Regional Economic Impacts of Climate Change: A Computable General Equilibrium Analysis for an Alaska Fishery

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Abstract

We compute the effects on the Alaska economy of reduced pollock harvests from rising sea surface temperature using a regional dynamic computable general equilibrium (CGE) model coupled with a stochastic stock-yield projection model for eastern Bering Sea (EBS) walleye pollock. We show that the effects of decreased pollock harvest are offset to some extent by increased pollock price, and that fuel costs and the world demand for the fish, as well as the reduced supply of the fish from rising sea surface temperature, are also important factors that determine the economic and welfare effects.

Key Words: sea surface temperature, climate change, eastern Bering Sea walleye pollock fishery, economic impacts

JEL Codes: Q22, Q54, R13

1 Introduction

In 2012, pollock catch in Alaska waters totaled 1.31 million metric tons with a total ex-vessel revenue of $497 million (Fissel et al. 2013). As with other fisheries in Alaska, the Alaska pollock fishery is closely monitored and regulated. One key management control is the annually specified (and seasonally apportioned) total allowable catch (TAC) set by the Department of Commerce as recommended by the North Pacific Fishery Management Council. The pollock TAC recommendations begin with evaluating the annual stock assessment. Recent studies have suggested that pollock productivity is sensitive to rising sea surface temperatures (SSTs) and hence climate change. These studies have developed hypotheses on how climate change may affect pollock stock productivity with possible consequences that may lead to expected catch reductions of about 29% over the period from 2009 to 2050 (Mueter et al. 2011, Ianelli et al. 2011).[1]

[1] The average percentage reduction in catch of pollock is based on simulated climate scenarios (Ianelli et al., 2011).

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Such a reduction in pollock catches will have significant economic impacts on the region. The revenue from the pollock fishery will decrease, implying a reduction in the number of jobs in pollock harvesting and processing sectors, a decrease in use of intermediate inputs (such as fuel and food), and a decrease in income of the stakeholders engaged in the fishery. This, in turn, will generate a wide range of economic impacts on the fishing-dependent communities. The Magnuson-Stevens Fishery Conservation and Management Act National Standard 8 (MSFCMA Section 301[a]8), which was re-authorized in 2006, requires that fishery conservation and management actions formally consider the importance of fishery resources to fishing communities. To satisfy this requirement, fishery managers must take into account economic impacts on various stakeholders (e.g., fishermen, processors, and fishing-dependent communities) of management actions, which include changes in TACs arising from, for example, climate-driven changes in stock of fish. However, other exogenous shocks such as changes in world demand for US seafood can affect stakeholders as well and should be considered.

Many studies have focused on investigating the temporal, functional relationships between climate variability, fish production, recruitment, and stock dynamics (Hollowed et al. 2012; Salinger et al. 2012; Siddon et al. 2013). There also exist several studies of economic effects of change in fish production and catch from climate change.[2] For example, Arnason (2007) calculated the impacts of changes in fish stocks arising from global warming on the time paths of gross domestic products (GDPs) of Iceland and Greenland economies, using stochastic simulations accounting for uncertainties associated with marine biological predictions and econometric estimation of the role of the fisheries. Cooley and Doney (2009) provided a rough estimate of the economic losses for the entire US from declining mollusk arising from ocean acidification, using an economic multiplier which was borrowed from a previous study. Norman-Lopez et al. (2011) estimated the economic impacts from climate change on Australian marine fisheries using an input-output (IO) model. Narita et al. (2012) calculated the economic losses from reduced mollusk harvest caused by ocean acidification, using a partial equilibrium analysis.[3]

The present study is different from previous studies of economic impacts from climate-change-induced changes in fisheries. Unlike most of previous studies, including Arnason (2007), Cooley and Doney 2009), Norman-Lopez et al. (2011), and Narita et al. (2012), our study relies on a theoretically rigorous model, a CGE model, that is firmly grounded on modern micro-economic theory, and enables calculation of economy-wide impacts and welfare changes. Our study couples a stock-yield projection model (Ianelli et al. 2011) for eastern Bering Sea (EBS) pollock with a regional dynamic CGE model in order to compute the dynamic effects of reductions in pollock yields caused by rising SST on the economy of a region (here, Alaska) which is heavily dependent on the fishery.

In our study, we first randomly selected 20 different time paths covering 42 years (2009-2050) of pollock yields out of a total of 820 time paths in the stock-yield projection model (Ianelli et al.,

[2] Many studies exist that investigate the economic impacts from climate change occurring through non-fishery sectors of the economy. For a review of these studies, including those using CGE models, see Tol (2009).

[3] Recently, Haynie and Pfeiffer (2013) and Pfeiffer and Haynie (2012) investigated how changes in climate and stock conditions impact variations in fishing spatially and temporally, although these studies did not calculate the economy-wide impacts.

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2011)[4] for both benchmark case (without climate change) and for counterfactual case (with climate change). Next, we run an Alaska dynamic CGE model to estimate the temporal and aggregate regional economic impacts of the reduced pollock harvest from climate change, based on the harvest projections from the stock-yield projection model. We present the regional economic impacts including those on output, real gross regional product (RGRP), and household welfare. The magnitude of economic effects of climate-change-driven change in pollock fishery will depend on how the world economic conditions will change in the future. For example, the increase in world demand for whitefish including pollock, which is due to human population increase and economic development, will lessen the adverse economic effects of climate change. On the other hand, rising fuel prices[5] may exacerbate the adverse impacts. This study considers both the effects of change in world demand for Alaska pollock and the effects of fuel price change in calculating the economic impacts of climate change.

In Section 2, the pollock stock-yield projection model (Ianelli et al. 2011) is briefly described. Section 3 describes our CGE model. The next section (Section 4) explains the economic data needed to construct our CGE model, followed by Section 5 that explains our experimental design. Results and discussion are presented in Sections 6 and 7, respectively, with conclusions in Section 8.

2 Pollock Stock-yield Projection Model

To eliminate climate change scenarios (IPCC, 2007) that performed poorly in the EBS region we selected those identified in Wang et al. (2010). Their approach compared the fit of predicted SSTs relative to the observed values and also examined the variability and resulted in 82 IPCC climate change models. Each of these models (with unique SST signatures) then formed the basis for driving pollock productivity (with generally warmer conditions resulting in lower average recruitment). The simulated pollock population started with estimated numbers at-age in 2010 and propagated forward with catches based on harvest control rules (HCRs). Performance of the HCRs was tracked with catch and spawning biomass which depend on assumed age-specific schedules for selectivity, maturity, natural mortality, and mean body mass. The functional form of mean recruitment relative to temperature was based on Mueter et al. (2011) hypothesis (Fig. 1). For contrast, alternative hypothesis was included based simply on historical patterns of recruitment (i.e., assuming no climate effect and using mean historical recruitment and estimated variability).

The HCRs evaluated included the status quo policy for catch determination in year t that is based on F_t, the fishing mortality, as a function of the spawning biomass (B_t):

[4] In Ianelli et al. (2011), pollock recruitments were projected using 82 IPCC climate change models, and conducted 10 Monte Carlo simulations for each model and year. This results in 820 simulations for each year from 2009 to 2050. Out of these 820 simulations, the present study randomly selected 20 simulations. The frequency of closures (near zero catches) between the original 820 and the selected 20 were similar (19% compared to 16%) as was the variability and means of recruitment. See Figure 1.
[5] Impacts of fuel prices on Alaska fisheries are also discussed in Criddle (2012) and Criddle and Strong (2013).

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$$
\begin{aligned}
&\text{Stock status: } B_t \geq B_{msy} \\
&\qquad F_t = F_{msy} \\
&\text{Stock status: } 0.05 < B_t < B_{msy} \\
&\qquad F_t = F_{msy} \frac{B_t / B_{msy} - 0.05}{1 - 0.05} \\
&\text{Stock status: } B_t < 0.05 \\
&\qquad F_t = 0.0
\end{aligned} \tag{1}
$$

where B_{msy} (in this case) is roughly 27% of the expected spawning biomass produced per recruit relative to unfished (Ianelli et al. 2013). A further constraint occurs due to overall catch limits in this management region which effectively caps pollock catches to be less than 1,500,000 t per year. In some years the allowable catch based on eq 1 exceeds this amount. For example, in 2004 the TAC was set well below the limit to account for 2 million t all-groundfish species limit on TAC (the actual TAC for pollock in 2004 was 1.492 million t).

The biomass of catch by year arises from the Baranof catch equation:

$$
C_t = \sum_{a=1}^{15} w_a N_{a,t} \frac{F_{a,t}}{Z_{a,t}} \left(1 - e^{-Z_{a,t}}\right) \tag{2}
$$

where $N_{a,t}$ is the begin-year numbers at age a, in year t, w_a is the mean body mass at age for pollock and the age-specific fishing mortality follows a "separable" form ($F_{a,t}=s_aF_t$) and $Z_{a,t}=M_a+F_{a,t}$ with s_a the selectivity at age and M_a the assumed age-specific natural mortality age (Ianelli et al. 2013). Numbers at age in future years are given as:

$$
\begin{aligned}
N_{a,t} &= N_{a-1,t-1} e^{-Z_{a,t}} && 1 < a < 15 \\
N_{15,t} &= N_{14,t-1} e^{-Z_{14,t}} + N_{15,t-1} e^{-Z_{15,t}} \\
N_{1,t} &= \bar{R}_t e^{\varepsilon_{t,E}} && \varepsilon_t \sim N\left(0, \sigma_E^2\right)
\end{aligned} \tag{3}
$$

where $\bar{R}_t = e^{9.7886 - 1.763 SST - 0.6626 SST^2}$ represents the climate impact (in terms of SST); otherwise $\bar{R}_t$ is set as constant over time and equal the historical level of recruitment as estimated in Ianelli et al. (2013). The subscript E is an indicator variable on if climate effects are included. For both (with and without climate impact) scenarios, total recruitment variability was specified to equal 0.67^2.

The performance indicator on spawning biomass was computed using an age-specific maturity, ϕ_a, for female pollock:

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$$B_t = \sum_{a=1}^{15} \phi_a w_a N_{a,t} e^{-0.25 Z_{a,t}} \quad (4)$$

and assuming peak spawning occurs on April 1st. Finally, the current (status quo) HCR specifies that if the spawning biomass (B_t) falls below 20% of unfished stock size, then the directed fishery for pollock would be closed (see Ianelli et al. 2011 for further details).

3 Economic Model

Our study utilizes a regional CGE model due to its advantages over linear models including input-output (IO) model and social accounting matrix (SAM) model which assume that prices do not change. The model is a forward-moving dynamic model, which makes it possible to calculate the endogenous variables including price variables over time. It is inappropriate to use a static economic model in order to evaluate the economic effects of government policies or exogenous shocks (such as climate change in this study). This is because the shocks or government policies often produce permanent effects. In this study, in particular, because change in SSTs is a dynamic process which has impacts over many years and the stock-yield projection model produces annual projections of the pollock harvests, it is appropriate to use a forward-moving dynamic CGE model which can solve for the endogenous variables in each period (year) with the change in pollock harvest from the stock-yield projection model given as a shock in each period.

This section describes briefly the structure of our Alaska CGE model. The model equations in GAMS (General Algebraic Modeling System) code are in Appendix. In this paper, a "sector" refers to a group of industries. There are three sectors in this study – the fish harvesting sector (consisting of 9 fish harvesting industries), the fish processing sector (consisting of 9 fish processing industries), and the non-seafood sector (consisting of the remaining non-seafood industries).

Production and Consumption

There are 32 producing industries (9 fish harvesting industries, 9 seafood processing industries, and 14 other industries), and 32 corresponding commodities. An industry's value-added function is characterized by a constant-returns-to-scale, constant-elasticity-of-substitution (CES) technology. Each industry is assumed to use two primary factors of production (labor and capital). Intermediate inputs are combined according to Leontief technology (i.e., in fixed ratios). Intermediate inputs are combined with value added in fixed proportions. An industry's conditional factor demand for the primary factors of production is derived by minimizing the cost of production given a production level.

There are three different types of households in the model, representing three different income levels[6], specified based on the nine types of household in IMPLAN (Minnesota IMPLAN Group, 2004).

[6] Following 2004 IMPLAN data, low income households earn less than $25,000 a year; medium income households earn $25,000 to $75,000; high income households earn more than $75,000. The seafood sectors' data which this study uses does not distinguish among labor income going to three different types (groups) of workers, each of which corresponds to each of the three types of households (consumers) modeled in this

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The preferences of each type of household are characterized by a CES utility function. It is assumed that each type of household consumes (i) regionally produced commodities; and (ii) imported commodities from the rest of the world (ROW). The ROW includes the non-Alaska U.S. states and foreign countries. Each type of household's demand for a commodity is derived by maximizing its utility given its budget in each period.

Factor Markets and Mobility

We assume that labor is homogenous and is completely mobile among all industries in the region. Therefore, there is only one single wage rate that is determined endogenously in each period in the model. Labor is partially mobile between regions.[7] Capital in the model is sector-specific. For example, capital in the fish harvesting sector is not used in the other two sectors. This is reasonable assumption for Alaska fisheries where fish harvesting sector's capital (mostly fishing vessels) are not likely to be used for producing non-seafood commodities produced in the non-seafood sector. For each sector, the amount of total capital stock is fixed in each time period. Given the amount of total capital stock in each period, each sector's capital is perfectly mobile only among the industries within the sector.[8] This implies that there are three different returns to capital that are endogenously determined in the model. Each seafood sector's (i.e., fish harvesting sector and fish processing sector) capital is partially mobile between regions. The assumption of the partial mobility of labor and capital between regions is consistent with the dynamic features in regional factor markets, and implies that interregional differentials in returns to the factors resulting from an exogenous shock persist until regional factor markets adjust completely in the long run. Table 1 summarizes the types and mobility of the factors of production.

Resource Rent

Resource rent is generated due to exogenously fixing the catch levels of pollock and other species, and represents the return above the normal return (i.e., the level of factor income that is determined in competitive market). It is calculated by subtracting from the ex-vessel revenue the opportunity costs (normal return) of the primary inputs and the costs of the intermediate inputs (e.g., fuel, food) used in catching fish. In this study, we treat resource rents as additional factor

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study. There is one homogenous labor in the economy, and the total labor income from all industries in the economy is distributed to the three different types of households according to the ratios implied in the IMPLAN data. If the information about how much of labor income from fish harvesting industries and other industries flows to each of the three different types of workers were available, more detailed distributional impacts for different types of workers could be calculated.

[7] Partial mobility of labor between regions is modeled using the following net labor migration function:

$$LMIG_t = LSTK_t\left[\left(\frac{W_t}{WROW}\right)^{LME} - 1\right]$$

where t denotes time period; $LMIG_t$ is net labor in-(or out-)migration; $LSTK_t$ aggregate labor stock at the beginning of t; W_t wage rate; WROW average wage rate in ROW (fixed); and LME is labor migration elasticity. We used a similar function to model interregional capital mobility.

[8] In our study, total capital stock in the non-seafood sector is assumed to grow at a certain annual rate, and is updated each period. Once the total capital stock for the non-seafood sector is updated in each period, the capital stock is allocated to different non-seafood industries such that the return to capital is equalized across the non-seafood industries.

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payments. Quota share lease rate (QSLR) is then calculated as dividing the resource rent by the ex-vessel revenue.

Specifically, for a fish harvesting industry,

$$(PV)X = (1 + RTS)[wL + rK] \tag{5}$$

where PV is net price of a unit of value added (i.e., net of intermediate input cost); X is the output (harvest) level; RTS is a variable representing the share of the value added allocated to the resource rent; w is market wage rate; L is labor; r is market return to capital; and K is capital. So (PV)X measures total factor payments; (wL+rK) normal factor payments; and RTS(wL+rK) resource rent. The QSLR is set to 0.50 (i.e., 50% of the ex-vessel revenue) for pollock in the base year (2004).[9]

The changes in resource rent and QSLR arising from the climate change-induced changes in the pollock yields, which are calculated within our CGE framework, will be different from those that would be obtained from a partial equilibrium analysis. That is, the changes in resource rent and QSLR calculated in this study will reflect the changes occurring not only in the pollock industry but also changes in the other sectors in the economy while the corresponding results from a partial equilibrium analysis would reflect only the changes in the pollock industry, ignoring the "general equilibrium" effects from the other sectors.

Imports

Import demand

We employ the Armington assumption. That is, it is assumed that commodities from different regions are qualitatively different. Import demand is derived through two stages. The first stage determines the quantity demanded of a composite commodity c (Q_c) by the economic agents (households, firms, and governments). The second stage determines the imported quantity (M_c) and the domestically produced quantity (D_c) of the composite commodity via minimization of the total expenditure on the composite commodity subject to a CES trade aggregation function (Armington function) given below:

$$Q_c = A_c^C[\delta_c M_c^{-\rho_c} + (1-\delta_c)D_c^{-\rho_c}]^{-\frac{1}{\rho_c}} \tag{6}$$

where A_c^C is Armington function shift parameter; δ_c is Armington function share parameter; and ρ_c is Armington function exponent. The first-order condition from the second stage yields import demand function [Equation (7)] below:

[9] The base-year QSLR of 0.5 for pollock is derived as follows. According to conversations with seafood industry participants, pollock quota has been selling at about $1,900 per metric ton. We assumed a discount rate of 10%, which implies a perpetuity (resource rent) of $190 per metric ton. In 2012, ex-vessel prices were about $0.17/lb or $375 per metric ton. This leads to a QSLR in our study that is approximately 0.5 of the ex-vessel price (Felthoven 2014). Haynie (2014) found that the annual mean royalty rate for Western Alaska Community Development Quota (CDQ) for pollock is similar to the mean nominal catcher vessels' (CVs) ex-vessel pollock prices for many years. However, since catcher-processors (CPs) are the users of the CDQ fishing rights, this does not mean that QSLR for the CDQ pollock is equal to one.

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$$M_c = \left(\frac{PD_c}{PM_c}\right)^{\upsilon_c} \left(\frac{\delta_c}{1-\delta_c}\right)^{\upsilon_c} D_c \qquad (7)$$

where υ_c is the elasticity of substitution between imports and locally produced goods. This equation says that the quantity of imports of commodity c depends on the ratio of the prices of locally produced to its imported version of commodity c (PD_c and PM_c).

By using the Armington function (1969), we assume that firms in a country (Alaska in our regional CGE model) have the same level of productivity, face perfectly competitive markets, and earn zero profit. The number of firms in a country is assumed to be given exogenously. In Krugman model (1980), firms have the same level of productivity as in Armington model, but are monopolistically competitive. The number of firms in a country adjusts endogenously until zero profits are earned. As in the Krugman model, firms in Melitz model (2003) are monopolistically competitive. However, the number of firms in a country is determined endogenously such that the firms earn zero profit in the Melitz model. One important difference between the first two models (Armington model and Krugman model) and Melitz model is that productivity varies across firms in a country in the Melitz model (Dixon et al. 2015). In our study, since there is no firm empirical evidence that the markets in Alaska are monopolistically competitive and/or different productivity levels exist among firms in Alaska, we used the traditional Armington model.

Import supply

To specify import supply, we adopt a small country assumption which says that Alaska is unable to influence the price of imports of commodities. Under this assumption, import supply by ROW is perfectly elastic, and is represented by a horizontal line as below:

$$PM_c = PWM_c ER \qquad (8)$$

where PM_c is domestic import price of commodity c; PWM_c is the world price of the commodity; ER is the exchange rate. Because PWM_c and ER are fixed in our model, PM_c is fixed (horizontal line).

Exports

Export demand

For pollock, we assume that Alaska exerts some market power in the world market for pollock, and can influence the price of pollock exported to ROW with a finite value of the export demand elasticity. So the export demand function is specified as:

$$E_{p=} E_{p,0} \left(\frac{1}{PWE_p}\right)^{\varepsilon} \qquad (9)$$

where E_p is the level of pollock exports and $E_{p,0}$ is its base-year level; PWE_p is the world price of pollock; and Ɛ is the export demand elasticity.

For all the other commodities, we use the small country assumption, and fix the domestic export price (PE_{np}) as follows:

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$$PE_{np} = PWE_{np}ER \quad (10)$$

where PWE_{np} is world price of a non-pollock commodity, which is fixed.

Export supply

To specify export supply, firms in Alaska are assumed to allocate their output between the regional (i.e., Alaska) market and ROW market via a constant elasticity of transformation (CET) function. A two-stage optimization determines the exports of commodity c (E_c). In the first stage, profit maximization by producers determines the level of commodity output (Z_c). In the second stage, producers maximize their revenue (from sales to both regional market and ROW market) subject to a CET function [equation (11)]:

$$Z_c = A_c^T[\Psi_c E_c^{\theta_c} + (1-\Psi_c)D_c^{\theta_c}]^{\frac{1}{\theta_c}} \quad (11)$$

where A_c^T is CET function shift parameter; ψ_c is CET function share parameter; and θ_c is CET function exponent.

The first-order condition from the second stage yields export supply function [equation (12)] given below.

$$E_c = \left(\frac{PE_c}{PD_c}\right)^{\Lambda_c}\left(\frac{1-\Psi_c}{\Psi_c}\right)^{\Lambda_c} D_c \quad (12)$$

where PE_c is domestic price of exports and Λ_c is elasticity of transformation. The export supply function says that exports of commodity c depend on the ratio of the export price of the commodity (PE_c) to its domestic price (PD_c).

Dynamics

We assume that the population of the region (Alaska) grows at a constant annual rate. Labor stock in each period is updated based on change in population and net labor in-migration. Net labor in-migration is determined after solving a static CGE in each period, and is added to labor stock at the beginning of the next period. Total capital stock in non-seafood sector is assumed to grow at a constant annual rate. Investment is determined via the annual increase in capital in the non-seafood sector. Unlike many national-level CGE models where the level of savings determines the level of investment, our CGE model assumes that the level of regional investment determines the level of regional savings. In other words, our model assumes that, if the level of savings in the region is lower than is needed for regional investment in the region, there will be an inflow of savings from outside the region, and vice versa. This assumption seems reasonable because the economies of regions within US are highly open and therefore the investment funds are highly mobile among the regions.

The structure of our dynamic CGE model is similar to that in Seung and Kraybill (2001), Shoven and Whalley (1992) and Ballard et al. (1985). Our CGE model considers two different types of adjustment behavior for two different types of markets – the market for goods and services and the market for factors of production. In the market for goods and services, the prices and quantities adjust in a short period (a year) eliminating excess demand and attaining Walrasian equilibria. In the

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market for factors of production, it takes multiple periods for the prices and quantities to adjust due to lagged responses of factor supplies, measured by the factor migration elasticities.

We solve for the model to obtain static equilibrium in each period given capital stock and labor stock updated at the beginning of the period. Capital stock in a sector is updated with investment in each period. Labor stock in the region is updated with labor in-(or out-)migration and change in population. The sequence of equilibria thus obtained without any perturbation (government policy or exogenous shock) is benchmark sequence. The sequence generated with a perturbation (climate change in our study) is counterfactual sequence. We compare the two sequences of equilibria to compute the economic impacts.

Welfare Change

One important advantage of CGE models over linear models (IO and SAM models) is that prices are endogenously determined in CGE models. This enables analysts to calculate the welfare change of various policies. We follow Ballard et al. (1985) to calculate the welfare change occurring because of climate change for the three types of households. First, per capita expenditure is calculated for each period for each of the three types of households as:

$$PCE_{z,h,t} = \frac{e_{z,h,t}(p_{0,t}, U_{z,h,t})}{POP_{z,h,t}/_{POPB_h}} \tag{13}$$

where z is either benchmark (0) or counterfactual (1), h household type, t time (year), $e(p,U)$ the expenditure function, p a benchmark vector of prices, U utility, and $POP_{z,h,t}$ and $POPB_h$ household type h's population in t and in the base year, respectively. Next, the sum of the sequence of per capita expenditures (in present discounted values) from the base period to a terminal period (T) is calculated as:

$$PVE_{z,h,T} = \sum_{t=0}^{T} \frac{PCE_{z,h,t}}{(1+d)^t} \tag{14}$$

where d is the discount rate. The welfare change in present value (PVW) for household h from an exogenous shock is calculated as follows:

$$PVW_h = PVE_{1,h,T} - PVE_{0,h,T} + \frac{PCE_{1,h,T}}{d(1+d)^T} - \frac{PCE_{0,h,T}}{d(1+d)^T} \tag{15}$$

Equation (8) computes the sum of the sequence of the *changes* in per capita expenditures in present discounted values.

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4 Data

We used 2004 IMPLAN data to construct the social accounting matrix (SAM) for Alaska[10]. We aggregated the 509 industries in IMPLAN into 14 non-seafood industries. Because of the unreliability of the fish harvesting and processing data in IMPLAN, we did not use the data. For fish harvesting and processing industries, we instead used data from Alaska Fisheries Information Network (AKFIN), Pacific Fisheries Information Network (PacFIN), Commercial Fisheries Entry Commission (CFEC), and National Marine Fisheries Service (NMFS).

The Fisheries Economic Assessment Model (FEAM) for Alaska was also useful because it provides information about budgets, supply distributions, and geographic expenditure distributions for the Alaska fish harvesting and processing industries. We used information on the locations of the businesses selling inputs to the seafood industries in order to distribute the industries' expenditures and vessel owners' profit to different regions or states (Alaska and other states). In addition, we conducted informal interviews of key industry informants (The Research Group 2007). Using the results from the interviews, we made adjustments to budgets and trade flows, and validated information on the seafood industries' expenditures, input suppliers' sales to the industries, seafood production and markets. As a final step, we compared the informal interview results with the financial information for the seafood industries, and constructed the final set of data set for the seafood industries.

The final set of data that we prepared for the seafood industries using the data and procedures mentioned above includes harvest of fish, sales of the fish to processors, purchases of inputs from non-seafood industries, seafood production, labor income, income for owners of vessels and processors (capital income), employment, tax payments, and other information that we needed to construct the SAM. Details about the methods that we used develop the data for the seafood industries can be found in The Research Group (2007). As noted above, in the final SAM thus developed, there are (i) 32 industry sectors each of which produces each of the corresponding 32 commodities, (ii) three value-added accounts (labor income, capital income, and indirect business tax payment), (iii) two government sectors (federal government and the combined state-local government), (iv) three household sectors, (v) investment-savings account, and (vi) the rest of the world account.

We specified the values of certain parameters (such as elasticities) in the model equations based on previous studies. We then calibrated the remaining parameters (parameters specifying the shares of labor income and capital income). In other words, to calculate the values of the remaining

[10] We used 2004 data for developing the seafood and non-seafood data in the SAM. Ideally, it would be best to use 2012 data because the stock-yield project model projected the pollock harvest for year 2012 and onward while we used the historical harvest data for simulations for the years 2004-2011. By using 2004 economic data as the base year data, we implicitly assume in the model that the Alaska economy projected for year 2012 (by updating labor and capital) by the CGE model is similar to the one described by actual 2012 economic data. Due to this assumption, the model may overestimate to some extent the projected Alaska economy in 2012 because it is likely that the Alaska economy, like those of other US states, were in the middle of severe recession in 2012.

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parameters, we solved the system of equations in the model for the remaining parameters with the values of variables given by the base-year data in the SAM and the values of the elasticities exogenously specified based on previous studies. Labor force participation rate (0.65) is based on Alaska Department of Labor and Workforce Development (ADOL 2013). Population growth rate (0.97%) is based on ADOL (2012). It is assumed that capital in non-seafood sector grows at an annual rate of 1.4%, which is the average rate growth of real gross domestic product for Alaska from 1997 to 2011 (Bureau of Economic Analysis). Factor migration elasticity is set at 0.137 (Plaut 1981). Table 2 presents the values of important parameters that we used when developing our CGE model and their sources.

It seems that, in Table 2, the most influential parameters to the model outcomes are population growth rate and capital growth rate. This is because the size of the economy projected over time will depend on the magnitudes of the growth of labor (population) and capital in the economy. Most elasticity values in Table 2 were estimated before 1990s, and therefore, are dated to some degree. In particular, some CGE modelers may hesitate to place much confidence on the elasticities of substitution in Armington function and the elasticities of transformation in CET supply aggregation function if these elasticities are used in a regional CGE model such as our CGE model. This is because these elasticities were estimated for national / international economies, not for a smaller region such as Alaska. We used these elasticity values because no previous studies have estimated these elasticity values specifically for the study region (Alaska).

Compared with the elasticity values, the dynamic parameters at the bottom of the table seem to be much more reliable because these parameters were either estimated for the study region (Alaska) (e.g., labor force participation rate, population growth rate, and capital grow rate) or estimated within a regional setting (factor migration elasticity). However, some of these dynamic parameters may not correctly predict the changes in the future economy of Alaska. For example, the assumed population growth rate of about 1% may overestimate the actual future population growth and therefore the size of the Alaska economy, if an unexpected event occurs to the Alaska economy that will result in a significant decline in Alaska population.

In our study, we conducted a sensitivity analysis for the elasticity of substitution in the Armington function for pollock because this elasticity is directly relevant to exogenous shocks in our study (i.e., changes in pollock harvest caused by climate change).

5. Experimental Design

Figures 2 and 3 show the pollock yield projections without climate change and those with climate change, respectively, for each of the 20 simulations utilized here.[11] Comparing the two figures, we see that the climate change reduces the pollock yields significantly over time. The average accumulated reduction in pollock yields from climate changes is about 22.2% (Table 3).

We calculated the economic effects of changes in pollock yield from climate change for each of the 20 simulations. Each simulation involves running the model without (benchmark) and with (counterfactual) climate change. Both benchmark and counterfactual are run for a 47-year period

[11] In the figures and in the simulations of the CGE model in this study, we included historical data for pollock catch from the base year of the CGE model (2004) to 2008.

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(2004-2050). In running the counterfactual, we use three different model versions, each representing a different experiment. In all experiments, we assume that the world demand curve for EBS pollock is downward sloping[12], implying that the world price of pollock changes endogenously with changes in EBS pollock yields.[13] In Experiment 1, we run the counterfactual model with the downward sloping demand curve that does not shift. In Experiment 2, we run the counterfactual model with the assumption that the demand curve shifts up every year slightly[14] in order to reflect the expectation that the world demand increases over time due to increasing world population and income. In Experiment 3, we run the counterfactual with the shifting demand curve *and* an expected fuel price increase.[15]

6 Results

Table 3 presents the *average* cumulative effects from climate change on industry output both in quantity and in value, for each of the three experiments. The results in Table 3 are obtained by running the CGE model over the 47-year period for each of the 20 simulations both without and with climate change. The table indicates that, in all three experiments, the cumulative output in pollock harvesting industry decreases exogenously, on average, by about 22.2% (or $3.2 billion) over the 47-year period due to climate change. This change in pollock industry output represents *direct* impacts of the climate change.

In Experiment 1, the output in the pollock processing industry decreases by 21.5% (or $7.8 billion). The accumulated output for all the non-seafood industries combined decreases by about $1.1 billion. This occurs because the reduced pollock harvest decreases demand for the intermediate inputs from non-seafood industries and the reduced household income from reduced pollock harvest decreases the household demand for the non-seafood goods and services. The total output in the region is reduced by 0.4% (or $12.0 billion) in Experiment 1.

While the quantity of pollock harvested decreases by about 22.2% on average, the value of the harvest does not decrease as much as the quantity. The value of the pollock harvest (i.e., the total

[12] There are many studies which estimated the demand elasticities for various fish species and different countries. Asche et al. (2007) provides a review of elasticity estimates from these studies. However, none of these studies have estimated the export demand elasticity for Alaska pollock. According to Asche et al. (2007), the elasticity of demand for whitefish species ranges from 0.95 (whitefish) to 8.33 (cod). Based on previous export demand elasticities used for CGE models, Allen and Ballingall (2011) updated the elasticities as 2.02 for "fish" and 3.3 for "prepared fish". However, these estimates are for New Zealand economy. De Melo and Tarr (1992) used an export demand elasticity of 3.0 for all traded sectors in a CGE model for US. Given lack of the elasticity estimates for Alaska pollock, we set the export demand elasticity for Alaska pollock to 3.

[13] Strong and Criddle (2014) estimated the inverse demand equations for individual Alaska pollock products (i.e., fillets, surimi, and roe) for different countries of destination of the products. However, they did not estimate the aggregate elasticity of export demand for all the products combined and for all the destination foreign countries combined.

[14] We assumed that the demand curve shifts to the right slightly such that the quantity demanded given a pollock price increases by 1.5% every year.

[15] We assume that the fuel price increases by 1% every year, based on Figure 6 in U.S. Energy Information Administration (2014).

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revenue from sales of raw pollock) decreases by only 9.0% in Experiment 1. In case of pollock processing industry, the value of output decreases by much smaller percentage than the quantity reduction (13.2% vs. 21.5%). This implies that the price effects (i.e., increase in the world price of pollock along the downward sloping demand curve, due to reduced supply of pollock from Alaska) partially offset the quantity effects (i.e., the reduction in supply of Alaska pollock) and the loss of fishery income (value added) from falling pollock yields with climate change.

In Experiment 2, we considered the effects of an exogenous increase in world price of processed pollock on the average impacts of climate change (Experiment 2, Table 3). We assumed that the world demand curve for pollock shifts to the right such that the quantity demanded of pollock at a given price increases by 1.5% every year during the simulation period. The effects of climate change on the quantities of output for different industries accounting for the exogenous shift of the demand curve (Experiment 2) are not significantly different in terms of percentage change from those obtained without considering the effect of the demand shift (Experiment 1). However, the results for the value of output for the seafood industries are remarkably different between the two experiments. While the value of pollock harvest decreases by about 9.0% (or $751 million) with the fixed demand curve (Experiment 1), the value in fact *increases* by 8.5% or $708.8 million with shifting demand curve (Experiment 2). Also, the value of processed pollock decreases by much less (4.6%, Experiment 2) with shifting demand curve than with fixed demand curve (13.2%, Experiment 1).

The value of total regional output decreases by $3.8 billion with a fixed demand curve while the value decreases by much less ($478.2 million) with a shifting demand curve. Results indicate that, if we consider the effects of a shifting demand curve, the impacts on the values of output from pollock harvesting and processing industries and total regional output are smaller than without the effects of the shifting demand curve.

When considering both shifting world demand curve for EBS pollock and fuel price increase (Experiment 3), the economic impacts on seafood industries are not significantly different from those calculated with shifting demand curve only (Experiment 2), with the catches (TACs) of EBS pollock exogenously given by the EBS stock-yield projection model. However, results for non-seafood industries are significantly different between Experiment 2 and Experiment 3. While the quantity and value of total non-seafood output decrease by only $861.2 million and $369.9 million, respectively, in Experiment 2, they decrease by $14.1 billion and $6.4 billion, respectively, in Experiment 3. This is because fuel is an important input to all industries and an important consumer good, and therefore, increases in fuel price generate much larger economy-wide impacts, affecting all industries' productive activities and households' purchasing power, while most of the impacts of the change in the world demand for EBS pollock occur only in seafood industries.

The standard deviation of change in pollock harvest in quantity is about $3.7 billion in all three experiments while the standard deviation of change in pollock processing in quantity ranges from $8.9 billion to $9.2 billion. The standard deviation of change in the harvest in value is about $960 million in Experiment 1 while the deviation is about $1.4 billion in the other two experiments. Generally, the standard deviations with exogenous changes in export demand (Experiment 2) or fuel price (Experiment 3) are larger than without these changes (Experiment 1). The wide range of the

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economic impacts represented by the large standard deviations is caused by the high degree of uncertainties reflected in the 20 different simulations from the stock-yield projection model.

Figure 4 summarizes the overall economic impacts for the three experiments by presenting the temporal changes in average reduction in RGRP. It is shown that the loss in RGRP with shifting world demand for pollock (Experiment 2) is slightly smaller than that with fixed demand curve (Experiment 1). However, the negative impacts of a fuel price hike outweigh by a large extent the positive effects of shifting world demand for pollock, resulting in a much larger loss in RGRP in Experiment 3.

The change in the resource rent is determined by the relative strength of the effects of changes in the price vs. quantity of pollock harvested. The price change with fixed demand curve is an endogenous change in the ex-vessel price of the pollock along the downward sloping export demand curve caused by changes in the harvests of the fish while the price change with shifting demand curve is a result of both endogenous change along the curve and exogenous change from the shift of the curve.

Figure 5 shows the average loss in resource rent for the EBS pollock harvesting industry calculated for each of the three experiments. Again, the impacts on resource rent calculated with shifting world demand for pollock (Experiment 2) are significantly different from those obtained with a fixed demand curve (Experiment 1). While the climate change with a fixed demand curve generates on average a loss in resource rent in most of the periods, due to the quantity effects (i.e., reduction in catches of pollock) outweighing the price effects, the climate change with shifting demand curve results in a "gain" in resource rent, due to price effects (i.e., higher pollock price with shifting demand curve) that outweigh the quantity effects. Comparing results for resource rent from Experiment 2 and Experiment 3, the figure indicates that the resource rent gain in Experiment 3 is slightly smaller than in Experiment 2 due to larger expenditures by pollock harvesters on now more expensive fuel. The average present discounted value of resource rent decreases by $109.9 million over the 47-year period in Experiment 1 while the resource rent increases by $1.39 billion and $1.34 billion, respectively, over the same period in Experiment 2 and Experiment 3 (not reported in a table).[16]

Table 4 presents average welfare loss occurring from climate change. When the world demand for pollock does not shift (Experiment 1), the welfare losses are $97.3 million, $679.0 million, and $859.8 million for low-, medium-, and high-income households, respectively, or a total of about $1.6 billion for all households. These results contrast with the welfare results obtained with exogenous shifts of the pollock export demand curve (Experiment 2). Not surprisingly, when we allow the demand curve to shift up, the values of output for the pollock industries (and therefore, value added or fishery income) and the value of the total regional output decrease by smaller amounts and percentages than when the demand curve does not shift (Table 3). Therefore, the welfare losses from climate change with shifts in the export demand curve are much smaller than those calculated with no shift in the demand curve ($0.4 billion vs. $1.6 billion, Table 4). However, with fuel price increase (Experiment 3), the welfare loss is the largest ($3.9 billion).

[16] We calculated changes in quota share lease rate for the pollock in the study, but do not report them in this paper. The model results for quota share lease rate are available upon request.

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Figure 6 presents welfare losses for all households for 20 different simulations. The figure shows that, with two exceptions (Simulations 12 and 20), the climate change will cause welfare losses in Experiment 1. Welfare losses with shifting export demand (Experiment 2) are smaller than with no shift (Experiment 1) in some simulations while there are some welfare gains in the other simulations. Experiment 3 generates welfare loss for all 20 simulations. As shown in Figure 6, there is a wide range of variation in the aggregate welfare results from variations in pollock harvests, originating from uncertainties in the 20 simulations derived from the stock-yield projection model. The standard deviations of aggregate welfare losses are $1.79 billion, $2.39 billion, and $2.35 billion for the three experiments, respectively (not reported in a table).

We conducted sensitivity analysis for the elasticity of substitution in Armington function for pollock. We used 0.31 (medium elasticity, Table 2) for the elasticity value in calculating the results shown in Tables 3 and 4 and Figures 4-6. We ran the model with 10% lower elasticity (low elasticity), and then with 10% higher elasticity (high elasticity). The results from the sensitivity analysis are reported in Table 5 (industry output) and Table 6 (welfare changes). In the two tables, the numbers under "medium elasticity" columns are from Tables 3 and 4.

Results in Table 5 indicate that, in all the three experiments, changing the elasticity values does not produce significantly different results for the accumulated output. The largest difference in the impacts on the accumulated output is shown for pollock processing industry in Experiment 1 when the elasticity value increases from medium to high elasticity; the high elasticity value generates the impacts on the accumulated processing output in the experiment that are 0.17% smaller than those with medium elasticity (21.47% minus 21.30 %). In the other cases, results indicate no significant differences in the accumulated outputs from varying the elasticity values. This implies that overall the results for the industry outputs are not very sensitive to the changes in the elasticity value.

Table 6 shows the results from sensitivity analysis for welfare changes. In Experiments 1 and 3, the changes in welfare losses from varying the elasticity value are not significant. In Experiment 1, the largest reduction in welfare loss (in % terms) is obtained for medium income households when the elasticity value increases from medium to high elasticity value; the welfare loss for the medium income households with high elasticity is 2.3% lower than the loss obtained with medium elasticity. In Experiment 2, however, the deviations in welfare loss with low and high elasticities are much larger in percentage terms than those obtained in Experiments 1 and 3. In case of high income households in Experiment 2, the high elasticity value yields welfare loss that is 6.3% smaller than the welfare loss obtained with medium elasticity. In Experiment 3, however, the deviations are all less than 2%.

7 Discussion

Previous studies tend to focus on investigation of the temporal and functional relationships between climate change, fish production, recruitment, and stock dynamics, failing to conduct a rigorous analysis of the economic effects generated by climate change for fisheries. Calculating the potential economic effects of climate change for fisheries is an important issue for US fishery managers who are required by MSFCMA National Standard 8 to consider economic impacts of fishery management policies (or environmental shock) on the communities dependent on fisheries (i.e., TAC changes arising from climate-driven changes in stock of fish in this study.) There are only a few studies aimed

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at evaluating the economic effects of climate change-induced changes in fisheries. However, these studies either rely on a partial equilibrium analysis or static analysis.

The present study uses an economic model linked to a stock-yield projection model with direct linkages to hypothesized climate-change impacts on fishing. The economic model overcomes the weaknesses of the previous studies of economic effects of climate change-induced impacts on fisheries by using a forward-moving dynamic CGE model which enables calculation of the endogenous variables such as prices over time showing how economic dynamics are affected by forces of nature (e.g., SST). We calculated the temporal and cumulative regional economic impacts of reduced pollock catches due to lower productivity under 20 alternative climate change scenarios projected for 40 years and stochastic simulations. In the experiments evaluated, we estimated a 22.2% (or $3.2 billion) decline in production due to climate change. Globally, the future demand for pollock is anticipated to increase due to human population growth and economic growth. It is also expected that the fuel price will rise. The three experiments in our study reflect the importance of considering the global demand-side conditions when investigating the impacts of supply-side shocks in EBS pollock fishery. By simulating different experiments (i.e., fixed world demand curve, shifting world demand curve, and both shifting world demand plus increasing fuel price), we evaluated a reasonable range of economic and welfare impacts linked to climate change.

We used a realistic assumption that the world demand for Alaska pollock is represented by a downward-sloping curve which is either fixed (Experiment 1) or shifting out (Experiment 2). With the fixed demand curve, the value of the pollock harvest decreases by a smaller percentage than the quantity reduction (Experiment 1). This arises because the effects of increase in the world price of pollock along the downward-sloping demand curve partially countervail the effects of the reduced supply of Alaska pollock. If we allow the demand curve to shift out annually, the value of the pollock harvest can *increase* even with decreases in pollock harvest due to climate change (Experiment 2). Comparing the impacts on total regional output from Experiment 2 and Experiment 3, we found that the impacts from Experiment 3 are much larger than those from Experiment 2 because fuel is an important input to all industries and an important consumer good. Without taking the larger global economic situation into account, the economic impact of reduced future pollock catches may be misleading.

Although this study found that the impacts from climate change on the seafood industries' output are significant, the impacts on the output of the non-seafood sector and on the total regional output are relatively small in percentage terms. The accumulated output (in quantity) for all the non-seafood industries combined decreases by about $1.1 billion (or less than 0.01%), $0.9 billion (or less than 0.01%), and $14.1billion (or 0.5%), respectively, in the three experiments. The total regional output (in quantity) decreases by about $12.0 billion (or 0.4%), $11.1 billion (or 0.3%)), and $24.4 billion (or 0.8%), respectively, in the three experiments. This indicates that the economic impacts of reduced pollock yields from climate change on total regional output are not significant relative to the size of the regional economy. One of the most important reasons is that much of labor income generated in many Alaska industries including EBS pollock harvesting and processing industries flows out of the state because a significant proportion of workers in Alaska (including crew members and processing workers in seafood industries) are non-Alaskan residents. Also, a large quantity of capital that industries in Alaska use is owned by non-Alaskan residents, which is also true for the case of

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seafood sector. This means that much of the capital income from these industries flows to other states. Additionally, a large share the commodities consumed by households or used in industries in Alaska are imported from outside of the state. All of these factors lower the impact on the total regional output.

Fishery managers may be interested in how the resource rent changes from climate change. It is important to estimate the resource rent within a general equilibrium framework as in our study. There are many variables that determine the resource rent from change in pollock yields, including price and quantity of pollock, returns to primary factors of production in pollock harvesting industry, and the prices and quantities of intermediate inputs such as fuel and food. In our general equilibrium model, these variables are determined by the changes occurring in the other industries in the economy because all the markets and economic sectors are all interlinked. The changes in resource rent thus calculated will be different from those that would be obtained from a partial equilibrium analysis. A partial equilibrium analysis would consider the changes occurring in the pollock industry only, ignore what happens in sectors other than pollock industry, and therefore be misleading. An interesting result from this study is that there will be an average loss in the resource rent when the world demand for pollock does not shift, but will be an average gain in resource rent when the demand shifts because of price effects (i.e., higher pollock price with shifting demand curve) outweighing the quantity effects.

8 Conclusion

We coupled a stock-yield projection model for pollock with a regional economic model to calculate the economic effects of changes in pollock yields induced by climate change. Unlike previous studies of similar topics, the present study used a theoretically rigorous economic model, that is, a CGE model. We used a dynamic framework, which enabled calculation of the temporal and aggregate regional economic impacts. The first type was endogenous changes from movement along a downward sloping export demand curve associated with falling yields for pollock with climate change. The second type was exogenous growth in world price of pollock, represented by exogenous shifts of a downward sloping export demand curve. We also considered the change in fuel price in calculating the economic impacts.

Major findings were as follows. First, the reductions in the value of the EBS pollock harvesting and processing industries' output were much smaller than the reductions in their quantities due to increases in the price of pollock (regardless of our assumptions about shifting world demand). This price increase partially offset the loss of fishery income (value added) for pollock industries from falling yields with climate change. Second, because of its regional income effects, the world price for pollock was an important factor determining the magnitude of the welfare changes from climate change. Welfare losses from climate change were found to be smaller with an exogenous shift in demand but larger with both an exogenous demand shift and an exogenous increase in fuel price. This result demonstrates that the effects on regional output and household welfare from climate change rely not just on the changes in pollock yields but on how the global pollock demand changes and on how fuel prices change in the future. Finally, results for welfare changes hinge on the

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uncertainties related to predictions of future pollock yields from the stock-yield projection model. Since forecasting pollock recruitment (and subsequent stock status) is highly uncertain and known to be naturally varying, extending such forecasts to economic impacts by connection is also highly uncertain. Whereas the expected value for pollock stock productivity is hypothesized to be related to ocean temperatures and hence affected by climate change, the variability of recruitment is expected to remain high and periods of poor recruitment interspersed with strong pollock year classes will ultimately affect future fishing opportunities and have concomitant economic impacts.

As such, there are several caveats to note in this study. First, we assumed that climate change will affect only pollock in calculating the economic impacts, ignoring what will happen to other species (and hence alternative fishing opportunities). Climate change will likely perturb the whole EBS marine ecosystem, which may increase stock, yields, and fishing costs of some species while decreasing the stock and yields of other species. Given lack of previous studies on how the yields of different species will change due to climate change, the present study was restricted to pollock. The pollock stock in the EBS occupies a unique ecological niche and the trophic relationships are complex and the subject of much debate (e.g., Ressler et al. 2014). Reduced catches of pollock are likely to provide increased opportunities to catch other species (e.g., Pacific cod, flatfish). However, predictions of outcomes are made difficult and complicated due to existing bycatch regulations and area and season closures, and further consideration of how they would interact would be speculative and is thus beyond the scope of our study. Second, the economic model we used is a single-region model for Alaska, focusing on economic impacts that will occur in Alaska only. However, the Alaska pollock fishery, as other Alaska fisheries, is characterized by a strong economic connection with other states (especially the state of Washington). Many fishing crew members in the Alaska pollock fishery are from other states as is much of the intermediate inputs used in the fishery, Therefore, the logical next step will be to develop a multi-regional model to capture these interregional effects.

Tables

Table 1 Types and Mobility of Labor and Capital

	Labor	Capital
Number of types	One, homogenous labor	Three sector-specific capital types for H, P, and NS.
Inter-industry mobility	Perfectly mobile across all industries	Each sector's capital is mobile only among the industries in the sector.
Interregional mobility	Partially mobile	Each of seafood sector's (H and P) capital is partially mobile.
Return to factor	Single wage rate is endogenously determined	Three different returns to capital are endogenously determined

Note: H = harvesting sector, P = processing sector, NS = non-seafood sector

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Table 2 **Values of Parameters used in Alaska CGE Model**

Name of Parameter	Value
Elasticity of Substitution in Production [a]	
All fish harvesting, agriculture	0.61
All fish processing	0.79
All the other industries	0.80
Elasticity of Substitution in Consumption [b]	
Low-income households	0.750
Medium-income households	1.125
High-income households	1.500
Elasticity of Substitution: Imported vs. Locally Produced Goods [c]	
All fish harvesting, agriculture	1.42
All fish processing	0.31
Oil and gas, refined petroleum	2.36
Other mining	0.50
Construction	3.15
Other manufacturing	3.55
All the other commodities	2.00
Elasticity of Transformation: Regionally supplied vs. Exported Goods [d]	
All fish harvesting, agriculture	3.9
All fish processing, oil and gas, other mining, construction, other manufacturing, refined petroleum	2.9
All the other commodities	0.7
Elasticity of Export Demand for Pollock	3.0
Dynamic Parameters	
Labor force participation rate[e]	0.65
Population growth rate[f]	0.0097
Capital growth rate[g]	0.014
Factor migration elasticity[h]	0.137
Discount rate (used to calculate the present discounted value of welfare change)	0.03

Source:

a. de Melo and Tarr (1992, p. 232).
b. Shoven and Whalley (1984, p. 1011). The value for medium income households is set at the average of the values for low- and high-income households.
c. de Melo and Tarr (1992, p. 231).
d. de Melo and Tarr (1992, p. 233).
e. Labor force participation rate is based on ADOL (2013).
f. Population growth rate is based on ADOL (2012).
g. Based on the average of the growth rates of real gross domestic product for Alaska from 1997 to 2011 (Bureau of Economic Analysis).
h. Factor migration elasticity is set at 0.137 (Plaut 1981).

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Table 3 **Average Accumulated Impacts of Climate Change on Output Over a 47-year Period**

	Without climate change ($million)	Experiment 1			Experiment 2			
		Change in amount ($million)	% Change	Standard deviation ($million)	Change in amount ($million)	% Change	Standard deviation ($million)	Change in amount ($million)
					Quantity of output[a]			
Pollock harvesting	14,464.8	-3,204.3	-22.2	3,658.9	-3,204.3	-22.2	3,658.9	-3,2
Other fish harvesting	41,211.3	0.0	0.0	0.0	0.0	0.0	0.0	
Pollock processing	36,254.7	-7,783.4	-21.5	8,929.4	-7,129.4	-19.7	9,246.6	-7,1
Other seafood processing	96,190.9	73.4	0.1	80.5	66.0	0.1	83.8	
All non-seafood industries	3,007,792.4	-1,062.3	0.0	1,671.9	-861.2	0.0	1,827.0	-14,0
TOTAL	3,195,914.1	-11,976.6	-0.4	14,076.3	-11,128.9	-0.3	14,536.6	-24,4
					Value of output[b]			
Pollock harvesting	8,310.1	-751.3	-9.0	960.4	708.8	8.5	1,387.1	6
Other fish harvesting	22,141.2	63.6	0.3	70.7	57.9	0.3	73.2	
Pollock processing	19,666.5	-2,604.4	-13.2	3,183.1	-906.1	-4.6	3,705.8	-9
Other seafood processing	51,224.3	35.1	0.1	41.4	31.1	0.1	42.9	
All non-seafood industries	1,478,572.5	-537.5	0.0	764.3	-369.9	0.0	823.5	-6,3
TOTAL	1,579,914.5	-3,794.5	-0.2	4,784.5	-478.2	0.0	5,785.8	-6,5

[a] The unit of output is calibrated such that one unit of output is sold at $1 million in the base year.
[b] The value of output is in present discounted value of revenue from sales of goods and services, and in $million.

Table 4 **Average Present Discounted Value of Welfare Loss ($ million)**

	Experiment 1	**Experiment 2**	**Experiment 3**
Low income household	$97.3	$31.6	$206.0
Medium income household	$679.0	$167.0	$1,651.4

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High income household	$859.8	$205.5	$2,086.4
All Households	$1,636.1	$404.0	$3,943.8

Table 5 **Results from Sensitivity Analysis for Elasticity of Substitution in Import Demand Function (Accumulated Impacts on Output in % Change)**

	Experiment 1 (% Change)			Experiment 2 (% Change)			Expe (% C	
	Low elasticity	Medium elasticity	High elasticity	Low elasticity	Medium elasticity	High elasticity	Low elasticity	Me ela
Pollock harvesting	-22.10	-22.10	-22.10	-22.10	-22.10	-22.10	-22.10	
Other fish harvesting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Pollock processing	-21.43	-21.47	-21.30	-19.59	-19.66	-19.60	-19.59	
Other seafood processing	0.08	0.08	0.07	0.07	0.07	0.07	-0.02	
All non-seafood industries	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.47	
TOTAL	-0.37	-0.37	-0.37	-0.35	-0.35	-0.35	-0.76	

Table 6 **Results from Sensitivity Analysis for Elasticity of Substitution in Import Demand Function (Average Present Discounted Value of Welfare Loss in $ million.)**

	Experiment 1			Experiment 2			
	Low elasticity	Medium elasticity	High elasticity	Low elasticity	Medium elasticity	High elasticity	Low elasticit
Low income household	97.0 (-0.3%)	97.3 (0.0%)	95.3 (-2.0%)	31.2 (-1.2%)	31.6 (0.0%)	30.3 (-4.0%)	203. (-1.4%
Medium income household	675.7 (-0.5%)	679.0 (0.0%)	663.6 (-2.3%)	161.4 (-3.3%)	167.0 (0.0%)	156.7 (-6.2%)	1631. (-1.2%
High income household	855.7 (-0.5%)	859.8 (0.0%)	841.0 (-2.2%)	198.4 (-3.4%)	205.5 (0.0%)	192.6 (-6.3%)	2061. (-1.2%
All Households	1628.3 (-0.5%)	1636.1 (0.0%)	1600.0 (-2.2%)	391.0 (-3.2%)	404.0 (0.0%)	379.6 (-6.1%)	3895. (-1.2%

Note: % numbers in the parentheses represent percentage deviation from welfare losses with medium elasticity.

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Figures

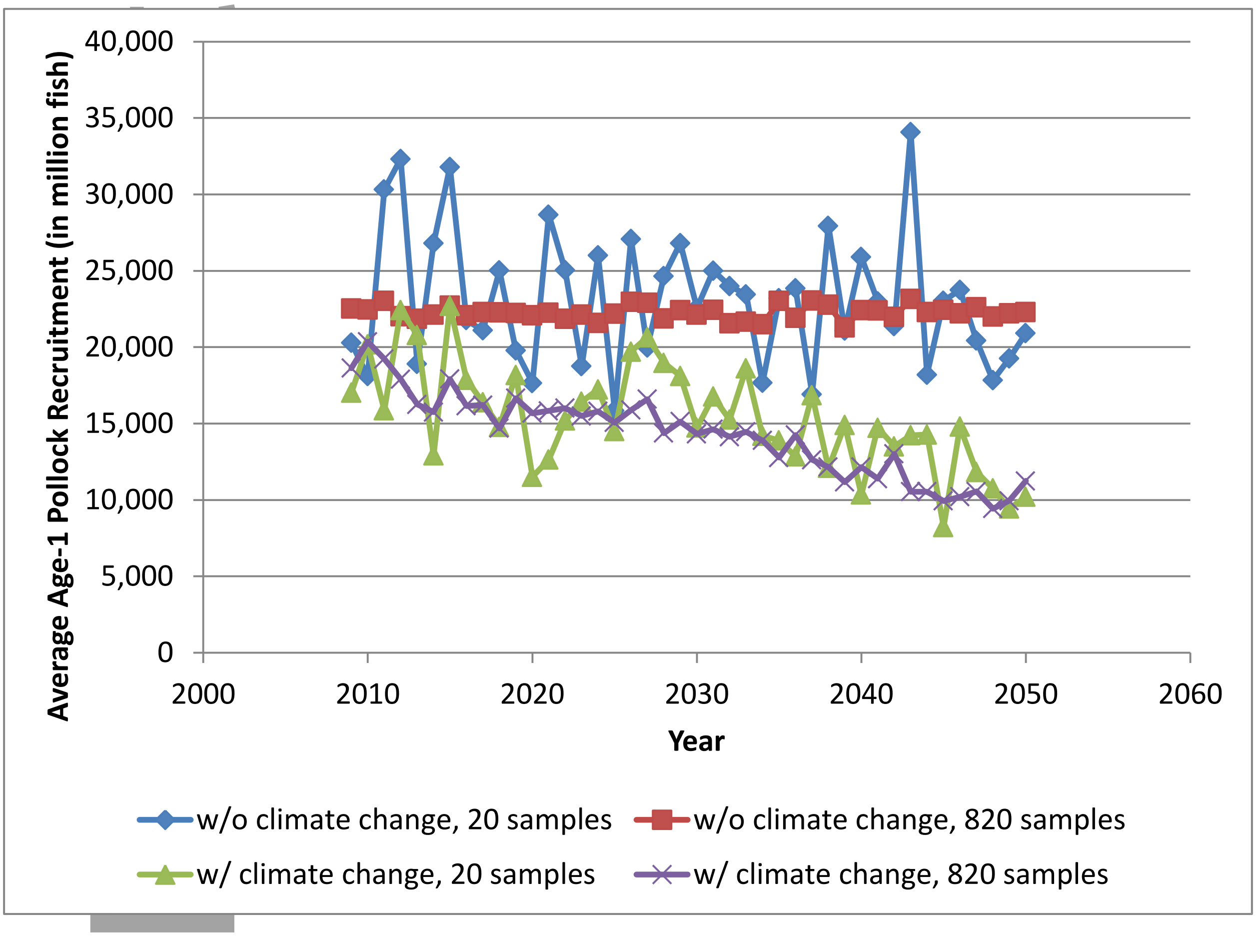

Figure 1 Average Age-1 Pollock Recruitment (in million fish)

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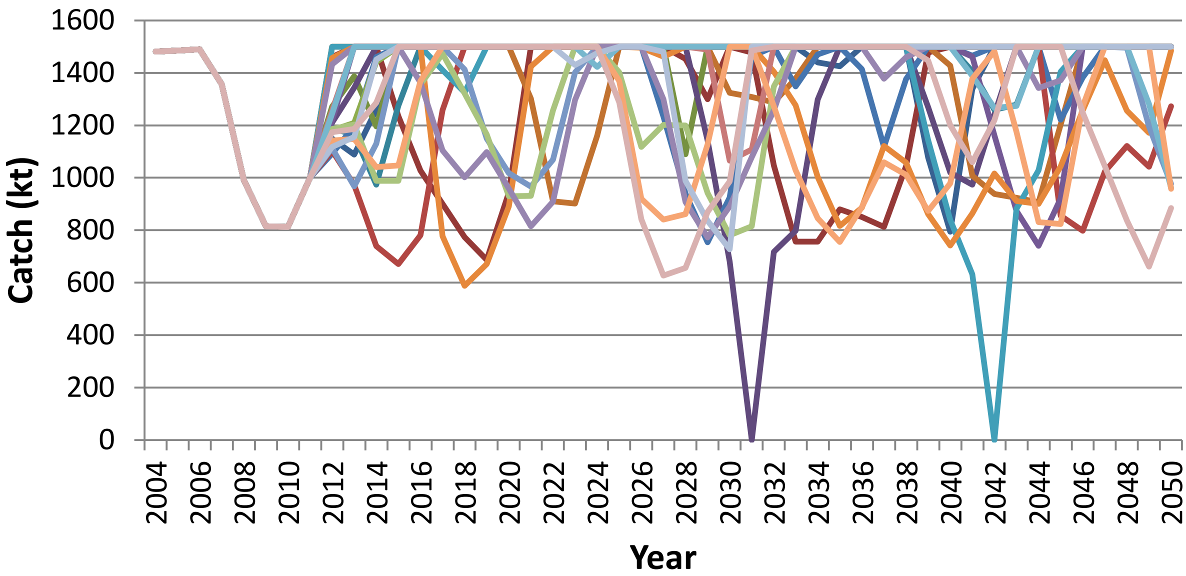

Figure 2 Pollock catch with no climate change for each of the 20 simulation cases.

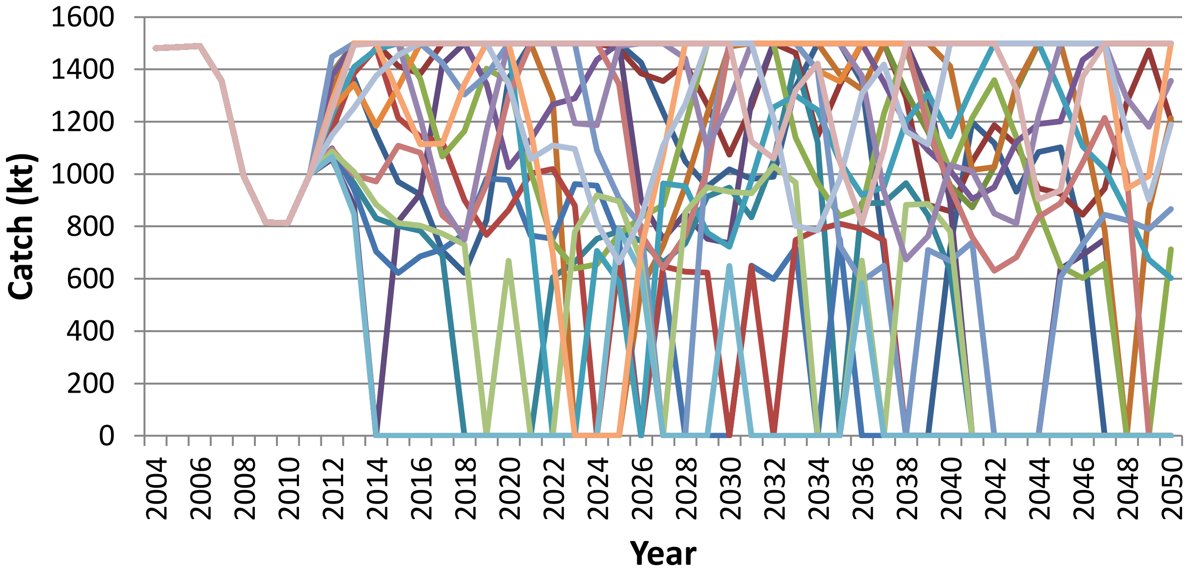

Figure 3 Pollock catch with climate change for each of the 20 simulation cases.

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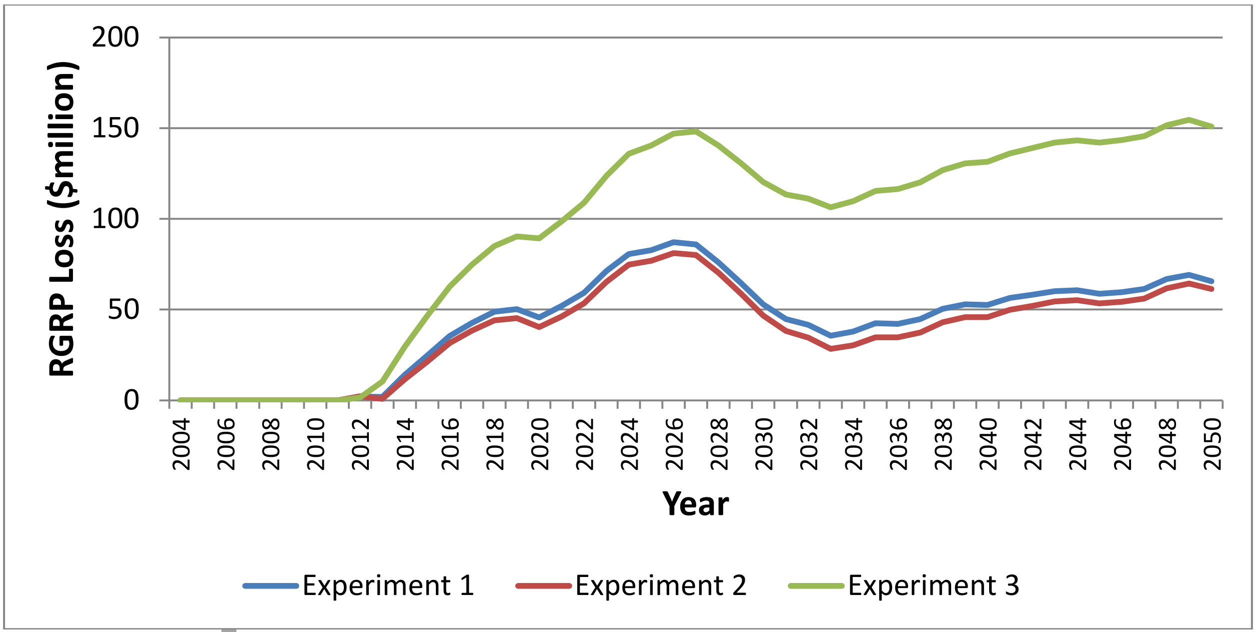

Figure 4 Average loss in RGRP (discounted).

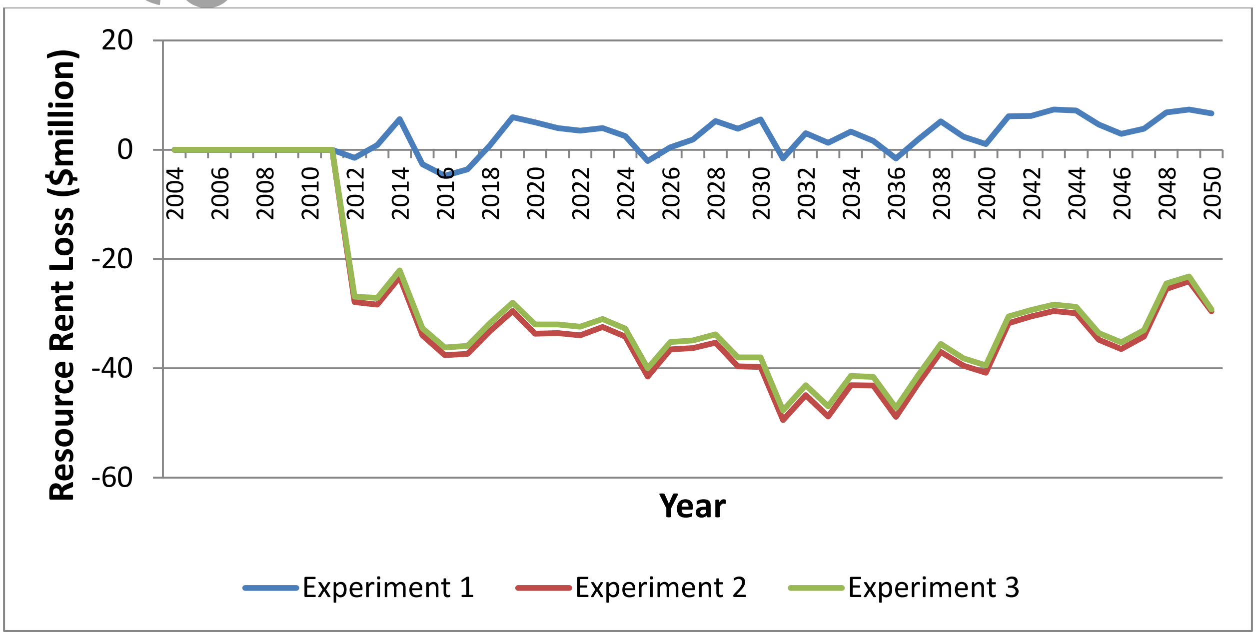

Figure 5 Average loss in resource rent (discounted)

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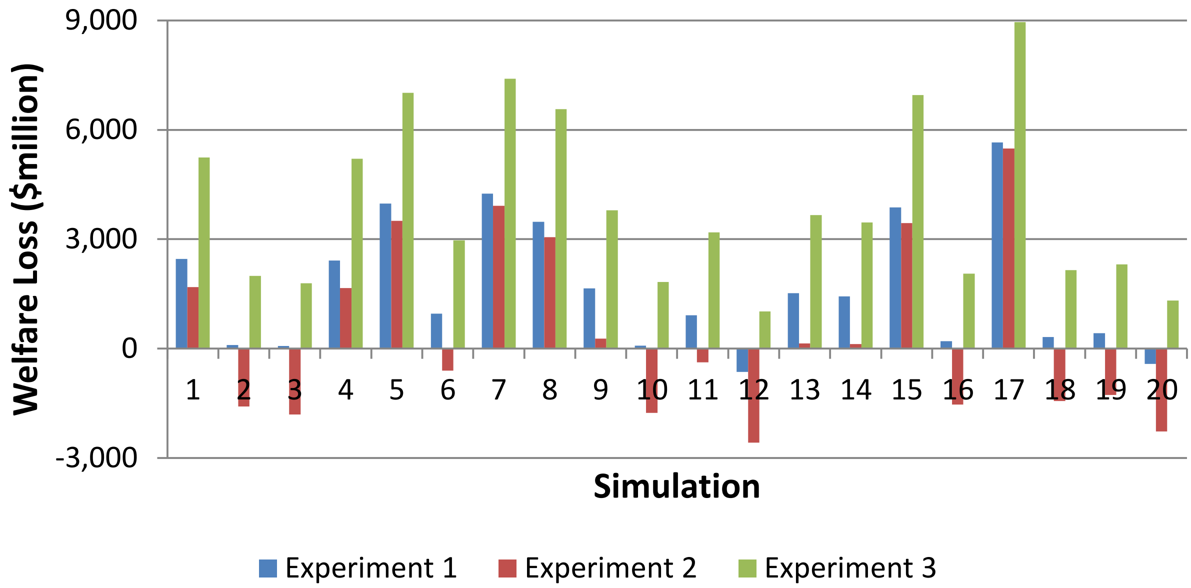

Figure 6Welfare loss from different simulations (discounted)

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APPENDIX GAMS Code for the Alaska CGE model

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```
* =======================  2004 AK DYNAMIC CGE MODEL using Results from Bioeconomic model ============================
* Cost is minimized
* DEVELOPED AND PROGRMMED BY CHANG SEUNG (2013)

$TITLE X SECTOR CGE MODEL USING IMPLAN SAM DATA
$OFFUPPER OFFDOLLAR
$OFFSYMLIST OFFSYMXREF OFFUELLIST OFFUELXREF

$SETGLOBAL PROGPATH \\nmfs.local\AKC-REFM\Users\chang.seung\My Documents\gamsdir\projdir\
$SETGLOBAL SAMNAM COUNTERSAM_CRAB

SET  K Aggregated SAM accounts /

* Industries-Activities
PacCod-A
Pollock-A
Sablefish-A
Crab-RK-A
Crab-SC-A
Crab-OT-A
Halibut-A
Salmonetc-A
OTHERFISH-A

PR-PCOD-A
PR-POLL-A
PR-SAB-A
PR-CRK-A
PR-CSC-A
PR-COT-A
PR-HAL-A
PR-SAL-A
PR-OTH-A

AGRI-A
OIL_GAS-A
OTHERMIN-A
UTILITIES-A
CONSTR-A
OTHERMAN-A
REFINED-A
WHOLESALE-A
TRANSPORT-A
RETAIL-A
INFO-A
FIRE-A
SERVICE-A
MISCEL-A

* Commodities
PacCod-C
Pollock-C
Sablefish-C
Crab-RK-C
Crab-SC-C
Crab-OT-C
Halibut-C
Salmonetc-C
OTHERFISH-C

PR-PCOD-C
PR-POLL-C
PR-SAB-C
PR-CRK-C
PR-CSC-C
PR-COT-C
PR-HAL-C
PR-SAL-C
PR-OTH-C

AGRI-C
OIL_GAS-C
OTHERMIN-C
UTILITIES-C
CONSTR-C
OTHERMAN-C
REFINED-C
```

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```
WHOLESALE-C
TRANSPORT-C
RETAIL-C
INFO-C
FIRE-C
SERVICE-C
MISCEL-C

* Factors
LAB       LABOR
CAP       CAPITAL
IBT       indirect business taxes

* Institutions

* ---Households
LOW_HH
MED_HH
HI_HH

*---Government
SLGOVT     State&Local Govt
FGOVT      Federal Govt

* ---Investment
INV

*---Trade
TRADE

* Row and Column Totals
TOTAL         Total

* Difference between column total and row total
DIFF          Difference
/;

SET I(K)   Industries-Activities /

PacCod-A
Pollock-A
Sablefish-A
Crab-RK-A
Crab-SC-A
Crab-OT-A
Halibut-A
Salmonetc-A
OTHERFISH-A

PR-PCOD-A
PR-POLL-A
PR-SAB-A
PR-CRK-A
PR-CSC-A
PR-COT-A
PR-HAL-A
PR-SAL-A
PR-OTH-A

AGRI-A
OIL_GAS-A
OTHERMIN-A
UTILITIES-A
CONSTR-A
OTHERMAN-A
REFINED-A
WHOLESALE-A
TRANSPORT-A
RETAIL-A
INFO-A
FIRE-A
SERVICE-A
MISCEL-A

/;

SET RES(I)    Resource-based Industries-Activities /

PacCod-A
Pollock-A
Sablefish-A
Crab-RK-A
Crab-SC-A
Crab-OT-A
Halibut-A
Salmonetc-A
```

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```
OTHERFISH-A

PR-PCOD-A
PR-POLL-A
PR-SAB-A
PR-CRK-A
PR-CSC-A
PR-COT-A
PR-HAL-A
PR-SAL-A
PR-OTH-A

AGRI-A
OIL_GAS-A
OTHERMIN-A

/;

SET NRES(I)   NON RESOURCE-based Industries-Activities /

UTILITIES-A
CONSTR-A
OTHERMAN-A
REFINED-A
WHOLESALE-A
TRANSPORT-A
RETAIL-A
INFO-A
FIRE-A
SERVICE-A
MISCEL-A
/;

SET FS(I)   Fish harvesting industries /
PacCod-A
Pollock-A
Sablefish-A
Crab-RK-A
Crab-SC-A
Crab-OT-A
Halibut-A
Salmonetc-A
OTHERFISH-A
/;

SET FSRKC(FS)   RED KING CRAB INDUSTRY /

Crab-RK-A
/;

SET FSNRK(FS)   NON RED KING CRAB INDUSTRIES /

PacCod-A
Pollock-A
Sablefish-A
Crab-SC-A
Crab-OT-A
Halibut-A
Salmonetc-A
OTHERFISH-A
/;

SET FSPOL(FS)   POLLOCK INDUSTRY /
Pollock-A
/;

SET FSNPL(FS)   NON POLLOCK INDUSTRIES /
PacCod-A
Sablefish-A
Crab-RK-A
Crab-SC-A
Crab-OT-A
Halibut-A
Salmonetc-A
OTHERFISH-A
/;

SET NFS(I) Non-fish harvesting industries /
PR-PCOD-A
PR-POLL-A
PR-SAB-A
PR-CRK-A
PR-CSC-A

PR-COT-A
PR-HAL-A
```

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```
PR-SAL-A
PR-OTH-A

AGRI-A
OIL_GAS-A
OTHERMIN-A
UTILITIES-A
CONSTR-A
OTHERMAN-A
REFINED-A
WHOLESALE-A
TRANSPORT-A
RETAIL-A
INFO-A
FIRE-A
SERVICE-A
MISCEL-A
/;

SET PRC(NFS) Processing industries /
PR-PCOD-A
PR-POLL-A
PR-SAB-A
PR-CRK-A
PR-CSC-A
PR-COT-A
PR-HAL-A
PR-SAL-A
PR-OTH-A
/;

SET PRNRK(PRC) NON RED KING CRAB Processing industries /
PR-PCOD-A
PR-POLL-A
PR-SAB-A
PR-CSC-A
PR-COT-A
PR-HAL-A
PR-SAL-A
PR-OTH-A
/;


SET SEA(I) SEAFOOD SECTORS /
PacCod-A
Pollock-A
Sablefish-A
Crab-RK-A
Crab-SC-A
Crab-OT-A
Halibut-A
Salmonetc-A
OTHERFISH-A

PR-PCOD-A
PR-POLL-A
PR-SAB-A
PR-CRK-A
PR-CSC-A
PR-COT-A
PR-HAL-A
PR-SAL-A
PR-OTH-A
/;

SET NSEA(I) NON SEAFOOD SECTORS /
AGRI-A
OIL_GAS-A
OTHERMIN-A
UTILITIES-A
CONSTR-A
OTHERMAN-A
REFINED-A
WHOLESALE-A
TRANSPORT-A
RETAIL-A
INFO-A
FIRE-A
SERVICE-A
MISCEL-A
/;

SET C(K)   Commodities /
PacCod-C
Pollock-C
Sablefish-C
```

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```
Crab-RK-C
Crab-SC-C
Crab-OT-C
Halibut-C
Salmonetc-C
OTHERFISH-C

PR-PCOD-C
PR-POLL-C
PR-SAB-C
PR-CRK-C
PR-CSC-C
PR-COT-C
PR-HAL-C
PR-SAL-C
PR-OTH-C

AGRI-C
OIL_GAS-C
OTHERMIN-C
UTILITIES-C
CONSTR-C
OTHERMAN-C
REFINED-C
WHOLESALE-C
TRANSPORT-C
RETAIL-C
INFO-C
FIRE-C
SERVICE-C
MISCEL-C
/;

SET CQ(C)   Commodities Consumed by HOUSEHOLDS /

PR-PCOD-C
PR-POLL-C
PR-SAB-C
PR-CRK-C
PR-CSC-C
PR-COT-C
PR-HAL-C
PR-SAL-C
PR-OTH-C

AGRI-C
OTHERMIN-C
UTILITIES-C
OTHERMAN-C
REFINED-C
WHOLESALE-C
TRANSPORT-C
RETAIL-C
INFO-C
FIRE-C
SERVICE-C
MISCEL-C
/;

SET NSC(C)   Non-seafood Commodities /

AGRI-C
OTHERMIN-C
UTILITIES-C
CONSTR-C
OTHERMAN-C
REFINED-C
WHOLESALE-C
TRANSPORT-C
RETAIL-C
INFO-C
FIRE-C
SERVICE-C
MISCEL-C
/;

SET NNSC(C)   Seafood Commodities /
PacCod-C
Pollock-C
Sablefish-C
Crab-RK-C
Crab-SC-C
Crab-OT-C
Halibut-C
```

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```
Salmonetc-C
OTHERFISH-C

PR-PCOD-C
PR-POLL-C
PR-SAB-C
PR-CRK-C
PR-CSC-C
PR-COT-C
PR-HAL-C
PR-SAL-C
PR-OTH-C

OIL_GAS-C
/;


SET PCOM(C)   RAW AND PROCESSED POLLOCK COMMODITIES  /
Pollock-C
PR-POLL-C
/;

SET NPCOM(C)   NON POLLOCK Commodities /
PacCod-C
Sablefish-C
Crab-RK-C
Crab-SC-C
Crab-OT-C
Halibut-C
Salmonetc-C
OTHERFISH-C

PR-PCOD-C
PR-SAB-C
PR-CRK-C
PR-CSC-C
PR-COT-C
PR-HAL-C
PR-SAL-C
PR-OTH-C

AGRI-C
OIL_GAS-C
OTHERMIN-C
UTILITIES-C
CONSTR-C
OTHERMAN-C
REFINED-C
WHOLESALE-C
TRANSPORT-C
RETAIL-C
INFO-C
FIRE-C
SERVICE-C
MISCEL-C
/;


SET F(K)   Factors /
     LAB       LABOR
     CAP       CAPITAL
     IBT       indirect business taxes
/;

SET IN(K)   Institutions /

* Institutions
** Households

LOW_HH
MED_HH
HI_HH

** Government
SLGOVT     State&Local Govt
FGOVT      Federal Govt

** Investment
INV
/;

SET T(K)   Trade /
TRADE
/;

ALIAS (K,KK);
```

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```
PARAMETER SAM(*,*)  ;
$call "GDXXRW.EXE I =AKSAM_CRAB_AGG6_RRR_CKS.xlsx O = AKSAM_CRAB_AGG6_RRR_CKS.GDX PAR = SAM RNG = SHEET1!A1:BW75 cdim=1 rdim=1 trace =3 "
$gdxin AKSAM_CRAB_AGG6_RRR_CKS.gdx
$LOADDC SAM=SAM

DISPLAY SAM;

SET H(IN)   Households
  /LOW_HH
   MED_HH
   HI_HH / ;

SET LH(H)   LOW INCOME Households
  /LOW_HH / ;

SET MH(H)   MED INCOME Households
  /MED_HH/ ;

SET HIH(H)  HIGH INCOME Households
  /HI_HH / ;

SET FF(F)   Production Factors
  /LAB     Employee Compensation
   CAP     Proprietary Income / ;

SET G(IN) Government units
  /SLGOVT  State&Local Govt
   FGOVT   Federal Govt / ;

SET NKK(C)  RESIDUAL COMMODITY  /MISCEL-C/ ;

SET ZKK(C)  ALL THE OTHER COMMODITIES /
PacCod-C
Pollock-C
Sablefish-C
Crab-RK-C
Crab-SC-C
Crab-OT-C
Halibut-C
Salmonetc-C
OTHERFISH-C

PR-PCOD-C
PR-POLL-C
PR-SAB-C
PR-CRK-C
PR-CSC-C
PR-COT-C
PR-HAL-C
PR-SAL-C
PR-OTH-C
AGRI-C
OIL_GAS-C
OTHERMIN-C
UTILITIES-C
CONSTR-C
OTHERMAN-C
REFINED-C
WHOLESALE-C
TRANSPORT-C
RETAIL-C
INFO-C
FIRE-C
SERVICE-C
 / ;

SET PSF(C)  PROCESSED SEAFOOD COMMODITIES /
PR-PCOD-C
PR-POLL-C
PR-SAB-C
PR-CRK-C
PR-CSC-C
PR-COT-C
PR-HAL-C
PR-SAL-C
PR-OTH-C
 / ;

ALIAS (I,J),(I,II),(C,CX),(FF,FFF),(H,HH),(G,GG),(NSC, NSC1) ;

EXECUTE_UNLOAD "%PROGPATH%AKSAM_CRAB_AGG6_RRR_CKS.GDX",SAM;
$call "GDXXRW.EXE I = %PROGPATH%AKSAM_CRAB_AGG6_RRR_CKS.GDX O = %PROGPATH%%SAMNAM%.xls PAR=SAM RNG=Base!A1:BX76 cdim=1 rdim=1 trace =3 MERGE";


* ##################### ASSIGN ECONOMIC LABELS  #######################
```

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```
PARAMETERS
MAKERNORM(I,C)    row-sum normalized make matrix
INTERMED(C,I)     interindustry transactions
LABOR(I)          sectoral employment
LABINCOME(I)      wages
CAPINCOME(I)      rents
ITAX(I)           indirect tax payments
COMOUTPUT(C)      total commodity output
COMOUTPUT2(C)     total commodity output calculated by other method
INDOUTPUT(I)      total industry output
CONSUME(C,H)      consumption
FEDDEMAND(C)      federal government purchases
SLDEMAND(C)       state-local government purchases
INVENTORY(I)      inventory investment
INVEST(C)         investment
EXPORTS(C)        exports
IMPORTS(C)        imports
TRANSFF(H,G)      GOVT TRANSFER TO HOUSEHOLDS ;

* ---------------------------------------------
INTERMED(C,I)     = SAM(C,I);
TRANSFF(H,G)      = SAM(H,G) ;
LABINCOME(I)      = SAM("LAB",I) ;
CAPINCOME(I)      = SAM("CAP",I) ;
* LABOR(I)        = EMPLOY(I);
ITAX(I)           = SAM("IBT",I);
CONSUME(C,H)      = SAM(C,H);
FEDDEMAND(C)      = SAM(C,"FGOVT");
SLDEMAND(C)       = SAM(C,"SLGOVT");
INVEST(C)         = SAM(C,"INV");
EXPORTS(C)        = SAM(C,"TRADE");
IMPORTS(C)        = SAM("TRADE",C);
COMOUTPUT(C)      = SUM(I,SAM(I,C));
INDOUTPUT(I)      = SUM(C,SAM(I,C));
MAKERNORM(I,C)    = SAM(I,C)/INDOUTPUT(I);
COMOUTPUT2(C)     = SUM(I,INDOUTPUT(I)*MAKERNORM(I,C));
CAPINCOME(I)      = INDOUTPUT(I) - SUM(C,INTERMED(C,I)) - LABINCOME(I) - ITAX(I);

* #######  CHECKING
PARAMETER CHECKI(I), CHECKC(C), CHECKI2(I), CHECKC2(C), EXPORTS1(C), EXPORTS2(C) ;

CHECKI(I)    = INDOUTPUT(I) - SUM(C,INTERMED(C,I)) - LABINCOME(I) - CAPINCOME(I) - ITAX(I);
CAPINCOME(I) = - CHECKI(I) + INDOUTPUT(I) - SUM(C,INTERMED(C,I)) - LABINCOME(I) - ITAX(I);
CHECKI2(I)   = INDOUTPUT(I) - SUM(C,INTERMED(C,I)) - LABINCOME(I) - CAPINCOME(I) - ITAX(I);
CHECKC(C)    = SUM(I,INTERMED(C,I)) + SUM(H,CONSUME(C,H)) + FEDDEMAND(C) + SLDEMAND(C) + INVEST(C) + EXPORTS(C)
            - COMOUTPUT(C) - IMPORTS(C)  ;
IMPORTS(C)   = - CHECKC(C) + SUM(I,INTERMED(C,I)) + SUM(H,CONSUME(C,H)) + FEDDEMAND(C) + SLDEMAND(C) + INVEST(C) + EXPORTS(C)
             - COMOUTPUT(C)  ;
CHECKC2(C)   = SUM(I,INTERMED(C,I)) + SUM(H,CONSUME(C,H)) + FEDDEMAND(C) + SLDEMAND(C) + INVEST(C) + EXPORTS(C)
             - COMOUTPUT(C) - IMPORTS(C)  ;
EXPORTS1(C)  = COMOUTPUT(C) + IMPORTS(C)
             - SUM(I,INTERMED(C,I)) - SUM(H,CONSUME(C,H)) - FEDDEMAND(C) - SLDEMAND(C) - INVEST(C) ;

DISPLAY
CHECKI, CHECKC, CHECKI2, CHECKC2, EXPORTS, EXPORTS1 ;

* ################### BENCHMARK PRICES AND PARAMETERS ###################
PARAMETERS
A(C,I)          technical coefficients
ALPHA(C,H)      expenditure share in household consumption
AT(C)           CET function shift parameter
AV(I)           production function coefficient
CCo(C,H)        benchmark household consumption
CSHARCHEK(H)    sum of household expenditure shares
DDo(C)          benchmark demand for domestic goods
DELTA           Armington ftn share parameter
DYHo(H)         benchmark household disposable income
Eo(C)           benchmark exports
EE(H)           enterprise income shares to household H
EDELA(C)        EXPORT DEMAND ELASTICITY
SFT             EXPORT DEMAND SHIFT PARAMETER
ELASUB(H)       elasticity of substitution in consumption of private goods
ENTSAVo         benchmark enterprise savings
ESAVRATE        enterprise savings rate
ERo             benchmark exchange rate
FEDGDo(C)       benchmark federal government purchases
FEDGDTOTo       benchmark federal government total demand
FEDGEXPo        benchmark federal government expenditure
FEDGLES(C)      federal government demand sectoral share
FEDGREVo        benchmark federal government revenue
FEDIBT          indirect business tax goes to federal gov't
FEDTDRT         ratio of total federal gov't demand to its revenue
FSRAT           ratio of fed. transfers to st.  gov't to fed. gov't exp.
GAMMA(C)        CET function share parameter
GRPo            benchmark nominal gross regional product
HHTRT(H)        HOUSEHOLD TRANSFERS PAYMENTS RECEIVED FROM GOVT
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HHTRFED(H) household federal income tax rate
HHTRST(H) household state income tax rate
IDDo(C) benchmark private investment by sector of origin
ITOTo benchmark total investment
ITAXR(I) indirect tax rate
ITAXF(I) indirect tax payment to federal govt by sector i
ITAXS(I) indirect tax payment to state govt by sector i
Ko(I) benchmark sectoral capital demand
KSHR(I) base-year share of investment by sector of destination
KTOTo benchmark regional capital stock
KTRFED capital tax rate: for federal government
KTRST capital tax rate: for state government
LAB_SLG_RATE RATIO OF LAB INCOME GOING TO STATE AND LOCAL GOVT
LAB_INV_RATE RATIO OF LAB INCOME GOING TO INV ACCOUNT
Lo(I) benchmark sectoral labor demand
LL(H) labor income shares to household H
LLL(H) LABOR SHARES
LPR labor force participation rate
POPG(H) POPULATION GROWTH RATE
LSo(H) benchmark household labor supply
LSHARE(I) production function labor share coefficient
LSTKo initial labor supply stock
LTOTo benchmark regional labor demand
Mo(C) benchmark imports
MPS(H) household rate of saving out of disposable income
NDo(C,I) benchmark intermediate demand
NFINo NET FINANCIAL INFLOW
PDo(C) benchmark price of domestic sales goods
PEo(C) benchmark domestic price of exports
PKo(I) benchmark price of capital goods by sector of destination
PMo(C) benchmark domestic price of imports
PQo(C) benchmark composite price index
PSHARCHEK(I) sum of production cost shares
PVo(I) benchmark domestic value-added prices
PWEo(C) world price of exports
PWM(C) world price of imports
PXo(I) benchmark industry output price index
PZo(C) benchmark commodity output price index
Qo(C) benchmark composite commodity
Ro benchmark rental rate
RGRPo benchmark real gross regional product
RHOC(C) Armington ftn exponent
RHOT(C) CET function exponent
RLEAKR rate of leakage of capital income
REMH(H) REMITTANCES FROM REST OF WORLD
ROW_INV AMOUNT THAT BALANCE SAVINGS AND INVESTMENT ACCOUNT (INV COLUMN & REST OF WORLD ROW)
INV_ROW ANOTHER BALANCING VARIABLE: REST OF WORLD COLUMN INV ROW
SFo benchmark foreign savings
SGFEDo benchmark federal government savings
SGSTo benchmark state government savings
SHo(H) benchmark household savings
STGDo(C) benchmark state government purchases
STGDTOTo benchmark state government total purchases
STGEXPo benchmark state government expenditure
STGLES(C) state government demand sectoral share
STGREVo benchmark state government revenue
STIBT indirect business tax shares goes to state gov't
SSTR social security tax rate
STOTo benchmark total savings
TAU(C) Armington ftn shift parameter:import for domestic in consumption demand
TRAFEDHH(H) federal government transfer to households
TRAFEDSTo federal government transfer to state government
TRASTHH(H) state government transfer to households
TYHo(H) TOTAL HOUSEHOLD INCOME KK
UR unemployment rate
Wo(I) benchmark sectoral wage rate: after distoration adjustment
WLEAKR rate of leakage of labor income
Xo(I) benchmark industry output
YHo(H) benchmark household factor income
YKo benchmark GROSS capital income
YLo benchmark GROSS labor income
YLLo LABOR INCOME AFTER LEAKAGE ETC
YKKo CAPITAL INCOME AFTER LEAKAGE ETC
ZZo(C) benchmark commodity output
STGTRNS INTRA-SL GOVT TRANSFER
STGINV NEGATIVE SAVINGS OF SL GOVT
STGROW INFLOW OF FUNDS FROM ROW TO SL GOVT
STGLEAK LEAKAGE FROM ST GOVT
FEDINV NEGATIVE SAVINGS OF FED GOVT
FEDSELF INTRA-FED GOVT TRANSFER
FEDROW INFLOW OF FUNDS FROM ROW TO FED
FEDLEAK LEAKAGE OF FED GOVT
DEPR(I) DEPRECIATION RATE
DEPRNo DEPRECIATION
LMIGo LABOR MIGRATION
LME labor migration elasticity

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WAVGo         benchmark average wage rate
WDIST(I)      wage rate distribution parameter
WROW          wage rate: outside of region
DCNT          DISCOUNT RATE ;

* ######### ASSIGN SHORT LABELS
DCNT     = 0.03 ;
EDELA(C)  = 3.0 ;
SFT      = 1 ;
Xo(I)    = INDOUTPUT(I);
PZo(C)   = 1 ;
PXo(I)   = 1;
ZZo(C)   = SUM(I,MAKERNORM(I,C)*Xo(I));

PARAMETER
FPRATIO, RSRENTo, LABINCOME1, CAPINCOME1, RNTL, RNTK, RENTDISL, RENTDISK,
RSRENT_L, RSRENT_K, RAT33o, RAT55o, RAT22o, PREMo ;

FPRATIO(FSRKC) = 0.75 ;
FPRATIO(FSNRK) = 0.50 ;
FPRATIO(NFS)   = 0    ;
RSRENTo(I)     = FPRATIO(I)*PXo(I)*Xo(I) ;
RSRENT_L(I)    = RSRENTo(I)*LABINCOME(I)/(LABINCOME(I)+CAPINCOME(I)) ;
RSRENT_K(I)    = RSRENTo(I)*CAPINCOME(I)/(LABINCOME(I)+CAPINCOME(I)) ;
LABINCOME1(I)  = LABINCOME(I) - RSRENT_L(I) ;
CAPINCOME1(I)  = CAPINCOME(I) - RSRENT_K(I) ;
RAT22o(I)      = RSRENTo(I) / (LABINCOME1(I) + CAPINCOME1(I))  ;
PREMo(I)       = 1+RAT22o(I) ;
RNTL(I)        = LABINCOME(I) / ( LABINCOME(I) + CAPINCOME(I) ) ;
RNTK(I)        = 1 - RNTL(I) ;
RENTDISL(I)    = LABINCOME1(I) / ( LABINCOME1(I) + CAPINCOME1(I) ) ;
RENTDISK(I)    = 1 - RENTDISL(I) ;

Lo(I)        = LABINCOME1(I);
NDo(C,I)     = INTERMED(C,I);
CCo(C,H)     = CONSUME(C,H) ;
IDDo(C)      = INVEST(C);
Eo(C)        = EXPORTS(C);
Mo(C)        = IMPORTS(C);
FEDGDo(C)    = FEDDEMAND(C);
STGDo(C)     = SLDEMAND(C);

* ######### GOVERNMENT EXPENDITURE AND REVENUE
FEDIBT       = SAM("FGOVT","IBT") / SUM(G,SAM(G,"IBT")) ;
STIBT        = SAM("SLGOVT","IBT")/ SUM(G,SAM(G,"IBT")) ;

* ######### CALCULATING TECH. COEFFCIENTs AND INDIRECT TAX RATES
A(C,I)       = INTERMED(C,I) / Xo(I);
ITAXR(I)     = ITAX(I) / Xo(I);

* ######### BENCHMARK PRICES
PZo(C)       = 1.0;
PDo(C)       = 1.0;
PQo(C)       = 1.0;
PMo(C)       = 1.0;
PEo(C)       = 1.0;
PKo(I)       = 1.0;
ERo          = 1.0;
PVo(I)       = PXo(I) * (1 - ITAXR(I) - SUM(C,A(C,I)*PQo(C) ) );
PWM(C)       = PMo(C) / ERo;
PWEo(C)      = PEo(C) / ERo;

* ##########  FACTORS OF PRODUCTION AND FACTOR SHARE
LTOTo        = SUM(I,Lo(I));
Wo(I)        = LABINCOME1(I)/Lo(I);
Ro           = 1.0;
LME          = 0.137 ;
* LME of  0.137 is from Plaut (1981)

PARAMETER
KME, KMIGo ;

KME = 0.137 ;

WAVGo        = SUM(I,LABINCOME1(I))/SUM(I,Lo(I));
WROW         = WAVGo;
WDIST(I)     = Wo(I)/WAVGo ;
LPR          = 0.65 ;
POPG(H)      = 0.0097 ;

SET CRB(FS)   Crab harvesting industries /
Crab-RK-A
Crab-SC-A
Crab-OT-A
/;
```

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```
SET NCB(FS) Non-CRAB harvesting industries /
PacCod-A
Pollock-A
Sablefish-A
Halibut-A
Salmonetc-A
OTHERFISH-A
/;

PARAMETER
KTOT1o, KTOT2o, KTOT3o, QSLR1, QSLR2, QSLR3 ;

Ko(I)       = CAPINCOME1(I)/Ro;
KTOTo       = SUM(I,Ko(I));
KTOT1o      = SUM(FS,Ko(FS));
KTOT2o      = SUM(PRC,Ko(PRC));
KTOT3o      = SUM(NSEA,Ko(NSEA));
QSLR1(I)    = RSRENTo(I)/(PXo(I)*Xo(I)) ;
QSLR2(I)    = RAT22o(I)*( Wo(I)*Lo(I) + Ro*Ko(I) ) / (PXo(I)*Xo(I)) ;

* ######### USE OF CES TECHNOLOGY
PARAMETER       ELAS_PDN(I)   elasticity of sub in CES production function
/
PacCod-A      0.61
Pollock-A     0.61
Sablefish-A   0.61
Crab-RK-A     0.61
Crab-SC-A     0.61
Crab-OT-A     0.61
Halibut-A     0.61
Salmonetc-A   0.61
OTHERFISH-A   0.61
PR-PCOD-A     0.79
PR-POLL-A     0.79
PR-SAB-A      0.79
PR-CRK-A      0.79
PR-CSC-A      0.79
PR-COT-A      0.79
PR-HAL-A      0.79
PR-SAL-A      0.79
PR-OTH-A      0.79
AGRI-A        0.61
OIL_GAS-A     0.8
OTHERMIN-A    0.8
UTILITIES-A   0.8
CONSTR-A      0.8
OTHERMAN-A    0.8
REFINED-A     0.8
WHOLESALE-A   0.8
TRANSPORT-A   0.8
RETAIL-A      0.8
INFO-A        0.8
FIRE-A        0.8
SERVICE-A     0.8
MISCEL-A      0.8 / ;

PARAMETER
RHO_PDN(I)    exponent para in CES prod function
BETA_PDN(I)   share parameter for captial in CES
OMEGA_PDN(I)  shift para in CES
UNITCOSTo(I)  UNIT COST FUNCTION IN CES
K_DEM(I)      CAPITAL DEMAND IN BASE YEAR
L_DEM(I)      LABOR DEMAND IN BASE YEAR  ;

RHO_PDN(I)   = (ELAS_PDN(I) - 1)/ELAS_PDN(I) ;
BETA_PDN(I)  = (Ro*Ko(I)**(1/ELAS_PDN(I)))/(Ro*Ko(I)**(1/ELAS_PDN(I)) + Wo(I)*Lo(I)**(1/ELAS_PDN(I))) ;
OMEGA_PDN(I) = Xo(I)*(BETA_PDN(I)*Ko(I)**RHO_PDN(I)+(1-BETA_PDN(I))*Lo(I)**RHO_PDN(I))**(-1/RHO_PDN(I)) ;
UNITCOSTo(I) = (1/OMEGA_PDN(I))*(  (BETA_PDN(I)**ELAS_PDN(I))*(Ro**(1-ELAS_PDN(I)))+
             ((1-BETA_PDN(I))**ELAS_PDN(I))*(Wo(I)**(1-ELAS_PDN(I))))**(1/(1-ELAS_PDN(I))) ;
K_DEM(I)     = (Xo(I)/OMEGA_PDN(I))*(BETA_PDN(I)*OMEGA_PDN(I)*UNITCOSTo(I)/Ro)**ELAS_PDN(I) ;
L_DEM(I)     = (Xo(I)/OMEGA_PDN(I))*((1-BETA_PDN(I))*OMEGA_PDN(I)*UNITCOSTo(I)/Wo(I))**ELAS_PDN(I) ;

* ######### REGIONALLY PRODUCED OR IMPORTED GOODS
* Eo is re-calculated to balance the commodity account
Eo(C)      = ZZo(C) + Mo(C)  - SUM(I,NDo(C,I)) - SUM(H,CCo(C,H)) - STGDo(C) - FEDGDo(C) - IDDo(C) ;
DDo(C)     = ZZo(C) - Eo(C);
Qo(C)      = DDo(C) + Mo(C)   ;

DISPLAY
EXPORTS, EXPORTS1, Eo ;

*######### TRADE ELASTICITIES AND CALIBRATE CET AND ARMINGTON FUNCTION
parameter    ELAS_TR(C)   ELASTICITY OF SUB IN CET TRANSFORMATION FUNCTION
/
PacCod-C      3.9
Pollock-C     3.9
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Sablefish-C    3.9
Crab-RK-C      3.9
Crab-SC-C      3.9
Crab-OT-C      3.9
Halibut-C      3.9
Salmonetc-C    3.9
OTHERFISH-C    3.9
PR-PCOD-C      2.9
PR-POLL-C      2.9
PR-SAB-C       2.9
PR-CRK-C       2.9
PR-CSC-C       2.9
PR-COT-C       2.9
PR-HAL-C       2.9
PR-SAL-C       2.9
PR-OTH-C       2.9
AGRI-C         3.9
OIL_GAS-C      2.9
OTHERMIN-C     2.9
UTILITIES-C    0.7
CONSTR-C       2.9
OTHERMAN-C     2.9
REFINED-C      2.9
WHOLESALE-C    0.7
TRANSPORT-C    0.7
RETAIL-C       0.7
INFO-C         0.7
FIRE-C         0.7
SERVICE-C      0.7
MISCEL-C       0.7/;

parameter    ELAS_AR(C)   ELASTICITY OF SUB IN CES ARMINGTON FUNCTION
/
PacCod-C       1.42
Pollock-C      1.42
Sablefish-C    1.42
Crab-RK-C      1.42
Crab-SC-C      1.42
Crab-OT-C      1.42
Halibut-C      1.42
Salmonetc-C    1.42
OTHERFISH-C    1.42
PR-PCOD-C      0.31
PR-POLL-C      0.31
PR-SAB-C       0.31
PR-CRK-C       0.31
PR-CSC-C       0.31
PR-COT-C       0.31
PR-HAL-C       0.31
PR-SAL-C       0.31
PR-OTH-C       0.31
AGRI-C         1.42
OIL_GAS-C      2.36
OTHERMIN-C     0.5
UTILITIES-C    2
CONSTR-C       3.15
OTHERMAN-C     3.55
REFINED-C      2.36
WHOLESALE-C    2
TRANSPORT-C    2
RETAIL-C       2
INFO-C         2
FIRE-C         2
SERVICE-C      2
MISCEL-C       2/ ;

RHOT(C)    = 1+(1/ELAS_TR(C));
GAMMA(C)   = 1/(1+PDo(C)/PEo(C)*(Eo(C)/DDo(C))**(RHOT(C)-1));
AT(C)      = ZZo(C)/(GAMMA(C)*Eo(C)**RHOT(C)+(1-GAMMA(C))*DDo(C)**RHOT(C))**(1/RHOT(C));
RHOC(C)    = -1+(1/ELAS_AR(C));
DELTA(C)   = (PMo(C)/PDo(C))*(Mo(C)/DDo(C))**(1+RHOC(C));
DELTA(C)   = DELTA(C)/(1+DELTA(C));

** Note: This two-step calibration is eqiuvalent to the following one-step method:
** DELTA(C) = (Mo(C)  **(1+RHOC(C )))*PMo(C )/(Mo(C  )**(1+RHOC(C ))*PMo(C)  + DDo(C )**(1+RHOC(C ))*PDo(C));

TAU(C)     = Qo(C)/(DELTA(C)*Mo(C)**(-RHOC(C))+(1-DELTA(C))*DDo(C)**(-RHOC(C)))**(-1/RHOC(C));

* ######### INCOME AND SAVINGS
YKo = SUM(I,PREMo(I)*Ro*Ko(I))    ;
YLo = SUM(I,PREMo(I)*Wo(I)*Lo(I))     ;

WLEAKR      = SAM("TRADE","LAB") / SUM(I,LABINCOME(I)) ;
SSTR        = SAM("FGOVT","LAB") / SUM(I,LABINCOME(I)) ;
LAB_SLG_RATE = SAM("SLGOVT","LAB")/ SUM(I,LABINCOME(I)) ;
LAB_INV_RATE = SAM("INV","LAB")   / SUM(I,LABINCOME(I)) ;
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* LAB_INV_RATE denotes payment from LAB account to INV account in the SAM
YLLo        = (1 - WLEAKR - SSTR - LAB_SLG_RATE - LAB_INV_RATE) * YLo ;
RLEAKR      = SAM("TRADE","CAP")  / SUM(I,CAPINCOME(I)) ;
KTRFED      = SAM("FGOVT","CAP")  / SUM(I,CAPINCOME(I)) ;
KTRST       = SAM("SLGOVT","CAP") / SUM(I,CAPINCOME(I)) ;
ESAVRATE    = SAM("INV","CAP") /   SUM(I,CAPINCOME(I)) ;
ENTSAVo     = ESAVRATE * YKo ;
YKKo        = (1 - RLEAKR - KTRFED - KTRST - ESAVRATE) * YKo ;
DEPR(I)     = 0 ;
DEPRNo      = SUM(I,DEPR(I)*PKo(I)*Ko(I)) ;
LL(H)       = SAM(H,"LAB") / SUM(HH,SAM(HH,"LAB") )  ;
EE(H)       = SAM(H,"CAP") / SUM(HH,SAM(HH,"CAP") )  ;
YHo(H)      = LL(H)*YLLo + EE(H)*YKKo ;
HHTRT(H)    = SUM(G,TRANSFF(H,G) ) ;
TRAFEDHH(H)  = TRANSFF(H,"FGOVT") ;
TRASTHH(H)   = TRANSFF(H,"SLGOVT") ;
REMH(H)     = SAM(H,"TRADE") ;
* TYHo(H)     =  YHo(H) +  TRASTHH(H) + TRAFEDHH(H) ;
TYHo(H)     =  YHo(H) +  TRASTHH(H) + TRAFEDHH(H) + REMH(H) ;
HHTRFED(H)   = SAM("FGOVT",H) / TYHo(H);
HHTRST(H)    = SAM("SLGOVT",H) / TYHo(H);
MPS(H)      = SAM("INV",H) / TYHo(H);
DYHo(H)     = TYHo(H) * (1 - HHTRFED(H) - HHTRST(H) - MPS(H) )  ;
SHo(H)      = MPS(H)*TYHo(H) ;

* In the AK CGE, DYH is the same as HEXP in previous CGE models

* ######## LABOR IMMIGRATION AND SUPPLY
UR      = 0.05 ;
LLL(H)   = 1/3 ;
LSo(H)   = LLL(H)*(LTOTo/(1-UR));
LSTKo    = SUM(H,LSo(H));
LMIGo    = LSTKo*((WAVGo/WROW)**LME-1);

PARAMETER
POPo, POPB ;

POPo(H)     = LSo(H)/LPR ;
POPB(H)     = POPo(H) ;

* #########  CONSUMER DEMAND COEFFICIENT
* The following ELASUB's are based upon Shoven and Whalley (1984, p. 1011)
* J. of Economic Literature Vol. 12, Sept. 1984 pp. 1007-1051
* Because the authors (Shoven and Whalley) do not report the elasticity
* for medium income household, we use the intermediate value
* i.e., elas for med class = (1.5+0.75)/2 = 1.125

PARAMETER   ELASUB(H)   ELAS OF SUB IN CONSUMPTION
/LOW_HH    0.75
 MED_HH    1.125
 HI_HH     1.5 / ;

ALPHA(C,H)          = (PQo(C)*CCo(C,H))/DYHo(H);
ALPHA("MISCEL-C",H)  = 1-SUM(ZKK,ALPHA(ZKK,H)) ;

TRAFEDSTo    = SAM("SLGOVT","FGOVT") ;
STGDTOTo     = SUM(C,STGDo(C));
STGLES(C)    = STGDo(C)/STGDTOTo;
STGTRNS      = SAM("SLGOVT","SLGOVT") ;
STGINV       = SAM("SLGOVT","INV") ;
STGROW       = SAM("SLGOVT","TRADE") ;
STGREVo      = KTRST*YKo + LAB_SLG_RATE*YLo + STIBT*(SUM(I,ITAXR(I)*PXo(I)*Xo(I)))
              + SUM(H,HHTRST(H)*TYHo(H)) + STGTRNS + TRAFEDSTo  + STGINV + STGROW ;
SGSTo        = SAM("INV","SLGOVT") ;
STGLEAK      = SAM("TRADE","SLGOVT") ;
STGEXPo      = SUM(C,PQo(C)*STGDo(C)) + SUM(H,TRASTHH(H)) + STGTRNS + STGLEAK ;
FEDGDTOTo    = SUM(C,FEDGDo(C));
FEDGLES(C)   = FEDGDo(C)/FEDGDTOTo;
FEDINV       = SAM("FGOVT","INV") ;
FEDSELF      = SAM("FGOVT","FGOVT") ;
FEDROW       = SAM("FGOVT","TRADE") ;
FEDGREVo     = SSTR*YLo + KTRFED*YKo + FEDIBT*SUM(I,ITAXR(I)*PXo(I)*Xo(I)) + SUM(H,HHTRFED(H)*TYHo(H)) + FEDINV + FEDSELF + FEDROW ;
SGFEDo       = SAM("INV","FGOVT") ;
FEDLEAK      = SAM("TRADE","FGOVT") ;

FEDGEXPo     = SUM(C,PQo(C)*FEDGDo(C)) + SUM(H,TRAFEDHH(H)) + TRAFEDSTo  + FEDSELF + FEDLEAK ;
SGSTo        = STGREVo  - STGEXPo;
SGFEDo       = FEDGREVo - FEDGEXPo;
FSRAT        = TRAFEDSTo / FEDGREVo ;

* ######### TOTAL SAVINGS AND INVESTMENT
ROW_INV       = SAM("TRADE","INV") ;
INV_ROW       = SAM("INV","TRADE") ;
ITOTo         = SUM(C,IDDo(C));
NFINo         = LAB_INV_RATE*YLo + ESAVRATE*YKo + SUM(H,SHo(H)) + SGSTo + SGFEDo + INV_ROW
               - ITOTo - STGINV - FEDINV ;
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SFo          = SUM(C,Mo(C)) + WLEAKR*YLo + RLEAKR*YKo + STGLEAK + FEDLEAK + NFINo
             - SUM(C,Eo(C)) -SUM(H,REMH(H)) - STGROW - FEDROW  ;
STOTo          =  LAB_INV_RATE*YLo + ESAVRATE*YKo + SUM(H,SHo(H)) + SGSTo + SGFEDo + ERo*SFo
             - STGINV - FEDINV - NFINo ;

PARAMETER
C1, C2, DSTRATE, DEPR, GRCAP, GRCAP3, NIo, RIo, DSTTo, DSTo, TOTINV,
DSTSUM, TOTTOT, DKo, IDo, NISAVo, NISAVRAT, IDo, INVRAT, TOTID,
DKKK, KSHR_N, TOT1, TOT2, ABC ;

DEPR(I)     = 0 ;
GRCAP(SEA)  = 0 ;
GRCAP(NSEA) = 0.014 ;
GRCAP3      = 0.014 ;
RIo(I)      = DEPR(I)*Ko(I) ;
NIo(I)      = GRCAP(I)*Ko(I) ;
TOTINV      = SUM(I, NIo(I) +RIo(I) ) ;
DSTSUM      = STOTo - TOTINV ;
INVRAT(C)   = INVEST(C) / SUM(CX,INVEST(CX)) ;
IDo(C)     = INVRAT(C)*TOTINV ;
DSTTo(C)   = INVEST(C) - IDo(C) ;
DSTRATE(C) = DSTTo(C)/ZZo(C) ;
DSTo(NSC)  = DSTRATE(NSC)*ZZo(NSC) ;
DSTo(NNSC) = 0 ;
TOTTOT     = SUM(I, NIo(I) +RIo(I)) + SUM(C,DSTo(C)) ;
DKo(I)     = NIo(I) + RIo(I) ;
IDo(C)     = INVEST(C) - DSTo(C) ;
KSHR(I)    = Xo(I) / SUM(J,Xo(J));
KSHR_N(I)  = DKo(I)/   (ITOTo-SUM(C,DSTo(C))) ;
DKKK(I)    = KSHR_N(I)*(ITOTo-SUM(C,DSTo(C)*PZo(C))) / PKo(I);
TOT1       = SUM(C,IDo(C)) ;
TOT2       = SUM(I,DKo(I)) ;
ABC        = DSTSUM+TOTINV ;

* ######## ADJUSTMENT OF CAPITAL COMPOSITION MATRIX
SET
RAS row-and-column sum elements /1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,
                          17,18,19,20,21,22,23,24,25,26,27,28,29,30,
                          31,32,33,34,35,36,37,38,39,40,41,42,43,44,
                          45,46,47,48,49,50/;

PARAMETER
IMAT ;

IMAT(RAS,NSC,I) = 1/13  ;

PARAMETER HOLD1(RAS,NSC)
PARAMETER HOLD2(RAS,I)
PARAMETER TEMP(RAS,NSC,I)
PARAMETER B(NSC,I) adjusted IMAT

LOOP(RAS,
B(NSC,I)          = IMAT(RAS,NSC,I);
HOLD1(RAS,NSC)    = SUM(I,IMAT(RAS,NSC,I)*DKo(I));
TEMP(RAS,NSC,I)   = IMAT(RAS,NSC,I)*IDo(NSC)/HOLD1(RAS,NSC);
HOLD2(RAS,I)    = SUM(NSC,TEMP(RAS,NSC,I));
IMAT(RAS+1,NSC,I) = TEMP(RAS,NSC,I)/HOLD2(RAS,I) );

PARAMETER DIFFCOL(NSC)
PARAMETER DIFFROW(I);

DIFFCOL(NSC)  = SUM(I,B(NSC,I)*DKo(I))-IDo(NSC);
DIFFROW(I)  = SUM(NSC,B(NSC,I))-1;
DISPLAY DIFFCOL,DIFFROW;

PARAMETER
BBB, BSUM, RATIO1, RATIO2, NIo, PARA5 ;

BBB(NSC)= SUM(I, B(NSC,I)) /32 ;
BSUM(I) = SUM(NSC,B(NSC,I)) ;
NIo(I)  = DKo(I) - RIo(I) ;
RATIO1(I) = NIo(I)/Ko(I) ;
RATIO2(I) = DKo(I) / Xo(I) ;
PARA5     = SUM(I, NIo(I) + RIo(I)) ;

* ######## GROSS REGIONAL PRODUCT
GRPo    = SUM(I,PVo(I)*Xo(I) + ITAXR(I)*PXo(I)*Xo(I));
RGRPo   = SUM(C,SUM(H,CCo(C,H))+IDo(C)+DSTo(C)+ STGDo(C)+FEDGDo(C)+Eo(C)-Mo(C));

* ######## VERIFY THAT PRODUCTION AND CONSUMPTION SHARES SUM TO ONE
PSHARCHEK(I)   = SUM(C,A(C,I)) + PVo(I) + ITAXR(I) ;
CSHARCHEK(H)   = SUM(C,ALPHA(C,H)) ;

*###############################################################
VARIABLES
*###############################################################
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CC(C,H)       household consumption
DD(C)         domestic goods
DYH(H)        household disposal income
E(C)          exports
ENTSAV        enterprise savings
ER            exchange rate
FEDGD(C)      federal gov't demand
FEDGDTOT      federal gov't total demand
FEDGEXP       federal gov't expenditure
FEDGREV       federal gov't revenue
GRP           gross regional product at market prices
ID(C)         volume of investment by sector of origin
ITOT          total investment
KI(I)         capital in sector I
TDK           TOTAL DKKK
KTOT1         total capital stock in the economy 1
KTOT2         total capital stock in the economy 2
KTOT3         total capital stock in the economy 3
KMIG1         CAP MIGR 1
KMIG2         CAP MIGR 2
L(I)          employment in sector I
LS(H)         household labor supply
LSTK          total labor supply in base year
LTOT          total regional employment
M(C)          imports
ND(C,I)       intermediate demand
NFIN          NET FINANCIAL INFLOW
PD(C)         price of domestic sales goods
PE(C)         domestic price of exports
PWE(C)        WORLD PRICE OF EXPORTS
PM(C)         domestic price of imports
PQ(C)         composite price index
PV(I)         domestic value-added prices
PX(I)         price of domestic industry output
PZ(C)         price of domestic commodity output
PREM(I)       FACTOR PRICE PREMIUM
RRP(I)        RESOURCE RENT PARAMETER
POP(H)        POPULATION
Q(C)          composite commodity
QSLR(I)       QUOTA SHARE LEASE RATE
R1            rental price of capital 1
R2            rental price of capital 2
R3            rental price of capital 3
RAT22(I)      RATIO
RSRENT(I)     RESROUCE RENT
RGRP          real gross regional product
SF            foreign savings
SGFED         federal government savings
SGST          state government savings
SH(H)         household savings
STGD(C)       state gov't demand
STGDTOT       state gov't total demand
STGEXP        state gov't expenditure
STGREV        state gov't revenue
STOT          total savings available for regional investment
TRAFEDST      transfer from federal gov't to state gov't
W             wage rate
X(I)          industry output
YH(H)         household factor income
YK            capital income
YL            labor income
ZZ(C)         commodity output
TYH(H)        TOTAL HOUSEHOLD INCOME
YLL           LABOR INCOME AFTER LEAKAGE ETC
YKK           CAPIAL INCOME AFTER LEAKAGE
UNITCOST(I)   UNIT COST FUNCTION
LMIG          LAB MIGRATION
WAVG          benchmark average wage rate
NI(I)         NET INVESTMENT
DST(C)        DSTT VARIABLE
DK(I)         DKK  VARIABLE
DEPRN         DEPRNN VARIABLE
RI(I)         REPLACEMENT INVESTMENT
PK(I)         PRICE OF CAPITAL
TIME          TIME VAR
EXFN(H)       per capita expenditure
EXPD(H)       per capita discounted expenditure
UTIL(H)       UTILITY ;

* #################### VARIABLE INITIALIZATION #####################

TIME.L = 0 ;

* USE INITIAL VALUES OF VARIABLES
PK.L(I)     = 1 ;
ER.L        = ERo;
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PZ.L(C)      = PZo(C);
PD.L(C)      = PDo(C);
PQ.L(C)      = PQo(C);
PE.L(C)      = PEo(C);
PM.L(C)      = PMo(C);
PWE.L(C)     = PWEo(C) ;

R1.L    = 1 ;
R2.L    = 1 ;
R3.L    = 1 ;

X.L(I)       = Xo(I);
E.L(C)       = Eo(C);

TRAFEDST.L   = TRAFEDSTo;
STGDTOT.L    = STGDTOTo;
FEDGDTOT.L   = FEDGDTOTo;

* COMPUTE INITIAL VALUES FOR OTHER VARIABLES
* PRICES
ZZ.L(C)   = ZZo(C) ;
PX.L(I)   = PXo(I) ;
*PX.L(I)  = SUM(C,MAKERNORM(I,C)*PZ.L(C));
PV.L(I)   = PX.L(I)*(1-ITAXR(I)) - SUM(C,A(C,I)*PQ.L(C));
W.L       = 1 ;

UNITCOST.L(FS)   = (1/OMEGA_PDN(FS))*((BETA_PDN(FS)**ELAS_PDN(FS))*(R1.L**(1-ELAS_PDN(FS)))+
               ((1-BETA_PDN(FS))**ELAS_PDN(FS))*(W.L**(1-ELAS_PDN(FS))))**(1/(1-ELAS_PDN(FS))) ;

UNITCOST.L(PRC)   = (1/OMEGA_PDN(PRC))*((BETA_PDN(PRC)**ELAS_PDN(PRC))*(R2.L**(1-ELAS_PDN(PRC)))+
               ((1-BETA_PDN(PRC))**ELAS_PDN(PRC))*(W.L**(1-ELAS_PDN(PRC))))**(1/(1-ELAS_PDN(PRC))) ;

UNITCOST.L(NSEA)   = (1/OMEGA_PDN(NSEA))*((BETA_PDN(NSEA)**ELAS_PDN(NSEA))*(R3.L**(1-ELAS_PDN(NSEA)))+
               ((1-BETA_PDN(NSEA))**ELAS_PDN(NSEA))*(W.L**(1-ELAS_PDN(NSEA))))**(1/(1-ELAS_PDN(NSEA))) ;

KI.L(FS)        = (X.L(FS)/OMEGA_PDN(FS))*(BETA_PDN(FS)*OMEGA_PDN(FS)*UNITCOST.L(FS)/R1.L)**ELAS_PDN(FS) ;
KI.L(PRC)       = (X.L(PRC)/OMEGA_PDN(PRC))*(BETA_PDN(PRC)*OMEGA_PDN(PRC)*UNITCOST.L(PRC)/R2.L)**ELAS_PDN(PRC) ;
KI.L(NSEA)      = (X.L(NSEA)/OMEGA_PDN(NSEA))*(BETA_PDN(NSEA)*OMEGA_PDN(NSEA)*UNITCOST.L(NSEA)/R3.L)**ELAS_PDN(NSEA) ;

L.L(FS)         = (X.L(FS)/OMEGA_PDN(FS))*((1-BETA_PDN(FS))*OMEGA_PDN(FS)*UNITCOST.L(FS)/W.L)**ELAS_PDN(FS) ;
L.L(PRC)        = (X.L(PRC)/OMEGA_PDN(PRC))*((1-BETA_PDN(PRC))*OMEGA_PDN(PRC)*UNITCOST.L(PRC)/W.L)**ELAS_PDN(PRC) ;
L.L(NSEA)       = (X.L(NSEA)/OMEGA_PDN(NSEA))*((1-BETA_PDN(NSEA))*OMEGA_PDN(NSEA)*UNITCOST.L(NSEA)/W.L)**ELAS_PDN(NSEA) ;

* INPUTS DEMAND AND PRODUCTION
ZZ.L(C)   = SUM(I,MAKERNORM(I,C)*X.L(I));
KI.L(I)   = Ko(I) ;
TDK.L     = SUM(I,DKo(I)) ;
LTOT.L    = SUM(I,L.L(I));
KTOT1.L   = SUM(FS,KI.L(FS));
KTOT2.L   = SUM(PRC,KI.L(PRC));
KTOT3.L   = SUM(NSEA,KI.L(NSEA));
DD.L(C)   = ZZ.L(C) - E.L(C);
ND.L(C,I) = A(C,I)*X.L(I);

* LABOR SUPPLY
LS.L(H)  = LSo(H) ;
LSTK.L   = SUM(H,LS.L(H));
WAVG.L   = WAVGo ;
LMIG.L   = LSTK.L*((WAVG.L/WROW)**LME-1);
POP.L(H) = LS.L(H)/LPR ;
KMIG1.L  = KTOT1.L*((R1.L/1)**KME-1);
KMIG2.L  = KTOT2.L*((R2.L/1)**KME-1);

* INCOME BLOCK
RAT22.L(I) = RAT22o(I) ;
PREM.L(I)  = 1+ RAT22.L(I)   ;
RRP.L(I)   = 0 ;

RSRENT.L(FS)    = RAT22.L(FS)*   (W.L*L.L(FS)   + R1.L*KI.L(FS))  ;
RSRENT.L(PRC)   = RAT22.L(PRC)*  (W.L*L.L(PRC)  + R2.L*KI.L(PRC))  ;
RSRENT.L(NSEA)  = RAT22.L(NSEA)* (W.L*L.L(NSEA) + R3.L*KI.L(NSEA))  ;

QSLR.L(I) = RSRENT.L(I)/(PX.L(I)*X.L(I)) ;
YL.L      = SUM(I,PREM.L(I)*W.L*L.L(I))  ;
YK.L      = SUM(FS,PREM.L(FS)*R1.L*KI.L(FS)) + SUM(PRC,PREM.L(PRC)*R2.L*KI.L(PRC)) + SUM(NSEA,PREM.L(NSEA)*R3.L*KI.L(NSEA))  ;

ENTSAV.L    = ESAVRATE*YK.L ;
YLL.L       = (1 - WLEAKR - SSTR - LAB_SLG_RATE - LAB_INV_RATE) * YL.L ;
YKK.L       = (1 - RLEAKR - KTRFED - KTRST - ESAVRATE) * YK.L ;
YH.L(H)     = LL(H)*YLL.L + EE(H)*YKK.L ;
TYH.L(H)    = YH.L(H) +  TRAFEDHH(H) + TRASTHH(H) + REMH(H) ;
DYH.L(H)    = TYH.L(H)*(1 - HHTRFED(H) - HHTRST(H) - MPS(H) ) ;

* SAVINGS AND COMMODITY DEMAND
SH.L(H)      = MPS(H) * TYH.L(H) ;
CC.L(C,H)    = ALPHA(C,H)*DYH.L(H)/((PQ.L(C)**ELASUB(H))*SUM(CX,ALPHA(CX,H)*
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         PQ.L(CX)**(1-ELASUB(H)))) ;

* GOVERNMENT BLOCK
STGREV.L    = KTRST*YK.L + LAB_SLG_RATE*YL.L + STIBT*(SUM(I,ITAXR(I)*PX.L(I)*X.L(I)))
         + SUM(H,HHTRST(H)*TYH.L(H)) + STGTRNS + TRAFEDSTo  + STGINV + STGROW ;
STGD.L(C)   = STGLES(C)*STGDTOT.L/PQ.L(C);
STGEXP.L    = SUM(C,PQ.L(C)*STGD.L(C)) + SUM(H,TRASTHH(H)) + STGTRNS + STGLEAK ;
FEDGREV.L   = SSTR*YL.L + KTRFED*YK.L + FEDIBT*SUM(I,ITAXR(I)*PX.L(I)*X.L(I)) + SUM(H,HHTRFED(H)*TYH.L(H))
         + FEDINV + FEDSELF + FEDROW ;
FEDGD.L(C)  = FEDGLES(C)*FEDGDTOT.L/PQ.L(C);
FEDGEXP.L   = SUM(C,PQ.L(C)*FEDGD.L(C)) + SUM(H,TRAFEDHH(H)) + TRAFEDST.L  + FEDSELF + FEDLEAK ;
TRAFEDST.L  = FSRAT*FEDGREV.L ;

* SAVING AND INVESTMENT
M.L(C)      = Mo(C);
Q.L(C)      = (PD.L(C)*DD.L(C) + PM.L(C)*M.L(C)  ) / PQ.L(C);
SGFED.L     = FEDGREV.L - FEDGEXP.L;
SGST.L      = STGREV.L - STGEXP.L;
NFIN.L      = NFINo ;
SF.L        = SUM(C,PWM(C)*M.L(C)) + WLEAKR*YL.L + RLEAKR*YK.L  + STGLEAK + FEDLEAK + NFIN.L
          - SUM(C,PWE.L(C)*E.L(C)) - SUM(H,REMH(H)) - STGROW - FEDROW  ;
STOT.L      =  LAB_INV_RATE*YL.L + ESAVRATE*YK.L + SUM(H,MPS(H)*TYH.L(H)) + SGST.L + SGFED.L + ER.L*SF.L
          - STGINV - FEDINV - NFIN.L  ;
ITOT.L   = ITOTo ;
DST.L(C) = DSTRATE(C)*ZZ.L(C);
RI.L(I)  = DEPR(I)*KI.L(I);
DK.L(I)  = KSHR_N(I)*(STOT.L-SUM(C,DST.L(C)*PZ.L(C))) / PK.L(I);
NI.L(I)  = DK.L(I) - RI.L(I) ;

ID.L(NSC)  = SUM(J,B(NSC,J)*DK.L(J));
ID.L(NNSC) = 0 ;
DEPRN.L    = SUM(I,DEPR(I)*PK.L(I)*KI.L(I));
ITOT.L     = SUM(C,PQ.L(C)*(ID.L(C)+DST.L(C)));
M.L(C)     = ((PD.L(C)/PM.L(C)*DELTA(C)/(1-DELTA(C)))**(1/(1+RHOC(C)))) * DD.L(C) ;
E.L(C)     = ((PE.L(C)/PD.L(C)*(1-GAMMA(C))/GAMMA(C))**(1/(RHOT(C)-1))) * DD.L(C);
UTIL.L(H)  = (SUM(CQ,(ALPHA(CQ,H)**(1/ELASUB(H)))*(CC.L(CQ,H)**((ELASUB(H)-1)/ ELASUB(H)))))**(ELASUB(H)/(ELASUB(H)-1)) ;
EXFN.L(H)  = UTIL.L(H)* SUM(CQ,ALPHA(CQ,H)*PQ.L(CQ)**(1+ELASUB(H))  ) *
            ((  SUM(CQ,ALPHA(CQ,H)*PQ.L(CQ)**(1-ELASUB(H))  ) ) **( ELASUB(H)/(1-ELASUB(H))) )  ;
EXPD.L(H)  = EXFN.L(H)/((1+DCNT)**TIME.L) ;

* EQUILIBRIUM CONDITIONS
GRP.L    = SUM(I,PV.L(I)*X.L(I) + ITAXR(I)*PX.L(I)*X.L(I));
RGRP.L   = SUM(C,SUM(H,CC.L(C,H)) + ID.L(C) + DST.L(C)+STGD.L(C) + FEDGD.L(C) + E.L(C) - M.L(C));

PARAMETER
LABBBY, CAPPPY ;

LABBBY(I)    = W.L*L.L(I)  ;
CAPPPY(FS)   = R1.L*KI.L(FS)  ;
CAPPPY(PRC)  = R2.L*KI.L(PRC) ;
CAPPPY(NSEA) = R3.L*KI.L(NSEA);

OPTION
PQ:8 ;

DISPLAY
RGRPo, RGRP.L, Xo, X.L, PXo, PX.L, ZZo, ZZ.L, PZo, PZ.L, Q.L, PQ.L, E.L,
PE.L, M.L, PM.L, CC.L, PV.L,DD.L, PD.L,   KI.L, L.L,  STOT.L, ITOT.L,TYH.L,
RGRPo, RGRP.L, STGDTOTo, STGDTOT.L, FEDGDTOTo, FEDGDTOT.L, IDo, ID.L, DSTo,
DST.L, DKo, DK.L, NIo, NI.L, RIo, RI.L, TYHo, TYH.L, YHo, YH.L, DYHo, DYH.L,
CCo, CC.L, ENTSAVo, ENTSAV.L,Ko, KI.L, NFINo, NFIN.L, Qo, Q.L, SFo, SF.L,
Xo, X.L, YKo, YK.L, capincome1, CAPPPY, YLo, YL.L, LABINCOME1, LABBBY,
YLLo, YLL.L, YKKo, YKK.L, Ro, R1.L, R2.L, R3.L, Wo, W.L ;

* ############################################################################
EQUATIONS
* ############################################################################
PIMPORT(C)       definition of domestic import prices
PEXPORT(C)       definition of domestic export prices
PSALES(C)        definition of domestic sales prices
PXEQ(I)          definition of domestic industry prices
PCOMPOSITE(C)    definition of composite good prices
PACTIVITY(I)     definition of activity prices
PCAPITAL(I)      PRICE OF CAPITAL
ZEROPIEQ1(I)     ZERO PROFIT CONDITION 1
ZEROPIEQ2(I)     ZERO PROFIT CONDITION 2
ZEROPIEQ3(I)     ZERO PROFIT CONDITION 3
PREMEQ(I)        PRICE MARKUP EQN
RENTEQ1(I)       RENT EQN1
RENTEQ2(I)       RENT EQN2
RENTEQ3(I)       RENT EQN3
QSLREQ(I)        QUOTA SHARE LEASE RATE EQN
COSTEQ1(I)       UNIT COST EQUATION 1
COSTEQ2(I)       UNIT COST EQUATION 2
COSTEQ3(I)       UNIT COST EQUATION 3
LABDEMAND1(I)    labor demand function - first order condition 1
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LABDEMAND2(I)    labor demand function - first order condition 2
LABDEMAND3(I)    labor demand function - first order condition 3
CAPDEMAND1(I)    CAPITAL DEMAND 1
CAPDEMAND2(I)    CAPITAL DEMAND 2
CAPDEMAND3(I)    CAPITAL DEMAND 3
XSUPPLY(C)       definition of domestic commodity output
CET(C)           CET function
ESUPPLY(C)       export supply function
EDEMAND(C)       EXPORT DEAMND
CES(C)           CES FUNCTION
COST(C)          cost minimum function
INTDEMAND(C,I)   intermediate demand function
CONSUMEQ(C,H)    household consumption demand
CAPYEQ           capital income
LABYEQ           labor income
ENTSAVEQ         enterprise savings
LABINCEQ         SECOND LABOR INCOME EQUATION
CAPINCEQ         SECOND CAP INCOME EQN
HINCOME(H)       household factor income
TYHEQ(H)         TOTAL INCOME EQN FOR HH
HDINCOME(H)      household disposal income
HSAVE(H)         household savings
STGREVEQ         state gov't revenue
STGEXPEQ         state gov't expenditure
STGDEQ(C)        state gov't demand
FEDGREVEQ        federal gov't revenue
FEDGEXPEQ        federal gov't expenditure
FEDGDEQ(C)       federal gov't demand
TFSEQ            federal gov't transfers to state AND LOCAL gov't
TSAVE            total savings available for investment
FEDGBUDGET       federal government budget
STGBUDGET        state government budget
CURRACCT         current account balance
DSTEQ(C)         DSTT EQ
IDESTTT          DKKK EQ
IDEMAND(NSC)     IDDD EQ
DEPRNEQ          DEPRNNN EQ
REPINV(I)        RIII EQ
ITOTEQ           TOTAL INV
GDSMKT(C)        goods market equilibrium condition
LSTKEQ           aggregate labor stock
LTOTEQ           total labor demand
CAPMKT1          capital market equilibrium condition 1
CAPMKT2          capital market equilibrium condition 2
CAPMKT3          capital market equilibrium condition 3
SI               INV-SAV EQUALITY
LABMKT           labor market eqm condition
POPEQ(H)         POPULATION EQN
GRPY             gross regional product at market prices
RGRPY            real gross regional product
;

* #######################  MODEL EQUATIONS ##########################
* ### PRICES
PIMPORT(C)..     PM(C)      =E= PWM(C)*ER;
PEXPORT(C)..     PE(C)      =E= PWE(C)*ER;
PSALES(C)..      PZ(C)*ZZ(C) =E= PD(C)*DD(C) + PE(C)*E(C);
PXEQ(I)..        PX(I)      =E= SUM(C,MAKERNORM(I,C) * PZ(C));
PCOMPOSITE(C)..  PD(C)*DD(C) =E= PQ(C)*Q(C) - PM(C)*M(C)  ;
PACTIVITY(I)..   PV(I)      =E= PX(I) -SUM(C,A(C,I)*PQ(C)) - ITAXR(I)*PX(I);
PCAPITAL(I)..    PK(I)      =E= SUM(NSC,PQ(NSC)*B(NSC,I));

* ### INPUTS DEMAND AND PRODUCTION
ZEROPIEQ1(FS)..    PV(FS)*X(FS)      =E= PREM(FS)*(W*L(FS) + R1*KI(FS))  ;
ZEROPIEQ2(PRC)..   PV(PRC)*X(PRC)    =E= PREM(PRC)*(W*L(PRC) + R2*KI(PRC))  ;
ZEROPIEQ3(NSEA)..  PV(NSEA)*X(NSEA)  =E= PREM(NSEA)*(W*L(NSEA) + R3*KI(NSEA))  ;
PREMEQ(I)..        PREM(I)           =E= 1 + RAT22(I) ;
RENTEQ1(FS)..      RSRENT(FS)        =E= RAT22(FS)*  (W*L(FS)  + R1*KI(FS))  ;
RENTEQ2(PRC)..     RSRENT(PRC)       =E= RAT22(PRC)* (W*L(PRC) + R2*KI(PRC)) ;
RENTEQ3(NSEA)..    RSRENT(NSEA)      =E= RAT22(NSEA)*(W*L(NSEA)+ R3*KI(NSEA));
QSLREQ(I)..        QSLR(I)*PX(I)*X(I)=E= RSRENT(I)  ;

COSTEQ1(FS)..      UNITCOST(FS)  =E= (1/OMEGA_PDN(FS))*((BETA_PDN(FS)**ELAS_PDN(FS))*(R1**(1-ELAS_PDN(FS)))+
                       ((1-BETA_PDN(FS))**ELAS_PDN(FS))*(W**(1-ELAS_PDN(FS))))**(1/(1-ELAS_PDN(FS))) ;
COSTEQ2(PRC)..     UNITCOST(PRC) =E= (1/OMEGA_PDN(PRC))*((BETA_PDN(PRC)**ELAS_PDN(PRC))*(R2**(1-ELAS_PDN(PRC)))+
                       ((1-BETA_PDN(PRC))**ELAS_PDN(PRC))*(W**(1-ELAS_PDN(PRC))))**(1/(1-ELAS_PDN(PRC))) ;
COSTEQ3(NSEA)..    UNITCOST(NSEA)=E= (1/OMEGA_PDN(NSEA))*((BETA_PDN(NSEA)**ELAS_PDN(NSEA))*(R3**(1-ELAS_PDN(NSEA)))+
                       ((1-BETA_PDN(NSEA))**ELAS_PDN(NSEA))*(W**(1-ELAS_PDN(NSEA))))**(1/(1-ELAS_PDN(NSEA))) ;

LABDEMAND1(FS)..   L(FS)     =E= (X(FS)/OMEGA_PDN(FS))*((1-BETA_PDN(FS))*OMEGA_PDN(FS)*UNITCOST(FS)/W)**ELAS_PDN(FS) ;
LABDEMAND2(PRC)..  L(PRC)    =E= (X(PRC)/OMEGA_PDN(PRC))*((1-BETA_PDN(PRC))*OMEGA_PDN(PRC)*UNITCOST(PRC)/W)**ELAS_PDN(PRC) ;
LABDEMAND3(NSEA).. L(NSEA)   =E= (X(NSEA)/OMEGA_PDN(NSEA))*((1-BETA_PDN(NSEA))*OMEGA_PDN(NSEA)*UNITCOST(NSEA)/W)**ELAS_PDN(NSEA) ;
CAPDEMAND1(FS)..   KI(FS)    =E= (X(FS)/OMEGA_PDN(FS))*(BETA_PDN(FS)*OMEGA_PDN(FS)*UNITCOST(FS)/R1)**ELAS_PDN(FS) ;
CAPDEMAND2(PRC)..  KI(PRC)   =E= (X(PRC)/OMEGA_PDN(PRC))*(BETA_PDN(PRC)*OMEGA_PDN(PRC)*UNITCOST(PRC)/R2)**ELAS_PDN(PRC) ;
CAPDEMAND3(NSEA).. KI(NSEA)  =E= (X(NSEA)/OMEGA_PDN(NSEA))*(BETA_PDN(NSEA)*OMEGA_PDN(NSEA)*UNITCOST(NSEA)/R3)**ELAS_PDN(NSEA) ;
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```
XSUPPLY(C)..     ZZ(C)       =E= SUM(I,MAKERNORM(I,C) * X(I));
CET(C)..         ZZ(C)       =E= AT(C)*(GAMMA(C)*E(C)**RHOT(C) + (1-GAMMA(C))*DD(C)**RHOT(C))**(1/RHOT(C));
ESUPPLY(C)..     E(C)        =E= ((PE(C)/PD(C)*(1-GAMMA(C))/GAMMA(C))**(1/(RHOT(C)-1)))*DD(C);
EDEMAND(PCOM)..  E(PCOM)     =E= SFT*Eo(PCOM)*(  1/PWE(PCOM) ) ** EDELA(PCOM) ;
CES(C)..         Q(C)        =E= (TAU(C)*(DELTA(C)*M(C)**(-RHOC(C))+(1-DELTA(C))*DD(C)**(-RHOC(C)))**(-1/RHOC(C))) ;
COST(C)..        M(C)        =E= ((PD(C)/PM(C)*DELTA(C)/(1-DELTA(C)))**(1/(1+RHOC(C))))*DD(C);
INTDEMAND(C,I).. ND(C,I)     =E= A(C,I) * X(I);

* ### COMSUMER DEMAND
CONSUMEQ(C,H)..  CC(C,H)     =E= ALPHA(C,H)*DYH(H)/((PQ(C)**ELASUB(H))* SUM(CX,ALPHA(CX,H)*PQ(CX)**(1-ELASUB(H))));

* ### INCOME BLOCK
CAPYEQ..         YK       =E= SUM(FS,   PV(FS) *   X(FS) - PREM(FS)*L(FS) * W)
                           + SUM(PRC,  PV(PRC) *  X(PRC) - PREM(PRC)*L(PRC) * W)
                           + SUM(NSEA, PV(NSEA) * X(NSEA) - PREM(NSEA)*L(NSEA) * W) ;
LABYEQ..         YL       =E= SUM(FS,PREM(FS)*W * L(FS)) + SUM(PRC,PREM(PRC)*W * L(PRC)) + SUM(NSEA,PREM(NSEA)*W * L(NSEA)) ;
ENTSAVEQ..       ENTSAV   =E= ESAVRATE * YK ;
LABINCEQ..       YLL      =E= (1 - WLEAKR - SSTR - LAB_SLG_RATE - LAB_INV_RATE) * YL ;
CAPINCEQ..       YKK      =E= (1 - RLEAKR - KTRFED - KTRST - ESAVRATE) * YK ;
HINCOME(H)..     YH(H)    =E= LL(H) * YLL + EE(H) * YKK ;
TYHEQ(H)..       TYH(H)   =E= YH(H)  + TRAFEDHH(H) + TRASTHH(H) + REMH(H) ;
HDINCOME(H)..    DYH(H)   =E= TYH(H) * (1 - HHTRFED(H) - HHTRST(H) - MPS(H)) ;
HSAVE(H)..       SH(H)    =E= MPS(H) * TYH(H) ;

* ### STATE, LOCAL AND FEDERAL GOVERNMENT
STGREVEQ..       STGREV    =E= + KTRST*YK + LAB_SLG_RATE*YL + STIBT*(SUM(I, ITAXR(I)*PX(I)*X(I)))
                             + SUM(H,HHTRST(H)*TYH(H)) + STGTRNS + TRAFEDST + STGINV + STGROW ;
STGEXPEQ..       STGEXP    =E= SUM(C,PQ(C)*STGD(C)) + SUM(H,TRASTHH(H)) + STGTRNS + STGLEAK ;
STGDEQ(C)..      STGD(C)   =E= STGLES(C) * STGDTOT/PQ(C);
FEDGREVEQ..      FEDGREV   =E= SSTR*YL + KTRFED*YK + FEDIBT*SUM(I,ITAXR(I)*PX(I)*X(I))
                             + SUM(H,HHTRFED(H)*TYH(H)) + FEDSELF + FEDINV + FEDROW ;
FEDGEXPEQ..      FEDGEXP   =E= SUM(C,PQ(C)*FEDGD(C)) + SUM(H,TRAFEDHH(H)) + TRAFEDST + FEDSELF + FEDLEAK ;
FEDGDEQ(C)..     FEDGD(C)  =E= FEDGLES(C)*FEDGDTOT/PQ(C);
TFSEQ..          TRAFEDST  =E= FSRAT*FEDGREV ;

* ### SAVING AND INVESTMENT
TSAVE..          STOT      =E= LAB_INV_RATE*YL + ESAVRATE*YK + SUM(H,MPS(H)*TYH(H)) + SGST + SGFED + ER*SF
                             - STGINV - FEDINV - NFIN  ;
FEDGBUDGET..     SGFED     =E= FEDGREV - FEDGEXP;
STGBUDGET..      SGST      =E= STGREV  - STGEXP;
CURRACCT..       SF        =E= SUM(C,PWM(C)*M(C)) + WLEAKR*YL + RLEAKR*YK + STGLEAK + FEDLEAK + NFIN
                             - SUM(C,PWE(C)*E(C)) - SUM(H,REMH(H)) - STGROW - FEDROW  ;
DSTEQ(C)..       DST(C)    =E= DSTRATE(C)*ZZ(C);
IDESTTT..        TDK       =E= C1*SUM(I,DKo(I)) + C2*GRCAP3*KTOT3  ;
IDEMAND(NSC)..   ID(NSC)   =E= BBB(NSC)*TDK ;
DEPRNEQ..        DEPRN     =E= SUM(I,DEPR(I)*PK(I)*KI(I));
REPINV(I)..      RI(I)     =E= DEPR(I)*KI(I);
ITOTEQ..         ITOT      =E= SUM(C,PQ(C)*(ID(C)+DST(C)));

* ### EQUILIBRIUM CONDITIONS
GDSMKT(C)..      Q(C)      =E= SUM(I,ND(C,I)) + SUM(H,CC(C,H)) + STGD(C) + FEDGD(C) + ID(C) + DST(C) ;
LSTKEQ..         LSTK      =E= SUM(H,LS(H))  ;
LTOTEQ..         LTOT      =E= SUM(I,L(I))    ;
CAPMKT1..        KTOT1     =E= SUM(FS,KI(FS));
CAPMKT2..        KTOT2     =E= SUM(PRC,KI(PRC));
CAPMKT3..        KTOT3     =E= SUM(NSEA,KI(NSEA));
SI..             ITOT      =E= STOT ;
LABMKT..         LTOT      =E= (1-UR)*SUM(H,LS(H)) ;
POPEQ(H)..       POP(H)    =E= LS(H)/LPR ;

* ### GROSS REGIONAL PRODUCT
GRPY..           GRP       =E= SUM(I,PV(I)*X(I) + ITAXR(I)*PX(I)*X(I));
RGRPY..          RGRP      =E= SUM(C,SUM(H,CC(C,H)) + ID(C) + DST(C) + STGD(C) + FEDGD(C) + E(C) - M(C));

* ############### MODEL CLOSURE 1: BENCHAMRK REPLICATION #################
  C1 = 1 ;
  C2 = 0 ;

* ### CURRENT ACCOUNT CLOSURE
  ER.FX        =  ER.L;
  PWE.FX(NPCOM) = PWE.L(NPCOM)    ;
  SFT          = 1;

* TAC
  RAT22.FX(NFS)  = RAT22.L(NFS) ;
  X.FX(FS)       = X.L(FS) ;

* ### FACTOR MARKET CLOSURE
  LS.FX(H)   = LS.L(H) ;
  KTOT1.FX   = KTOT1.L ;
  KTOT2.FX   = KTOT2.L ;
  KTOT3.FX   = KTOT3.L ;

* ### INVESTMENT
  ID.FX(NNSC) = ID.L(NNSC) ;
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* ### GOVERNMENT
  STGDTOT.FX    = STGDTOT.L;
  FEDGDTOT.FX   = FEDGDTOT.L;

* ######################  END OF MODEL ##################################
OPTIONS ITERLIM=1000,SOLPRINT=OFF,SYSOUT=OFF;
MODEL AK_CGE /ALL/;
SOLVE AK_CGE MAXIMIZING RGRP USING NLP;

OPTION
PQ:8, PZ:8, PX:8 ;

PARAMETER
CKS ;

CKS(I) = NI.L(I) / KI.L(I) ;

parameter
RGRPB, XB, ZZB,PZB, MB, EB, QB, KB, LB, STOTB, ITOTB, WB, RB, YKB, YLB, DYHB,
FREVB, SREVB, USE_POLB, USE_NPLB, LAB_B, CAP_B,VAL_B, TYH_B ;

RGRPB = RGRP.L ;
XB(I)   = X.L(I) ;
ZZB(C)  = ZZ.L(C) ;
PZB(C)  = PZ.L(C);
MB(C)   = M.L(C) ;
EB(C)   = E.L(C) ;
QB(C)   = Q.L(C) ;
KB(I)   = KI.L(I) ;
LB(I)   = L.L(I) ;
STOTB   = STOT.L ;
ITOTB   = ITOT.L ;
YKB    = YK.L ;
YLB    = YL.L ;
DYHB(H) = DYH.L(H) ;
FREVB   = FEDGREV.L ;
SREVB   = STGREV.L ;
VAL_B(I) = PV.L(I)*X.L(I) ;
TYH_B(H) = TYH.L(H) ;

PARAMETER
ABC2 ;

ABC2(I) = NI.L(I) / KI.L(I) ;

* UPDATED STOCK

VARIABLES
LSU,KIU, KTOTU1, KTOTU2, KTOT3U ;

LMIG.L    = LSTK.L*((W.L/WROW)**LME-1) ;
LSU.L(H)  = LSo(H) ;
KMIG1.L   = KTOT1.L*((R1.L/1)**KME-1);
KMIG2.L   = KTOT2.L*((R2.L/1)**KME-1);
KTOTU1.L  = KTOT1o  ;
KTOTU2.L  = KTOT2o  ;
KIU.L(I)  = KI.L(I) ;
KTOT3U.L  = KTOT3.L ;

PARAMETER
KIP, LIP ;
KIP(I) = KI.L(I) ;
LIP(I) = L.L(I) ;

UTIL.L(H)  = (SUM(CQ,(ALPHA(CQ,H)**(1/ELASUB(H)))*(CC.L(CQ,H)**((ELASUB(H)-1)/ ELASUB(H)))))**(ELASUB(H)/(ELASUB(H)-1)) ;
EXFN.L(H)  = UTIL.L(H)* SUM(CQ,ALPHA(CQ,H)*PQ.L(CQ)**(1+ELASUB(H))  ) *
             ((  SUM(CQ,ALPHA(CQ,H)*PQ.L(CQ)**(1-ELASUB(H))  ) ) **( ELASUB(H)/(1-ELASUB(H))) )  ;
EXPD.L(H)  = EXFN.L(H)/((1+DCNT)**TIME.L) ;

* ###################     RESULTS REPORT      ###################
SETS  LEVEL variable name  /RGRP_L     RGRP level
               W_L       WAGE RATE
               R1_L      RENTAL RATE OF CAPITAL 1
               R2_L      RENTAL RATE OF CAPITAL 2
               R3_L      RENTAL RATE OF CAPITAL 2
               PQ_L      COMMODITY PRICE
               NI_L      net investment level
               KI_L      updated capital stock level
               LABY_L    labor income
               CAPY1_L   capital income including RESOURCE RENT 1
               CAPY2_L   capital income including RESOURCE RENT 2
               CAPY3_L   capital income including RESOURCE RENT 3
               PREM_L    PRICE MARKUP
               RRENT_L   RESOURCE RENT
               QSLR_L    QUOTA SHARE LEASE RATE
               RAT22_L   RATIO 22
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                  REMVAL_L   REMAINING VALUE ADDED
                  VAL_L      VALUE ADDED
                  SAL_L      OUTPUT VALUE
                  X_L        output
                  L_L        indutry labor
                  PX_L       price of output
                  KIP_L      capital stock level in the previous period
                  LIP_L      labor in the previous period
                  KTOT1_L    total capital stock 1
                  KTOT2_L    total capital stock 2
                  KTOT3_L    total capital stock 3
                  LTOT_L     total employment
                  LMIG_L     migration level /

    PCT             /RGRP_P     RGRP percent change
                  L_P        percent change in labor
                  LB_P       percent change in labor compared to base year
                  KB_P       percent change in CAPITAL compared to base year
                  KI_P       KI percent change /

    ACH             /RGRP_A     agg. RGRP
                  NI_A       agg. net investment
                  KTOT1_A    agg. capital stock 1
                  KTOT2_A    agg. capital stock 2
                  KTOT3_A    agg. capital stock 3
                  LTOT_A     agg. labor employment
                  LMIG_A     agg. labor migration /

   WEL              /EXPD_L     discounted expenditure
                  HOUY_L     HOUSEHOLD INCOME /

   AWEL              /EXPD_A     agg. discounted expenditure
                  HOUY_A     AGG. HOUSEHOLD INCOME /


   YEAR  simulation year number /YEAR1*YEAR47/
   SIMU  simulation number      /SIM1*SIM20/

   BC    BENCH OR COUNTER  /BEN     BENCHMARK DATA
                   COU      COUNTERFACTURAL DATA/
ALIAS(YEAR,YEARP);

PARAMETERS
REPORTA(LEVEL,*,*)        report aggregate results in levels
REPORTB(LEVEL,*,*,I)      report sectoral results in levels
REPORTE(PCT,*,*,I)        report aggregate results in percent change
REPORTG(ACH,*,*)          report agg. value of variable
REPORTJ(ACH,*,*,I)        report agg. sectoral variable
REPORTK(LEVEL,*,*,C)      commodity price
REPORTL(WEL,*,*,H)        discounted EXPENDITUREs
REPORTM(AWEL,*,*,H)       AGG. discounted EXPENDITUREs  ;

REPORTA("RGRP_L","SIMU0", "YEAR0")       = RGRP.L  ;
REPORTA("W_L","SIMU0", "YEAR0")          = W.L  ;
REPORTA("LTOT_L","SIMU0", "YEAR0")       = LTOT.L  ;
REPORTA("KTOT1_L","SIMU0", "YEAR0")      = KTOT1.L  ;
REPORTA("KTOT2_L","SIMU0", "YEAR0")      = KTOT2.L  ;
REPORTA("KTOT3_L","SIMU0", "YEAR0")      = KTOT3.L  ;
REPORTA("LMIG_L","SIMU0", "YEAR0")       = LMIG.L  ;
REPORTA("R1_L","SIMU0", "YEAR0")         = R1.L ;
REPORTA("R2_L","SIMU0", "YEAR0")         = R2.L ;
REPORTA("R3_L","SIMU0", "YEAR0")         = R3.L ;

REPORTB("NI_L","SIMU0", "YEAR0",I)       = NI.L(I) ;
REPORTB("KI_L","SIMU0", "YEAR0",I)       = KI.L(I);
REPORTB("LABY_L","SIMU0", "YEAR0",I)     = PREM.L(I)*  W.L* L.L(I)  ;
REPORTB("CAPY1_L","SIMU0", "YEAR0",FS)   = PREM.L(FS)*  R1.L*      KI.L(FS)  ;
REPORTB("CAPY2_L","SIMU0", "YEAR0",PRC)  = PREM.L(PRC)* R2.L*      KI.L(PRC) ;
REPORTB("CAPY3_L","SIMU0", "YEAR0",NSEA)  = PREM.L(NSEA)*R3.L* KI.L(NSEA);
REPORTB("PREM_L","SIMU0", "YEAR0",I)     = PREM.L(I)  ;
REPORTB("RRENT_L","SIMU0", "YEAR0",FS)   = RSRENT.L(FS) ;
REPORTB("QSLR_L","SIMU0", "YEAR0",FS)    = QSLR.L(FS) ;
REPORTB("RAT22_L","SIMU0", "YEAR0",FS)   = RAT22.L(FS) ;
REPORTB("REMVAL_L","SIMU0", "YEAR0",FS)  = W.L*L.L(FS)  + R1.L*KI.L(FS)    ;
REPORTB("VAL_L","SIMU0", "YEAR0",I)      = PV.L(I)*X.L(I) ;
REPORTB("SAL_L","SIMU0", "YEAR0",I)      = PX.L(I)*X.L(I) ;
REPORTB("X_L","SIMU0", "YEAR0",I)        = X.L(I);
REPORTB("L_L","SIMU0", "YEAR0",I)        = L.L(I);
REPORTB("PX_L","SIMU0", "YEAR0",I)       = PX.L(I);
REPORTB("KIP_L","SIMU0", "YEAR0",I)      = KIP(I);
REPORTB("LIP_L","SIMU0", "YEAR0",I)      = LIP(I);

REPORTG("RGRP_A","SIMU0", "YEAR0")       = SUM((SIMU,YEAR), REPORTA("RGRP_L", SIMU, YEAR)) ;
REPORTG("LTOT_A","SIMU0", "YEAR0")       = SUM((SIMU,YEAR), REPORTA("LTOT_L" ,SIMU,YEAR)) ;
REPORTG("KTOT1_A","SIMU0", "YEAR0")      = SUM((SIMU,YEAR), REPORTA("KTOT1_L" ,SIMU,YEAR)) ;
REPORTG("KTOT2_A","SIMU0","YEAR0")       = SUM((SIMU,YEAR), REPORTA("KTOT2_L" ,SIMU,YEAR)) ;
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REPORTG("KTOT3_A","SIMU0","YEAR0")       = SUM((SIMU,YEAR), REPORTA("KTOT3_L" ,SIMU,YEAR)) ;
REPORTG("LMIG_A","SIMU0","YEAR0")        = SUM((SIMU,YEAR), REPORTA("LMIG_L" ,SIMU,YEAR)) ;

REPORTJ("NI_A","SIMU0","YEAR0",I)        = SUM((SIMU,YEAR), REPORTB("NI_L" ,SIMU,YEAR,I)) ;
REPORTK("PQ_L","SIMU0","YEAR0",C)        = PQ.L(C) ;
REPORTL("EXPD_L","SIMU0","YEAR0",H)      = EXPD.L(H) ;
REPORTM("EXPD_A","SIMU0","YEAR0",H)      = SUM((SIMU,YEAR), REPORTL("EXPD_L" ,SIMU,YEAR,H)) ;
REPORTL("HOUY_L","SIMU0","YEAR0",H)      = DYH.L(H) ;
REPORTM("HOUY_A","SIMU0","YEAR0",H)      = SUM((SIMU,YEAR), REPORTL("HOUY_L" ,SIMU,YEAR,H)) ;

$INCLUDE CATCH_DAT.txt

* Note: CATCH_DAT.txt contains catch prediction data

PARAMETER
CH_POLL_BENCH, CH_POLL_COUNT ;

CH_POLL_BENCH(SIMU,YEAR) = CATCHDATA(SIMU,YEAR,"BEN") ;
CH_POLL_COUNT(SIMU,YEAR) = CATCHDATA(SIMU,YEAR,"COU") ;

* ##########################################################################################################
* ######################### BENCHMARK SIMULATION ##########################################################
* ##########################################################################################################

* ############################## LOOP FOR SOLVING MODEL IN SUCCESSIVE PERIODS  #########################
LOOP(SIMU,
LOOP(YEAR,

* ################ MODEL CLOSURE 1: BENCHAMRK REPLICATION #################
  C1          = 0 ;
  C2          = 1 ;
  TIME.FX      = ORD(YEAR);

* ### CURRENT ACCOUNT CLOSURE
  ER.FX        =  ER.L;
  PWE.FX(NPCOM) = PWE.L(NPCOM)     ;
  SFT          = (1+0.000)**TIME.L ;

* TAC
  RAT22.FX(NFS) = RAT22.L(NFS) ;

* =============== For BENCHMARK PATH       ============
  X.FX(FSPOL)       = CH_POLL_BENCH(SIMU,YEAR)*Xo(FSPOL)  ;
*   X.FX(FSPOL)       = CH_POLL_COUNT(SIMU,YEAR)*Xo(FSPOL)  ;
  X.FX(FSNPL)       =                          Xo(FSNPL)  ;

* =====================================================

* ### FACTOR MARKET CLOSURE
  LS.FX(H)   = LSU.L(H) ;
  KTOT1.FX   = KTOTU1.L ;
  KTOT2.FX   = KTOTU2.L ;
  KTOT3.FX   = KTOT3U.L ;

* ### INVESTMENT
  ID.FX(NNSC) = ID.L(NNSC) ;

* ### GOVERNMENT
  STGDTOT.FX    = STGDTOT.L;
  FEDGDTOT.FX   = FEDGDTOT.L;

* ### VARIABLE BOUNDS
E.LO(C)  = 0.0  ;
M.LO(C)  = 0.0  ;
DD.LO(C) = 0.0  ;

X.LO(I)  = 0.0000000000000000001 ;
ZZ.LO(C) = 0 ;
CC.LO(C,H)= 0.0 ;
Q.LO(C)   = 0.0 ;
TYH.LO(H) = 0.0 ;
YH.LO(H)  = 0.0 ;
DYH.LO(H) = 0.0 ;
YL.LO     = 0.0 ;
YK.LO     = 0.0 ;
KI.LO(I)  = 0.000000000000000001 ;
L.LO(I)   = 0.000000000000000001 ;
PD.LO(C) = 0.0001 ;
PM.LO(C) = 0.0001 ;
PE.LO(C) = 0.0001 ;
PQ.LO(C) = 0.0001 ;
PX.LO(I) = 0.0001 ;
PK.LO(I) = 0.0001 ;
PZ.LO(C) = 0.0001 ;
R1.LO    = 0.0000001 ;
R2.LO    = 0.0000001 ;
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R3.LO    = 0.0000001 ;
PV.LO(I) = 0.0000001 ;
W.LO     = 0.0000001 ;

SOLVE AK_CGE MAXIMIZING RGRP USING NLP;


LMIG.L    = LSTK.L*((W.L/WROW)**LME-1) ;
LSU.L(H)  = LS.L(H)*(1+POPG(H)) + LMIG.L ;
KMIG1.L   = KTOT1.L*((R1.L/1)**KME-1);
KMIG2.L   = KTOT2.L*((R2.L/1)**KME-1);
KTOTU1.L  = KTOT1.L + KMIG1.L ;
KTOTU2.L  = KTOT2.L + KMIG2.L ;
KIU.L(I)  = (1+GRCAP(I))*KI.L(I) ;
KTOT3U.L  = (1+GRCAP3)*KTOT3.L ;
UTIL.L(H) = (SUM(CQ,(ALPHA(CQ,H)**(1/ELASUB(H)))*(CC.L(CQ,H)**((ELASUB(H)-1)/ ELASUB(H)))))**(ELASUB(H)/(ELASUB(H)-1)) ;
EXFN.L(H) = UTIL.L(H)* SUM(CQ,ALPHA(CQ,H)*PQ.L(CQ)**(1+ELASUB(H))  ) *
          ((  SUM(CQ,ALPHA(CQ,H)*PQ.L(CQ)**(1-ELASUB(H))  ) ) **( ELASUB(H)/(1-ELASUB(H))) )  ;
EXPD.L(H) = EXFN.L(H)/((1+DCNT)**TIME.L) ;

* #################     RESULTS REPORT     ###################
REPORTA("RGRP_L", SIMU, YEAR)       = RGRP.L ;
REPORTA("W_L", SIMU, YEAR)          = W.L  ;
REPORTA("LTOT_L", SIMU, YEAR)       = LTOT.L  ;
REPORTA("KTOT1_L", SIMU, YEAR)      = KTOT1.L  ;
REPORTA("KTOT2_L", SIMU, YEAR)      = KTOT2.L  ;
REPORTA("KTOT3_L", SIMU, YEAR)      = KTOT3.L  ;
REPORTA("LMIG_L", SIMU, YEAR)       = LMIG.L  ;
REPORTA("R1_L", SIMU, YEAR)         = R1.L ;
REPORTA("R2_L", SIMU, YEAR)         = R2.L ;
REPORTA("R3_L", SIMU, YEAR)         = R3.L ;

REPORTB("NI_L", SIMU, YEAR,I)       = NI.L(I);
REPORTB("KI_L", SIMU, YEAR,I)       = KI.L(I);
REPORTB("LABY_L", SIMU, YEAR,I)     = (  PREM.L(I)*  W.L* L.L(I)       )   / (  (1+DCNT)**TIME.L  ) ;
REPORTB("CAPY1_L", SIMU, YEAR,FS)   = (  PREM.L(FS)*  R1.L* KI.L(FS)   )   / (  (1+DCNT)**TIME.L  ) ;
REPORTB("CAPY2_L", SIMU, YEAR,PRC)  = (  PREM.L(PRC)* R2.L* KI.L(PRC)  )   / (  (1+DCNT)**TIME.L  ) ;
REPORTB("CAPY3_L", SIMU, YEAR,NSEA) = (  PREM.L(NSEA)*R3.L* KI.L(NSEA) )   / (  (1+DCNT)**TIME.L  ) ;
REPORTB("PREM_L", SIMU, YEAR,I)     = PREM.L(I)  ;
REPORTB("RRENT_L", SIMU, YEAR,FS)   = RSRENT.L(FS) ;
REPORTB("QSLR_L", SIMU, YEAR,FS)    = QSLR.L(FS) ;
REPORTB("RAT22_L", SIMU, YEAR,FS)   = RAT22.L(FS) ;
REPORTB("REMVAL_L", SIMU, YEAR,FS)  = W.L*L.L(FS) + R1.L*KI.L(FS)    ;
REPORTB("VAL_L", SIMU, YEAR,I)      = (  PV.L(I)*X.L(I)  ) / (  (1+DCNT)**TIME.L  )  ;
REPORTB("SAL_L", SIMU, YEAR,I)      = (  PX.L(I)*X.L(I)  ) / (  (1+DCNT)**TIME.L  )  ;
REPORTB("X_L", SIMU, YEAR,I)        = X.L(I);
REPORTB("L_L", SIMU, YEAR,I)        = L.L(I);
REPORTB("PX_L", SIMU, YEAR,I)       = PX.L(I);
REPORTB("KIP_L", SIMU, YEAR,I)      = KIP(I);
REPORTB("LIP_L", SIMU, YEAR,I)      = LIP(I);

REPORTE("KI_P", SIMU, YEAR,I)       = ((REPORTB("KI_L", SIMU, YEAR,I)-REPORTB("KIP_L", SIMU, YEAR,I)) /REPORTb("KIP_L", SIMU, YEAR,I))*100;
REPORTE("L_P", SIMU, YEAR,I)        = ((REPORTB("L_L", SIMU, YEAR,I)-REPORTB("LIP_L", SIMU, YEAR,I))/REPORTb("LIP_L", SIMU, YEAR,I))*100;
REPORTE("KB_P",SIMU, YEAR,I)        = ((REPORTB("KI_L",SIMU, YEAR,I)-Ko(I))/Ko(I))*100;
REPORTE("LB_P",SIMU, YEAR,I)        = ((REPORTB("L_L", SIMU, YEAR,I)-Lo(I))/Lo(I))*100;
REPORTG("RGRP_A",SIMU, YEAR)        = REPORTA("RGRP_L","SIMU0","YEAR0")+SUM(YEARP, REPORTA("RGRP_L",SIMU, YEARP)) ;
REPORTG("LTOT_A",SIMU, YEAR)        = REPORTA("LTOT_L","SIMU0","YEAR0")+SUM(YEARP, REPORTA("LTOT_L", SIMU, YEARP)) ;
REPORTG("KTOT1_A",SIMU, YEAR)       = REPORTA("KTOT1_L","SIMU0","YEAR0")+SUM(YEARP, REPORTA("KTOT1_L", SIMU, YEARP)) ;
REPORTG("KTOT2_A",SIMU, YEAR)       = REPORTA("KTOT2_L","SIMU0","YEAR0")+SUM(YEARP, REPORTA("KTOT2_L", SIMU, YEARP)) ;
REPORTG("KTOT3_A",SIMU, YEAR)       = REPORTA("KTOT3_L","SIMU0","YEAR0")+SUM(YEARP, REPORTA("KTOT3_L", SIMU, YEARP)) ;
REPORTG("LMIG_A",SIMU, YEAR)        = REPORTA("LMIG_L","SIMU0","YEAR0")+SUM(YEARP, REPORTA("LMIG_L", SIMU, YEARP)) ;

REPORTJ("NI_A",SIMU, YEAR,I)        = REPORTB("NI_L","SIMU0","YEAR0",I)+SUM(YEARP, REPORTB("NI_L", SIMU, YEARP,I)) ;
REPORTK("PQ_L",SIMU, YEAR,C)        = PQ.L(C) ;
REPORTL("EXPD_L",SIMU, YEAR,H)      = EXPD.L(H) ;
REPORTM("EXPD_A",SIMU, YEAR,H)      = REPORTL("EXPD_L","SIMU0","YEAR0",H) + SUM(YEARP, REPORTL("EXPD_L", SIMU, YEARP,H)) ;
REPORTL("HOUY_L",SIMU, YEAR,H)      = DYH.L(H) ;
REPORTM("HOUY_A",SIMU, YEAR,H)      = REPORTL("HOUY_L","SIMU0","YEAR0",H) + SUM(YEARP, REPORTL("HOUY_L", SIMU, YEARP,H)) ;

KIP(I) = KI.L(I) ;
LIP(I) = L.L(I)  ;

 ) ;

* END OF YEAR LOOP

LSU.L(H)  = LSo(H) ;
KTOTU1.L  = KTOT1o  ;
KTOTU2.L  = KTOT2o  ;
KIU.L(I)  = Ko(I) ;
KTOT3U.L  = KTOT3o ;

 ) ;

* END OF SIMULATION LOOP
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* ####################################################################################################
* ############################## END OF LOOP #############################################################
* ####################################################################################################

* ######################     REPORT      ########################
OPTION
REPORTA:3:0:1, REPORTB:6:2:1, REPORTE:6:0:1, REPORTG:3:0:1, REPORTJ:3:2:1 ;

PARAMETER
LAB_POLL_H    Cumulative labor for pollock harvesting industry
LAB_NPLL_H    Cumulative labor for non pollock harvesting industry
LAB_POLL_P    Cumulative labor for pollock processing industry
LAB_NPLL_P    Cumulative labor for non pollock processing industry
LAB_NONSEA    Cumulative labor for non seafood industries
TLABOR        Cumulative total labor

CAP_POLL_H    Cumulative capital for pollock harvesting industry
CAP_NPLL_H    Cumulative capital for non pollock harvesting industry
CAP_POLL_P    Cumulative capital for pollock processing industry
CAP_NPLL_P    Cumulative capital for non pollock processing industry
CAP_NONSEA    Cumulative capital for non seafood industries
TCAPITAL      Cumulative total capital

OUT_POLL_H    Cumulative output for pollock harvesting industry
OUT_NPLL_H    Cumulative output for non pollock  harvesting industry
OUT_POLL_P    Cumulative output for pollock      processing industry
OUT_NPLL_P    Cumulative output for non pollock  processing industry
OUT_NONSEA    Cumulative output for non seafood industries
TOUTPUT       Cumulative total output

LINC_POLL_H   Cumulative labor income for pollock harvesting industry
LINC_NPLL_H   Cumulative labor income for non pollock  harvesting industry
LINC_POLL_P   Cumulative labor income for pollock      processing industry
LINC_NPLL_P   Cumulative labor income for non pollock  processing industry
LINC_NONSEA   Cumulative labor income for non seafood industries
TLABINC       Cumulative total labor income

KINC_POLL_H   Cumulative capital income for pollock harvesting industry
KINC_NPLL_H   Cumulative capital income for non pollock  harvesting industry
KINC_POLL_P   Cumulative capital income for pollock      processing industry
KINC_NPLL_P   Cumulative capital income for non pollock  processing industry
KINC_NONSEA   Cumulative capital income for non seafood industries
TCAPINC       Cumulative total capital income

TOTVAL        Cumulative total value added ;

* TO REPLACE

LAB_POLL_H(SIMU)  = SUM(YEAR, SUM(FSPOL,REPORTB("L_L",SIMU, YEAR,FSPOL)) ) ;
LAB_NPLL_H(SIMU)  = SUM(YEAR, SUM(FSNPL,REPORTB("L_L",SIMU, YEAR,FSNPL)) ) ;
LAB_POLL_P(SIMU)  = SUM(YEAR, REPORTB("L_L",SIMU, YEAR,"PR-POLL-A") ) ;
LAB_NPLL_P(SIMU)  = SUM(YEAR, SUM(PRC,REPORTB("L_L",SIMU, YEAR,PRC)) ) -   SUM(YEAR, REPORTB("L_L",SIMU, YEAR,"PR-POLL-A") ) ;
LAB_NONSEA(SIMU) = SUM(YEAR, SUM(NSEA, REPORTB("L_L",SIMU, YEAR,NSEA) ) ) ;
TLABOR(SIMU)     = SUM(YEAR,REPORTA("LTOT_L",SIMU, YEAR))  ;

CAP_POLL_H(SIMU)  = SUM(YEAR, SUM(FSPOL,REPORTB("KI_L",SIMU,YEAR,FSPOL)) ) ;
CAP_NPLL_H(SIMU)  = SUM(YEAR, SUM(FSNPL,REPORTB("KI_L",SIMU,YEAR,FSNPL)) ) ;
CAP_POLL_P(SIMU)  = SUM(YEAR, REPORTB("KI_L",SIMU,YEAR,"PR-POLL-A") ) ;
CAP_NPLL_P(SIMU)  = SUM(YEAR, SUM(PRC,REPORTB("KI_L",SIMU,YEAR,PRC)) ) -   SUM(YEAR, REPORTB("KI_L",SIMU,YEAR,"PR-POLL-A") ) ;
CAP_NONSEA(SIMU) = SUM(YEAR, SUM(NSEA, REPORTB("KI_L",SIMU,YEAR,NSEA) ) ) ;
TCAPITAL(SIMU)   = SUM(YEAR,REPORTA("KTOT1_L",SIMU,YEAR)) + SUM(YEAR,REPORTA("KTOT2_L",SIMU,YEAR))+ SUM(YEAR,REPORTA("KTOT3_L",SIMU,YEAR)) ;

OUT_POLL_H(SIMU)  = SUM(YEAR, SUM(FSPOL,REPORTB("X_L",SIMU,YEAR,FSPOL)) ) ;
OUT_NPLL_H(SIMU)  = SUM(YEAR, SUM(FSNPL,REPORTB("X_L",SIMU,YEAR,FSNPL)) ) ;
OUT_POLL_P(SIMU)  = SUM(YEAR, REPORTB("X_L",SIMU,YEAR,"PR-POLL-A") ) ;
OUT_NPLL_P(SIMU)  = SUM(YEAR, SUM(PRC,REPORTB("X_L",SIMU,YEAR,PRC)) ) -   SUM(YEAR, REPORTB("X_L",SIMU,YEAR,"PR-POLL-A") ) ;
OUT_NONSEA(SIMU) = SUM(YEAR, SUM(NSEA, REPORTB("X_L",SIMU,YEAR,NSEA) ) ) ;
TOUTPUT(SIMU)     = SUM(YEAR, SUM(I, REPORTB("X_L",SIMU,YEAR,I))) ;

LINC_POLL_H(SIMU)  = SUM(YEAR, SUM(FSPOL,REPORTB("LABY_L",SIMU,YEAR,FSPOL)) ) ;
LINC_NPLL_H(SIMU)  = SUM(YEAR, SUM(FSNPL,REPORTB("LABY_L",SIMU,YEAR,FSNPL)) ) ;
LINC_POLL_P(SIMU)  = SUM(YEAR, REPORTB("LABY_L",SIMU,YEAR,"PR-POLL-A") ) ;
LINC_NPLL_P(SIMU)  = SUM(YEAR, SUM(PRC,REPORTB("LABY_L",SIMU,YEAR,PRC)) ) -   SUM(YEAR, REPORTB("LABY_L",SIMU,YEAR,"PR-POLL-A") ) ;
LINC_NONSEA(SIMU) = SUM(YEAR, SUM(NSEA, REPORTB("LABY_L",SIMU,YEAR,NSEA) ) ) ;

TLABINC(SIMU)     = LINC_POLL_H(SIMU)  + LINC_NPLL_H(SIMU)  + LINC_POLL_P(SIMU) + LINC_NPLL_P(SIMU)  + LINC_NONSEA(SIMU)  ;

KINC_POLL_H(SIMU)  = SUM(YEAR, SUM(FSPOL,REPORTB("CAPY1_L",SIMU,YEAR,FSPOL)) ) ;
KINC_NPLL_H(SIMU)  = SUM(YEAR, SUM(FSNPL,REPORTB("CAPY1_L",SIMU,YEAR,FSNPL)) ) ;
KINC_POLL_P(SIMU)  = SUM(YEAR, REPORTB("CAPY2_L",SIMU,YEAR,"PR-POLL-A") ) ;
KINC_NPLL_P(SIMU)  = SUM(YEAR, SUM(PRC,REPORTB("CAPY2_L",SIMU,YEAR,PRC)) ) -   SUM(YEAR, REPORTB("CAPY2_L",SIMU,YEAR,"PR-POLL-A") ) ;
KINC_NONSEA(SIMU) = SUM(YEAR, SUM(NSEA, REPORTB("CAPY3_L",SIMU,YEAR,NSEA) ) ) ;

TCAPINC(SIMU)     = KINC_POLL_H(SIMU)  + KINC_NPLL_H(SIMU)  + KINC_POLL_P(SIMU) + KINC_NPLL_P(SIMU)  + KINC_NONSEA(SIMU)  ;
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PARAMETER
VAL_POLL_H, VAL_NPLL_H, VAL_POLL_P, VAL_NPLL_P, VAL_NONSEA,
SAL_POLL_H, SAL_NPLL_H, SAL_POLL_P, SAL_NPLL_P, SAL_NONSEA, TOTSAL ;

VAL_POLL_H(SIMU)  = SUM(YEAR, SUM(FSPOL,REPORTB("VAL_L",SIMU,YEAR,FSPOL)) ) ;
VAL_NPLL_H(SIMU)  = SUM(YEAR, SUM(FSNPL,REPORTB("VAL_L",SIMU,YEAR,FSNPL)) ) ;
VAL_POLL_P(SIMU)  = SUM(YEAR, REPORTB("VAL_L",SIMU,YEAR,"PR-POLL-A") ) ;
VAL_NPLL_P(SIMU)  = SUM(YEAR, SUM(PRC,REPORTB("VAL_L",SIMU,YEAR,PRC)) ) -   SUM(YEAR, REPORTB("VAL_L",SIMU,YEAR,"PR-POLL-A") ) ;
VAL_NONSEA(SIMU) = SUM(YEAR, SUM(NSEA, REPORTB("VAL_L",SIMU,YEAR,NSEA) ) ) ;
TOTVAL(SIMU)     = SUM(YEAR, SUM(I,REPORTB("VAL_L",SIMU,YEAR,I))) ;

SAL_POLL_H(SIMU)  = SUM(YEAR, SUM(FSPOL,REPORTB("SAL_L",SIMU,YEAR,FSPOL)) ) ;
SAL_NPLL_H(SIMU)  = SUM(YEAR, SUM(FSNPL,REPORTB("SAL_L",SIMU,YEAR,FSNPL)) ) ;
SAL_POLL_P(SIMU)  = SUM(YEAR, REPORTB("SAL_L",SIMU,YEAR,"PR-POLL-A") ) ;
SAL_NPLL_P(SIMU)  = SUM(YEAR, SUM(PRC,REPORTB("SAL_L",SIMU,YEAR,PRC)) ) -   SUM(YEAR, REPORTB("SAL_L",SIMU,YEAR,"PR-POLL-A") ) ;
SAL_NONSEA(SIMU) = SUM(YEAR, SUM(NSEA, REPORTB("SAL_L",SIMU,YEAR,NSEA) ) ) ;
TOTSAL(SIMU)     = SUM(YEAR, SUM(I,REPORTB("SAL_L",SIMU,YEAR,I))) ;

PARAMETER
PQQ ;

Note: PQQ is used to calculate the welfare change

PQQ(SIMU,YEAR,CQ) = REPORTK("PQ_L",SIMU,YEAR,CQ) ;

PARAMETER
TTERM ;

TTERM(SIMU,H) = REPORTL("EXPD_L",SIMU, "YEAR47",H) /DCNT ;

PARAMETER
REPORTB_PREM, REPORTB_RNTO, REPORTB_RNT, RKC_UNITRNT, REPORTB_QSR, REPORTB_RAT22, REPORTB_REM ;

REPORTB_PREM(SIMU,YEAR,I)  = REPORTB("PREM_L",SIMU,YEAR,I)   ;
REPORTB_RNTO(SIMU,FS)      = REPORTB("RRENT_L","SIMU0","YEAR0",FS) ;
REPORTB_RNT(SIMU,YEAR,FS)  = REPORTB("RRENT_L",SIMU,YEAR,FS) ;
RKC_UNITRNT(YEAR,FSNPL)    = 0 ;
REPORTB_QSR(SIMU,YEAR,FS)  = REPORTB("QSLR_L",SIMU,YEAR,FS) ;
REPORTB_RAT22(SIMU,YEAR,FS)= REPORTB("RAT22_L",SIMU,YEAR,FS) ;
REPORTB_REM(SIMU,YEAR,FS)  = REPORTB("REMVAL_L",SIMU,YEAR,FS) ;

OPTION
REPORTB_QSR:8 ;

* ============== NEW PARAMETER

SET CCB(FS)   CRAB harvesting industries /
Crab-RK-A
Crab-SC-A
Crab-OT-A
/;

PARAMETER
OUT_SEA, LAB_SEA,

REPORTM_EXPD_AA, TOTALEXP,TOTEXPALLH,

REPORTB_RNT_RKC, REPORTB_QSR_RKC ;

OUT_SEA(SIMU) =   OUT_POLL_H(SIMU) + OUT_NPLL_H(SIMU) + OUT_POLL_P(SIMU) + OUT_NPLL_P(SIMU) ;
LAB_SEA(SIMU) =   LAB_POLL_H(SIMU) + LAB_NPLL_H(SIMU) + LAB_POLL_P(SIMU) + LAB_NPLL_P(SIMU) ;

REPORTM_EXPD_AA(SIMU,H) = REPORTM("EXPD_A",SIMU,"YEAR47",H) ;
TOTALEXP(SIMU,H)       = REPORTM_EXPD_AA(SIMU,H) + TTERM(SIMU,H) ;
TOTEXPALLH(SIMU)       = SUM(H,TOTALEXP(SIMU,H)) ;
REPORTB_RNT_RKC(SIMU,YEAR,CCB) = REPORTB("RRENT_L",SIMU,YEAR,CCB) ;
REPORTB_QSR_RKC(SIMU,YEAR,CCB) = REPORTB("QSLR_L", SIMU,YEAR,CCB) ;

OPTION
PQQ:8;

* New addition

SET RSLT RESULTS SET /

POLLHOUT
NPLLHOUT
POLLPOUT
NPLLPOUT
NSEAAOUT
TOTTTOUT

POLLHSAL
NPLLHSAL
POLLPSAL
NPLLPSAL
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NSEAASAL
TOTTTSAL

POLLHVAL
NPLLHVAL
POLLPVAL
NPLLPVAL
NSEAAVAL
TOTTTVAL

POLLHLAB
NPLLHLAB
POLLPLAB
NPLLPLAB
NSEAALAB
TOTTTLAB

TOTXWELL
TOTXWELM
TOTXWELH

TOTTWELL

/;


PARAMETER
RESULTTT  ;

RESULTTT(SIMU,"POLLHOUT") = OUT_POLL_H(SIMU) ;
RESULTTT(SIMU,"NPLLHOUT") = OUT_NPLL_H(SIMU) ;
RESULTTT(SIMU,"POLLPOUT") = OUT_POLL_P(SIMU) ;
RESULTTT(SIMU,"NPLLPOUT") = OUT_NPLL_P(SIMU) ;
RESULTTT(SIMU,"NSEAAOUT") = OUT_NONSEA(SIMU) ;
RESULTTT(SIMU,"TOTTTOUT") = TOUTPUT(SIMU) ;
RESULTTT(SIMU,"POLLHSAL") = SAL_POLL_H(SIMU) ;
RESULTTT(SIMU,"NPLLHSAL") = SAL_NPLL_H(SIMU) ;
RESULTTT(SIMU,"POLLPSAL") = SAL_POLL_P(SIMU) ;
RESULTTT(SIMU,"NPLLPSAL") = SAL_NPLL_P(SIMU) ;
RESULTTT(SIMU,"NSEAASAL") = SAL_NONSEA(SIMU) ;
RESULTTT(SIMU,"TOTTTSAL") = TOTSAL(SIMU) ;
RESULTTT(SIMU,"POLLHVAL") = VAL_POLL_H(SIMU) ;
RESULTTT(SIMU,"NPLLHVAL") = VAL_NPLL_H(SIMU) ;
RESULTTT(SIMU,"POLLPVAL") = VAL_POLL_P(SIMU) ;
RESULTTT(SIMU,"NPLLPVAL") = VAL_NPLL_P(SIMU) ;
RESULTTT(SIMU,"NSEAAVAL") = VAL_NONSEA(SIMU) ;
RESULTTT(SIMU,"TOTTTVAL") = TOTVAL(SIMU) ;
RESULTTT(SIMU,"POLLHLAB") = LAB_POLL_H(SIMU) ;
RESULTTT(SIMU,"NPLLHLAB") = LAB_NPLL_H(SIMU) ;
RESULTTT(SIMU,"POLLPLAB") = LAB_POLL_P(SIMU) ;
RESULTTT(SIMU,"NPLLPLAB") = LAB_NPLL_P(SIMU) ;
RESULTTT(SIMU,"NSEAALAB") = LAB_NONSEA(SIMU) ;
RESULTTT(SIMU,"TOTTTLAB") = TLABOR(SIMU) ;
RESULTTT(SIMU,"TOTXWELL") = TOTALEXP(SIMU,"LOW_HH") ;
RESULTTT(SIMU,"TOTXWELM") = TOTALEXP(SIMU,"MED_HH") ;
RESULTTT(SIMU,"TOTXWELH") = TOTALEXP(SIMU,"HI_HH") ;
RESULTTT(SIMU,"TOTTWELL") = TOTEXPALLH(SIMU) ;

PARAMETER
RGRP_RPT, RESRENT_RPT_POLL,VAL_POLL_HAR_PROC ;

RGRP_RPT(SIMU,YEAR)          = REPORTA("RGRP_L", SIMU, YEAR) ;
RESRENT_RPT_POLL(SIMU,YEAR)  = REPORTB("RRENT_L",SIMU,YEAR,"Pollock-A") ;
VAL_POLL_HAR_PROC(SIMU,YEAR) = REPORTB("VAL_L", SIMU, YEAR,"Pollock-A") + REPORTB("VAL_L", SIMU, YEAR,"PR-POLL-A")   ;

DISPLAY
RESULTTT, RGRP_RPT ;
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