5.27%	2.81%
PETRO sector						
OUTPUT ($BILLION)	39.305	40.335	37.690	39.238	33.516	35.370
% CHANGE OUTPUT	0.07%	2.69%	-4.11%	-2.72%	-14.73%	-12.31%
IMPORTS ($BILLION)	15.683	14.222	15.565	13.711	15.281	13.459
% CHANGE IMPORTS	0.01%	-9.30%	-0.76%	-3.59%	-2.56%	-5.37%
EXPORTS ($BILLION)	11.998	13.361	12.074	13.405	12.258	13.612
% CHANGE EXPORTS	-0.02%	11.34%	0.63%	0.33%	2.17%	1.88%
ENGIN sector						
OUTPUT ($BILLION)	40.468	40.443	40.582	40.563	40.805	40.828
% CHANGE OUTPUT	0.05%	-0.01%	0.28%	0.30%	0.83%	0.95%
IMPORTS ($BILLION)	9.049	9.009	9.081	9.043	9.248	9.205
% CHANGE IMPORTS	0.02%	-0.42%	0.35%	0.37%	2.20%	2.17%
EXPORTS ($BILLION)	13.836	13.904	13.782	13.847	13.509	13.579
% CHANGE EXPORTS	-0.03%	0.46%	-0.39%	-0.41%	-2.36%	-2.33%
FOODS sector						
OUTPUT ($BILLION)	92.958	87.663	95.113	89.805	101.353	96.095
% CHANGE OUTPUT	0.14%	-5.56%	2.32%	2.44%	9.03%	9.62%
APPAR sector						
OUTPUT ($BILLION)	25.951	24.030	26.497	24.595	27.509	25.690
% CHANGE OUTPUT	0.20%	-7.22%	2.10%	2.35%	6.00%	6.91%
MOTOR sector						
OUTPUT ($BILLION)	18.224	17.880	18.161	17.829	17.855	17.565
% CHANGE OUTPUT	0.23%	-1.67%	-0.35%	-0.29%	-2.02%	-1.76%

while the price of other consumer goods remain constant or fall slightly (0.1-0.2%).[40] Domestic output in the energy and mining sector rises nearly $2.2 billion (35%) while domestic output in the petroleum sector rises $1.0 billion (2.6%) as higher world prices drive down imports in those sectors.[41] Other sectors contract in the face of world energy price inflation, *e.g.*, output of the FOODS and APPAR sectors falls by 5.6% and 7.2% respectively.

Comparing the gray and white "SCENARIO#" columns confirms the intuition that strategies to improve fuel efficiency reap greater rewards in a world with higher energy prices. Higher world prices induce greater domestic production that offsets declines in California's ENMIN and PETRO sector production triggered by demand reduction due to efficiency gains. In Scenario 4 with high world prices (*vs.* base model prices), for example, state output falls 0.4% (vs. 0.5%) and personal income falls 0.2% (*vs.* 0.4%); domestic ENMIN output falls 4.4% (*vs.* 9.7%) and PETRO production falls 12.3% (*vs.* 14.7%).

5.2.4 Summary of Petroleum Dependence Analyses:

The analyses above indicate that the statewide economic impacts of the strategies being considered to reduce petroleum dependence are small. This is not surprising, given that static costs estimates of the most aggressive scenario under consideration are $13.7 billion in 2020, a time when gross state product (GSP) is projected to be nearly $3.1 trillion, and $22.1 billion in 2050, when GSP is projected to be nearly $6.6 trillion. The highest static cost estimates are thus only 0.33-0.44% of projected GSP. Predicted impacts on petroleum refining and crude oil production sectors are much larger, however, but should be interpreted as worst-cases predictions given the model's weakness in allocating domestic demand reductions between domestic and imported products.

Scenario 1, which embodies the most modest fuel economy improvements, may cause state gross product (GSP) and state personal income (SPI) to be slightly lower than would otherwise be the case. E-DRAM predicts Scenario 1 lowering 2020 GSP by 0.10% – a magnitude within the bounds of model calibration error, and 2050 GSP by 0.17%. The scenario's predicted effect on state personal income is essentially zero in 2020 and 0.10% (again, a magnitude within the bounds of calibration error) in 2050. Impacts on the directly effected sectors – crude oil producers (ENMIN) and petroleum refiners (PETRO) – are significant. E-DRAM predicts ENMIN and PETRO output falling 5.9% and 16.8% respectively.[42] Declines in these sectors, triggered by fuel efficiency gains, are offset by fuel cost savings being spent in other sectors.

Scenario 4, which embodies the most aggressive change, has a modest impact on GSP and a marginal effect on SPI. E-DRAM predicts Scenario 4 lowering 2020 GSP by roughly 0.50%, and 2050

[40] The price of CFUEL rises by significantly less than 20% because the CFUEL sector also includes utilities.
[41] The domestic production as a share of imports is much lower in the ENMIN than in the PETRO sector.

GSP by 0.46%. The scenario's predicted effects on SPI are -0.42% in 2020 and –0.46% in 2050. As expected, the predicted impacts of this scenario on energy related sectors are large. E-DRAM predicts ENMIN output falling 9.67% in 2020 and 12.57% in 2050. PETRO output is projected to fall 14.73% in 2020 and 32.6% in 2050. Again, reduced spending in these sectors is displaced to others.

Intuitively, petroleum dependence reduction strategies become more attractive as world energy prices rise.

6 Conclusions:

This paper explains the development and demonstrates the implementation of E-DRAM – a computable general equilibrium model designed for Cal/EPA's use in assessing the economic impacts of large-scale environmental regulations. It outlines features of the model that enable policy analysts to parameterize regulations' direct effects on prices, inputs, capital requirements, and/or trade flows in 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.

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