Appendix to
Sue Wing, Rose and Wein (2013). Economic Impacts of the ARkStorm Scenario
CGE Model Description

A.1. Introduction

This appendix summarizes the design, construction and application of a recursive dynamic computable general equilibrium (CGE) simulation model of the California economy. The application is over a time horizon of ten semi-annual periods from the onset of a severe storm.

A CGE model is a stylized computational representation of the circular flow of the economy. It solves for the set of commodity and factor prices and activity levels of firms' outputs and households' incomes that equalize supply and demand across all markets in the economy (Sue Wing, 2009; 2011). The present model divides California's economy into 58 regions, each equivalent to a single county, and 29 industry sectors, each of which is modeled as representative firm characterized by a constant elasticity of substitution (CES) technology to produce a single good or service. Households are modeled as a representative agent with CES preferences and a constant marginal propensity to save and invest out of income. The government is also represented in a simplified fashion. Its role in the circular flow of the economy is passive: collecting taxes from industries and passing some of the resulting revenue to the households as a lump-sum transfer, in addition to purchasing commodities to create a composite government good which is consumed by the households. Three factors of production are represented within the model: labor, as well as intersectorally mobile and sector-specific varieties of capital, all of which are owned by the representative agent and rented out to the firms in exchange for factor income. California is modeled as an open economy which engages in trade with the rest of the U.S. and the rest of the world using the Armington specification (imports from other states and the rest of the world are imperfect substitutes for goods produced in the state).

The static component of the model computes the prices and quantities of goods and factors that equalize supply and demand in all markets in the economy, subject to constraints on the external balance of payments. This equilibrium sub-model is embedded within a dynamic process, which on a 6-month time-step specifies exogenous improvements in firms' productivity and updates the economy's capital endowments based on investment-driven accumulation of the stocks of capital. The impacts of a severe storm are modeled as exogenous shocks to the productivity of industries, reductions in household consumption and investment, and contemporaneous destruction of capital stock, with concomitant reductions in the economy's endowments of capital input.

A.2. Production

The supply side of the model employs a simple hierarchical nested CES production structure. In each region r and sector j, the price and quantity of output are given by $PY_{j,r}$ and $QY_{j,r}$. Output is produced by combining a composite of capital and labor ($QKL_{j,r}$, with price $PKL_{j,r}$) with a composite of intermediate inputs ($QZ_{j,r}$, with price $PZ_{j,r}$). This production relationship is represented in dual form by the unit cost function:

$$PY_{j,r} \leq \left(1 - \Phi_{Y,j,r}\right)^{-1} \cdot \Upsilon_{j,r}^{-1} \cdot \left[\alpha_{KL,j,r}^{\sigma_Y} PKL_{j,r}^{1-\sigma_Y} + \alpha_{Z,j,r}^{\sigma_Y} PZ_{j,r}^{1-\sigma_Y}\right]^{1/(1-\sigma_Y)}. \tag{1a}$$

Here, $\Upsilon_{j,r}$ and $\Phi_{Y,j,r}$ are productivity parameters that represent, respectively, technological progress and the impact of output losses associated with the storm. In turn, the capital-labor composite is produced from sector-specific capital ($QK_{j,r}$, with price $PK_{j,r}$) and labor ($QL_{j,r}$, with average wage PL) according to the unit cost function:

$$PKL_{j,r} \leq \left[\alpha_{K,j,r}^{\sigma_{KL}} PK_{j,r}^{1-\sigma_{KL}} + \alpha_{L,j,r}^{\sigma_{KL}} PL^{1-\sigma_{KL}}\right]^{1/(1-\sigma_{KL})}. \tag{1b}$$

Finally, the intermediate input composite is modeled as a CES aggregation of intermediate inputs of the i commodities ($q_{i,j,r}$, with "Armington" user prices $PA_{i,r}$) according to the unit cost function:

$$PZ_{j,r} \leq \left[\sum_i \alpha_{i,j,r}^{\sigma_Z} PA_{i,r}^{1-\sigma_Z}\right]^{1/(1-\sigma_Z)}. \tag{1c}$$

A.3. Trade and Commodity Supply

Trade is modeled according to a simplified Armington formulation, in which each sector's output feeds into a state-wide aggregate pool that supplies domestic and export markets. Symmetrically, on the demand side, each consumed commodity is a composite of domestic and imported varieties.

Looking first at the supply side, the pooled California-wide supply of the i^{th} commodity is a CES composite of the r county varieties of this good. Following Armington (1969), the imperfect substitutability of varieties implied by CES aggregation reflects transport costs, and from a modeling perspective has the practical benefit of preventing changes in relative prices from inducing wild swings in county market shares (so-called "bang-bang" behavior). The resulting aggregate supply satisfies both in-state uses (at the California-wide average consumer price, PCA_i) and rest-of-the-world uses (at the generalized price of foreign exchange, PFX). We model this two-step supply allocation through the device of the constant elasticity of substitution-transformation (CES-CET) function. Using $PYT_{i,r} =$

$(1+\tau^Y_{i,r})PY_{i,r}$ to represent the gross-of-tax price of i (where $\tau^Y_{i,r}$ denotes the production tax rate) and PN_i to denote the California-wide average producer price, the transformation of county-level output is specified in terms of the dual by:

$$PN_i \leq \left[\sum_r \beta_{Y,i,r}^{\sigma_{YY,i}} PYT_{i,r}^{1-\sigma_{YY,i}}\right]^{1/(1-\sigma_{YY,i})}. \tag{2a}$$

$$PN_i \geq \left[\beta_{XCA,i}^{\eta_{X,i}} PCA_i^{1-\eta_{X,i}} + \beta_{XF,i}^{\eta_{X,i}} PFX^{1-\eta_{X,i}}\right]^{1/(1-\eta_{X,i})}. \tag{2b}$$

Turning to the demand side, county r's use of the i^{th} commodity ($QA_{i,r}$, with price $PA_{i,r}$) is modeled as a CES composite of quantities of that good emanating from California and rest-of-world sources ($QMCA_{i,r}$ and $QMO_{i,r}$, with prices PCA_i and PFX, respectively). This is captured by the unit cost function

$$PA_{i,r} \leq \left(1-\Phi_{A,i,r}\right)^{-1} \cdot \left[\beta_{MCA,i,r}^{\sigma_{DM,i}} PCA_i^{1-\sigma_{DM,i}} + \beta_{MF,i,r}^{\sigma_{DM,i}} PFX^{1-\sigma_{DM,i}}\right]^{1/(1-\sigma_{DM,i})}, \tag{2c}$$

which determines the supply price of the Armington domestic-import composite good that fulfills each county's intermediate and final demands for good i. We introduce the productivity parameter $\Phi_{A,i,r} \in (0,1)$ as a proxy for the effect of storm-related disruptions in commodity supplies—particularly utility lifelines.

We adopt a simple trade closure for the model. Each county is treated as a small open economy which cannot affect the price of foreign exchange. Following open-economy modeling convention, we designate the variable PFX as the numeraire price by fixing its value at unity. Then, the state's net export position vis-a-vis the rest of the world is easily calculated by applying Shephard's lemma, yielding the supply-demand balance condition:

$$\sum_r QXCA_{i,r} \geq \sum_r QMCA_{i,r} \Rightarrow \sum_r \frac{\partial PTY_{i,r}}{\partial PCA_i} QY_{i,r} \geq \sum_r \frac{\partial PA_{i,r}}{\partial PCA_i} QA_{i,r}. \tag{2d}$$

A.4. Final Demands and Commodity Market Closures

In each county there are h household archetypes, each of which is modeled as a representative agent who with CES preferences over consumption of commodities ($q_{i,C,h,r}$, at price $PA_{i,r}$). The associated dual expenditure functions are given by:

$$PU_{h,r} \leq \left[\sum_i \gamma_{i,C,h,r}^{\sigma_C} PA_{i,r}^{1-\sigma_C}\right]^{1/(1-\sigma_C)}, \tag{3a}$$

where $PU_{h,r}$ is the unit expenditure index. There are also g levels of government, each of which consumes commodity inputs ($q_{i,G,g,r}$ at price $PA_{i,r}$) for the purpose of producing a government good ($QG_{g,r}$, at price $PG_{g,r}$) with CES technology. The associated cost functions are:

$$PG_{g,r} \leq \left[\sum_i \gamma_{i,G,g,r}^{\sigma_G} PA_{i,r}^{1-\sigma_G}\right]^{1/(1-\sigma_G)}. \tag{3b}$$

As well, each county produces an investment good (QI_r, at price PI_r) from a CES aggregation of commodities ($q_{i,I,r}$ at price $PA_{i,r}$):

$$PI_r \leq \left[\sum_i \gamma_{i,I,r}^{\sigma_I} PA_{i,r}^{1-\sigma_I}\right]^{1/(1-\sigma_I)}. \tag{3c}$$

We assume that each representative agent exhibits a fixed marginal propensity to save (MPS) and invest out of income. Supply-demand balance for households' savings ($QS_{h,r}$) requires:

$$QI_r \leq \sum_h QS_{h,r}, \tag{3d}$$

while a fixed MPS implies a constant of proportionality, $\mu_{h,r}$, which allows savings to scale with changes in activity (consumption) levels:

$$QS_{h,r} = \mu_{h,r} U_{h,r}. \tag{3e}$$

Government consumption is financed out of tax revenue and transfers. We model government g as claiming a fraction $\xi_{g,r}$ of the total tax revenue raised within county r, as well as receiving a net transfer, $GXFER_{g,r}$ (which for convenience we denominate in units of the numeraire). The activity level of public provision is then given by:

$$QG_{g,r} \leq \left(\xi_{g,r} \sum_j \tau_{j,r}^Y PY_{j,r} QY_{j,r} + PFX \cdot GXFER_{g,r}\right) / PG_{g,r}. \tag{3f}$$

Lastly, the supply-demand balance for commodities is closed via the condition

$$QA_{i,r} \geq \sum_j q_{i,j,r} + \sum_h q_{i,C,h,r} + q_{i,I,r} + \sum_g q_{i,G,g,r} \tag{3g}$$

in which the unconditional demands on the right-hand side are given by Shephard's Lemma: $q_{i,j,r} = \frac{\partial PY_{j,r}}{\partial PA_{i,r}} QY_{j,r}$, $q_{i,C,h,r} = \frac{\partial PU_{h,r}}{\partial PA_{i,r}} U_{h,r}$, $q_{i,I,r} = \frac{\partial PI_r}{\partial PA_{i,r}} QI_r$ and $q_{i,G,g,r} = \frac{\partial PG_{g,r}}{\partial PA_{i,r}} QG_{g,r}$.

A.5. Inter-Sectoral Factor Mobility and Static Income Closures

Given the short duration of each time step, the assumption of frictionless inter-sectoral reallocation of capital common in CGE models is unlikely to accurately capture the behavior of factor markets. While we continue to treat labor as mobile across industries and counties, we model capital as a sectorally geographically fixed factor at each time-step, with instantaneous supply-demand balance determined by the county-level aggregate supply of capital input ($\mathcal{E}_{K,j,r}$):

$$\mathcal{E}_{K,j,r} \geq \frac{\partial PKL_{j,r}}{\partial PK_{j,r}} QKL_{j,r}. \tag{4a}$$

The effect of capital stock destruction on the left-hand side of this expression is the primary driver of the storm's economic impact. Traditional CGE models close the labor market either through the "neoclassical" assumption of full employment (perfectly inelastic supply) or "Keynesian" variable employment (perfectly elastic supply at a fixed wage). Neither of these extremes adequately captures the impact of a large transitory shock, which typically induces simultaneous adjustments in both employment and wages. Accordingly, we model labor as a variable factor whose endowment is price responsive. This is achieved by specifying a short-run labor supply curve with elasticity η_L, which scales each county's labor supply from its benchmark level ($\mathcal{E}_{L,r}$):

$$\sum_r \mathcal{E}_{L,r} \cdot PL^{\eta_L} \geq \sum_j \sum_r \frac{\partial PKL_{j,r}}{\partial PL} QKL_{j,r}. \tag{4b}$$

County-level household, investment and government activities are bound together by an income-expenditure balance condition that constrains the value of expenditure and saving to equal the value of factor returns plus net household transfers ($HXFER_{h,r}$, also denominated in units of the numeraire). Thus, using $\zeta_{K,h,r}$ and $\zeta_{L,h,r}$ to denote the fixed household proportions of labor and capital remuneration within each county, income balance is given by

$$\zeta_{K,h,r} \cdot \sum_j PK_{j,r}\mathcal{E}_{K,j,r} + \zeta_{L,h,r} PL^{1-\eta_L}\mathcal{E}_{L,r} + PFX \cdot HXFER_{h,r}$$
$$\geq PU_{h,r}U_{h,r} + PI_r\, QS_{h,r} + \sum_i PCA_i\, SA_{i,h,r}. \tag{4c}$$

Our final closure rule is the statewide balance of payments constraint, which balances the net supply of foreign exchange against the demands for transfer payments that make up the idiosyncratic components of household and government income:

$$\sum_i QXO_i + \sum_i \sum_r QMO_{i,r} + \sum_g \sum_r GXFER_{g,r} + \sum_h \sum_r HXFER_{h,r} = 0. \tag{4d}$$

California's exports and counties' imports are both valued at the numeraire foreign exchange price (PFX), with quantities given by Shepard's Lemma: $QXO_i = \frac{\partial PN_i}{\partial PFX}$ and $QMO_{i,r} = \frac{\partial PA_{i,r}}{\partial PFX}$.

A.6. The Dynamic Process of the Economy and the Impacts of a Severe Storm

The static equilibrium sub-model made up of eqs. (1)-(4) is embedded within a dynamic process that exogenously updates the productivity parameters $\Upsilon_{j,r}$ and the endowments of capital. Counties' labor endowments are left to adjust endogenously according to eq. (4b), and are not exogenously updated.

In the business as usual (BAU) scenario the shock parameters $\Phi_{Y,j,r}$ and $\Phi_{A,j,r}$ are zero. The neutral sectoral productivity shift parameter $\Upsilon_{j,r}$ is set to one in the first period and grows at an annual average rate of 1% thereafter, capturing the effect of balanced technological progress. We model the accumulation of stocks of sector-specific capital ($X_{j,r,t}$) using the standard perpetual inventory approach. The stocks are initialized by dividing the capital endowments recorded in the benchmark dataset by observed gross rates of return: $X_{j,r,0} = \overline{\mathcal{E}}_{K,j,r}/(\rho + \delta)$, where ρ and δ denote the risk-free interest rate and average rate of depreciation. One-period-ahead capital stocks are then determined by the balance between geometric depreciation and the level of investment computed by the static equilibrium sub-model at each time step.

In the storm scenario generalized BI losses stem from both property damage and diminished productivity due to firms reorganizing production to cope with the exigencies of the post-disaster economic environment. HAZUS quantifies these impacts through two metrics, property losses as the replacement value of destroyed capital stock and output losses as the value of forgone production over a repair and reconstruction "downtime" period. But in a general equilibrium setting there is substantial overlap between the two components of economic loss. Destruction of capital stocks reduces sectors' productive capacity, which suggests that simply including production time lost as an additional shock in the CGE model would result in double-counting of impacts to a degree that is unknown but potentially large. To avoid double-counting we focus on destruction of capital stocks in the initial period as the principal driver of subsequent economic impacts. However, this procedure has the disadvantage of precluding the ability of production rescheduling to mitigate losses that might persist beyond the initial period. This "recapture" is a key factor within HAZUS that acts to partially offset the trajectory of simulated output declines, and reduce the present value of output losses. Our approach to reconciliation is to reinterpret recapture as induced innovation which enables industries to stretch their surviving productive capacity. Within the CGE model's dynamic process, recapture is treated as a wedge that enables the quantity of capital input to the economy (i.e., the flows of economic services from asset stocks) to decline by a smaller amount than the quantities of capital assets themselves. The fact that such an increase in firms' productivity arises only in response to the exigencies of the post-disaster environment, together with the increasing likelihood of their customers canceling orders as production delays mount, suggest that recapture is a fundamentally short-term phenomenon whose beneficial impact diminishes with the passage of time and the resumption of a normal business environment. Our assumption of a linear decay in recapture limits its impact to the first two periods.

A key feature of the capital accumulation process is the incorporation of the property damage associated with a severe storm. We specify destruction of initial sectoral capital stocks in the amount $XLoss_{j,r,t}$ and exogenous trajectories of capital repair and reconstruction by county in the amount $XRecon_{r,t}$. These variables are used to adjust the standard perpetual inventory formulation that describes the motion of the economy's capital stocks:

$$X_{j,r,t+1} = \psi_{j,r}\left(QI_{r,t} + XRecon_{r,t}\right) + (1-\delta)\left(X_{j,r,t} - XLoss_{j,r,t}\right), \tag{5a}$$

where the parameter $\psi_{j,r}$ indicates the sectors' shares of a county's new investment. The one-shot character of capital stock destruction is given by $XLoss_{j,r,0} \geq 0$ and $XLoss_{j,r,t} = 0 \; \forall \; t > 0$.

Turning to capital input, at the beginning of each time-step we use a rate of return formula to translate the capital stocks into endowments of services from sector-specific capital:

$$\mathcal{E}_{K,j,r,t} = (\rho + \delta)X_{j,r,t}, \; t > 1. \tag{5b}$$

If $X_{j,r,t} < X_{j,r,0}$ the capital endowment of the relevant sector-county combination is reduced relative to its benchmark level, in turn reducing productive capacity and output relative to the initial condition of the economy. This idea is captured by the "loss triangle" in the text. Less obviously, if the level of $X_{j,r,t}$ is reduced below the level it would otherwise attain in a baseline economic scenario without the storm, the resulting capital input endowment and output quantity represent the counterfactual losses associated with the economy being shifted to a lower growth path. We modify eq. (5b) for the special cases of $t = 0$ and $t = 1$. The former reflects both the adverse impact of the initial destruction of capital stocks and the ability of recapture to mitigate the concomitant reduction in the flow of services from capital:

$$\mathcal{E}_{K,j,r,0} = (\rho + \delta)\left[X_{j,r,0} - \left(1 - Recapture_{j,0}\right)XLoss_{j,r,0}\right], \tag{5c}$$

where $Recapture_{j,t}$ denotes exogenous time-varying recapture factors derived from HAZUS (Table A.2). The latter reflects the ability of recapture to ameliorate losses in productive capacity below benchmark levels that persist beyond the initial period:

$$\mathcal{E}_{K,j,r,1} = (\rho + \delta) \cdot \begin{cases} \left[X_{j,r,0} - \left(1 - Recapture_{j,1}\right)(X_{j,r,0} - X_{j,r,1})\right] & X_{j,r,1} < X_{j,r,0} \\ X_{j,r,1} & \text{otherwise} \end{cases}. \tag{5d}$$

We capture the impact of persistent BI output losses through the device of exogenous adverse productivity shocks applied only in the in the storm scenario. Industries in the model, instead of becoming increasingly productive as in the BAU scenario, are assumed to see productivity stagnate in the first year after the disaster ($\Upsilon_{j,r} = 1$ for $t = 0, 1$), after which technological progress resumes ($\Upsilon_{j,r} > 1 \; \forall \; t > 1$). Disruptions in utility services ($i' =$ electric power, water/wastewater and telecommunications) are modeled by imposing reductions in the productivity of the relevant aggregate supply ($\Phi_{A,i',r} > 0$). As discussed in the text, flood and wind damages have little impact on capital stocks in agriculture sectors, but do affect crops in the field and the quality of arable land. The persistent impacts of the storm on these sectors ($j' =$ annual crops, perennial crops, other agriculture) are captured through the relevant sectoral productivity loss coefficients ($\Phi_{A,j',r} > 0$). Losses associated with the evacuation, relocation and return of firms' employees are not explicitly modeled, but are assumed to be encompassed by the labor market adjustments in eq. (4b).

The mitigating effects of recapture on lifeline disruptions and agricultural losses are modeled as follows. The shocks to the economy are the fractions of each county's baseline supply of utility services ($\widetilde{\Phi}_{A,i',r}$) and agricultural output ($\widetilde{\Phi}_{A,j',r}$) accounted for by the damages from the HAZUS and DWR models, respectively. Since recapture of lifeline losses occurs on the demand side, we adjust these shocks downward by a factor that depends on the distribution of demand for utility services across using sectors:

$$\Phi_{A,i',r,t} = \left(1 - \textstyle\sum_j \zeta_{j,i',r} \cdot Recapture_{j,t}\right) \widetilde{\Phi}_{A,i',r} \tag{5e}$$

where $\zeta_{j,i',r} = \frac{\partial PZ_{j,r,0}}{\partial PA_{i',r,0}} \Big/ \sum_j \frac{\partial PZ_{j,r,0}}{\partial PA_{i',r,0}}$ indicates the benchmark shares of industries' demands shares in total supply. Finally, shocks to agriculture are adjusted downward based on the relevant sectors' own recapture factors:

$$\Phi_{A,j',r,t} = \left(1 - Recapture_{j',t}\right) \widetilde{\Phi}_{A,j',r}. \tag{5f}$$

A.7. Model Calibration, Formulation and Solution

The vectors of technical coefficients $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ in eqs. (1)-(4) are calibrated using an IMPLAN social accounting matrix for the state of California for the year 2007 (Minnesota IMPLAN Group, 2007) in conjunction with values of the elasticities of substitution, transformation and supply in Table A.3. The model is formulated as a mixed complementarity problem using the MPSGE subsystem for GAMS (Rutherford, 1999; Brooke et al., 1998) and is solved using the PATH solver (Ferris et al., 2000).

References

1. Brooke, A., D. Kendrick, A. Meeraus and R. Raman (1998). GAMS: A User's Guide, Washington DC: GAMS Corp.
2. Ferris, M.C., T.S. Munson, and D. Ralph (2000). A Homotopy Method for Mixed Complementarity Problems Based on the PATH Solver, in D.F. Griffiths and G.A. Watson (Eds.), Numerical Analysis 1999, London: Chapman and Hall, 143-167.
3. Rutherford, T.F. (1999). Applied General Equilibrium Modeling with MPSGE as a GAMS Subsystem: An Overview of the Modeling Framework and Syntax, Computational Economics 14: 1-46.
4. Sue Wing, I. (2009). Computable General Equilibrium Models for the Analysis of Energy and Climate Policies, in J. Evans and L.C. Hunt (eds.), International Handbook On The Economics Of Energy, Cheltenham: Edward Elgar, 332-366.
5. Sue Wing, I. (2011). Computable General Equilibrium Models for the Analysis of Economy-Environment Interactions, in A. Batabyal and P. Nijkamp (eds.) Research Tools in Natural Resource and Environmental Economics, Hackensack: World Scientific, 255-305.

Table A.1. CGE Model Sectors

Sectors	NAICS industries	HAZUS Occupancy Class
Annual crops	1111-2, 1119	Agriculture
Perennial crops	1113-4	
Other agriculture	112-5	
Mining, metals & minerals	21, 327, 331	Metals & minerals processing
Electric power	2211	Professional & technical services
Water & wastewater utilities	2213	Professional & technical services
Construction	23	Construction
Food, drugs & chemicals	311, 3121-4, 324-5	Food, drugs & chemicals
Light industry	3122, 313-6, 321-3, 3346, 335, 337, 339*, 5111	Light industry
Heavy industry	332, 333*, 336*	Heavy industry
High-tech industry	33329, 33314, 3341-5, 3364, 3391, 51121, 518-9	High-tech industry
Wholesale trade	42	Wholesale trade
Retail trade	44-5, 532	Retail trade
Professional & technical services	2212, 48-9, 53*-56,	Professional & technical services
Motion picture & video industries	5121	Theaters
Entertainment & recreation	5122, 515, 711-3, 722	Entertainment & recreation
Telecommunications	517	Telecommunications
Banking & finance	521-5	Banking & finance
Real estate	531, 721, 814	Housing
Schools & libraries	6111, 6114-7	Schools & libraries
Colleges & universities	6112-3	Colleges & universities
Medical services n.e.c.	621	Medical offices & clinics
Hospitals	622	Hospitals
Nursing homes	623	Nursing homes
Personal & repair services	6241, 6244, 811*-2	Personal & repair services
Parking services	8111	Parking services
Religious & nonprofit activities	813	Church & membership orgs.
Government industry	491	General services
Community food, housing & relief svcs.	6242-3	Institutional dormitories

* Part of sector

Table A.2. Recapture Factors Used in the CGE Model

HAZUS Occupancy Classes	0-6 months	6-12 months
Housing	0	0
Institutional dormitories	0.53	0.23
Nursing homes	0.53	0.23
Retail trade	0.76	0.33
Wholesale trade	0.76	0.33
Personal & repair services	0.45	0.19
Business, professional & technical services	0.79	0.34
Depository institutions	0.79	0.34
Hospitals	0.53	0.23
Medical offices & clinics	0.53	0.23
Entertainment & recreation	0.53	0.23
Theaters	0.53	0.23
Heavy industries	0.86	0.37
Light Industries	0.86	0.37
Food, drugs & chemicals	0.86	0.37
Metals & minerals processing	0.86	0.37
High technology industries	0.86	0.37
Construction	0.83	0.36
Agriculture	0.66	0.28
Church & membership organizations	0.53	0.23
General services	0.70	0.30
Emergency response	0	0
Schools & libraries	0.53	0.23
Colleges & universities	0.53	0.23

Table A.3. Elasticities of Substitution, Transformation and Supply

Elasticities of substitution:		
Between value added and a composite of intermediate inputs in production	σ_Y	0.1
Between capital and labor in production	σ_{KL}	0.25
Among intermediate inputs to production	σ_Z	0.1
Among counties' outputs of a particular good in aggregate commodity supply	$\sigma_{YY,i}$	4*
Between domestic (California) and imported (rest of world) varieties of each good in county Armington composite	$\sigma_{DM,i}$	2*
Among inputs to household consumption	σ_C	0.25
Among inputs to investment	σ_I	0.25
Among inputs to government	σ_G	0.25
Elasticities of transformation:		
Between California aggregate supply and rest of world exports in California-wide sectoral supply composite	η_X	2*
Elasticities of supply:		
Labor	η_L	0.3

* 0.1 in utility lifeline sectors (Electric power, Water & wastewater, Telecommunications)