# IUU Fishing: Economic Effects of IUU Imports on U.S. Commercial Fishers

## Species: Cod and Pollock

*Model Release*

**Read Me :**
This model accompanies the USITC report, *Seafood Obtained via Illegal, Unreported, and Unregulated Fishing: U.S. Imports and Economic Impact on U.S. Commercial Fisheries*, Inv. 332-575. The report includes a quantitative analysis of the economic impact of IUU imports on U.S. commercial fishers and U.S. commercial fishing production, trade, and prices. Economic effects are modeled by species, with each species-level model customized to fit the unique features of the U.S. domestic industry. Consumers of seafood products choose between domestic marine-capture sources, imports, and in some models, domestic aquaculture products. Imports include both legal and IUU sources that enter the U.S. at the same price, so consumers cannot distinguish an IUU from non-IUU product. 2018 data is used to establish an initial equilibrium with imports of IUU products included in the baseline. The model then removes the IUU imports, as estimated in chapter 3, and solves for a new equilibrium absent those products.

In the cod and pollock model, products are differentiated at the regional level. The four domestic varieties in the model are Atlantic cod, Pacific cod, Atlantic pollock, and Alaskan pollock. The two import sources are imported cod and imported pollock. The cod and pollock model includes cross-species substitution, so changes in the price of a pollock variety impacts the price of the cod varieties. Annual catch limits (ACLs) are enforced in the model so modeled increases in domestic landings cannot exceed their legal limits. Catch limits are modeled as a vertical asymptote directly in the supply equation and not as a constraint.

There are two markets modeled: unprocessed and processed products. Landings of cod and pollock flow to three destinations: the unprocessed market, the processed market, or are exported outside the country. The price of the processed cod and pollock is a constant markup over the price of the unprocessed cod and pollock, so increases in domestic prices of landed fish affect the price of processing. Initial consumption of unprocessed products, before the policy change was implemented, was calculated as a residual using 2018 conversion factors from NOAA.

Data inputs in the simulation are in the BLUE-shaded cells (with sources for the input data listed in the cell below). Outputs are in the GREEN-shaded cells. The white cells are intermediate calculations.

Note: p_xDU is the price of the unprocessed product sold to consumers. q_xDU is the quantity of landings, not the unprocessed quantity sold to U.S. consumers. The unprocessed quantity sold to U.S. consumers must exclude exports and processed product * conversion rate.

This PDF is a printout of the Mathematica file “IUU Fishing Model - cod and pollock - model release.nb”

```
ClearAll[f];
```

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# 1. Model Parameters

## 1.1 Within-Species Elasticity of Substitution

*Source: USITC's econometric estimation using the trade cost method in Riker (2020). More information can be found in the technical appendix (appendix I).*

**Unprocessed cod:** elasticity of substitution across varieties of unprocessed cod

In[ ]:=
```
sigmacu = 4.706;
```

**Processed cod:** elasticity of substitution across varieties of processed cod

In[ ]:=
```
sigmacp = 4.706;
```

**Unprocessed pollock:** elasticity of substitution across varieties of unprocessed pollock

In[ ]:=
```
sigmapu = 11.615;
```

**Processed pollock:** elasticity of substitution across  varieties of processed pollock

In[ ]:=
```
sigmapp = 11.615;
```

## 1.2 Cross-Species Elasticity of Substitution

*Source: USITC Staff Estimate and Interviews with Industry Participants.*

**Unprocessed:** elasticity of substitution across unprocessed cod and pollock

In[ ]:=
```
betau = 5.0;
```

**Processed:** elasticity of substitution across processed cod and pollock

In[ ]:=
```
betap = 5.0;
```

## 1.3 Industry Price Elasticity of Demand

*Source: USITC Staff Estimate.*

**Unprocessed**

In[ ]:=
```
etau = -1.0;
```

**Processed**

In[ ]:=
```
etap = -1.0;
```

## 1.4 Illegal Imports Replacement Rates

*Source: USITC Staff Estimate.  Further discussion on qualitative factors and rate determination can be found in appendix I of the USITC's report.*

**Unprocessed cod:** fraction of illegal imports replaced by legal imports of unprocessed cod

In[ ]:=
```
replcu = 0.30;
```

**Unprocessed pollock:** fraction of illegal imports replaced by legal imports of unprocessed pollock

In[ ]:=
```
replpu = 0.30;
```

**Processed cod:** fraction of illegal imports replaced by legal imports of processed cod

In[ ]:=
```
replcp = 0.30;
```

**Processed pollock:** fraction of illegal imports replaced by legal imports of processed pollock

In[ ]:=
```
replpp = 0.30;
```

### 1.5 Price Elasticity of Supply

*Source: USITC Staff Estimate and Interviews with Industry Participants.*

**U.S. landings of Pacific Cod**

In[ ]:=
```
ecb = 5.0;
```

**U.S. landings of Atlantic Cod**

In[ ]:=
```
eca = 5.0;
```

**U.S. landings of Alaskan Pollock**

In[ ]:=
```
epw = 5.0;
```

**U.S. landings of Atlantic Pollock**

In[ ]:=
```
epa = 5.0;
```

### 1.6 Conversion Factors

*Source: Conversion factors were obtained from NOAA Fisheries*

In[ ]:=
```
cr = 1.39;
```

## 2. Data Inputs

### 2.1 U.S. Landings Quantities and Prices

*Source: National Oceanic and Atmospheric Administration. National Marine Fisheries Service (NOAA Fisheries). Fisheries of the United States 2018. Current Fishery Statistics No. 2018. U.S. Department of Commerce. Silver Spring MD: NOAA, February 2020. https://www.-fisheries.noaa.gov/resource/document/fisheries-united-states-2018-report.*

**Alaskan Pollock**

In[ ]:=
```
qpwd0 = 1,525,855,000; (*kg*)
```

In[ ]:=
```
ppwd0 = 0.2957; (*$/kg*)
```

**Atlantic Pollock**

In[ ]:=
```
qpad0 = 3,074,000; (*kg*)
```

In[ ]:=
```
ppad0 = 1.7339;(*$/kg*)
```

### Pacific Cod

In[ ]:=
```
qcbd0 = 232,578,000;(*kg*)
```

In[ ]:=
```
pcbd0 = 1.0280;(*$/kg*)
```

### Atlantic Cod

In[ ]:=
```
qcad0 = 976,000;(*kg*)
```

In[ ]:=
```
pcad0 = 4.8945;(*$/kg*)
```

In[ ]:=
```
shrca = N[qcad0 / (qcad0 + qcbd0)];
```

## 2.2 U.S. Processing Production Quantities and Prices

*Source: National Oceanic and Atmospheric Administration. National Marine Fisheries Service (NOAA Fisheries). Fisheries of the United States 2018. Current Fishery Statistics No. 2018. U.S. Department of Commerce. Silver Spring MD: NOAA, February 2020. https://www.-fisheries.noaa.gov/resource/document/fisheries-united-states-2018-report.*

### Processed Alaskan Pollock

In[ ]:=
```
qpwpd0 = 200,304,000; (*kg*)
```

In[ ]:=
```
ppwpd0 = 3.0378; (*$/kg*)
```

### Processed Atlantic Pollock

In[ ]:=
```
qpapd0 = 358,000; (*kg*)
```

In[ ]:=
```
ppapd0 = 7.7067; (*$/kg*)
```

### Processed Atlantic Cod

In[ ]:=
```
qcapd0 = 28,288,000 shrca ; (*kg*)
```

In[ ]:=
```
pcapd0 = 11.7518; (*$/kg*)
```

### Processed Pacific Cod

In[ ]:=
```
qcbpd0 = 28,288,000 (1 - shrca); (*kg*)
```

In[ ]:=
```
pcbpd0 = 2.47; (*$/kg*)
```

## 2.3 Import Quantities and Prices

*Source: IUU Estimate Database as described in Chapter 3 of the report. Note that Alaskan pollock refers to Walleye pollock in the database, and Pacific cod refers to Pacific/Greenland cod in the database.*

### Unprocessed Pollock

Total imports

In[ ]:=
```
qput0 = 1,977,996; (*kg*)
```

In[ ]:=
```
put0 = 2.54326;(*$/kg*)
```

Illegal imports

In[ ]:=
```
qpui0 = 174,230;(*kg*)
```

### Unprocessed Cod

Total imports

In[ ]:=
```
qcut0 = 5,792,445; (*kg*)
```

In[ ]:=
```
pcut0 = 4.67084; (*$/kg*)
```

Illegal imports

In[ ]:=
```
qcui0 = 352,828; (*kg*)
```

### Processed Pollock

Total imports

In[ ]:=
```
qppt0 = 48,591,750; (*kg*)
```

In[ ]:=
```
pppt0 = 2.86468; (*$/kg*)
```

Illegal imports

In[ ]:=
```
qppi0 = 6,889,089;(*kg*)
```

### Processed Cod

Total imports

In[ ]:=
```
qcpt0 = 67,589,782; (*kg*)
```

In[ ]:=
```
pcpt0 = 8.11826;(*$/kg*)
```

Illegal imports

In[ ]:=
```
qcpi0 = 4,781,077;(*kg*)
```

Calculation of legal imports

In[ ]:=
```
qpul0 = qput0 - qpui0;
```

In[ ]:=
```
qcul0 = qcut0 - qcui0;
```

In[ ]:=
```
qppl0 = qppt0 - qppi0;
```

In[ ]:=
```
qcpl0 = qcpt0 - qcpi0;
```

## 2.4 Export Quantities

*Source:National Oceanic and Atmospheric Administration. National Marine Fisheries Service (NOAA Fisheries). NOAA US Trade in Fishery Products database. Accessed September 1, 2020. https://foss.nmfs.noaa.gov/apexfoss/f?p=215:2:14884747663545::NO*

In[ ]:=
```
qpae0 = 446,433 ; (*kg*)
```

In[ ]:=
```
qpwe0 =  55,839,578; (*kg*)
```

In[ ]:=
```
qcae0 = 284,184; (*kg*)
```

In[ ]:=
```
qcbe0 =  67,720,141;(*kg*)
```

In[ ]:=
```
qpwpe0 = 140,548,922; (*kg*)
```

In[ ]:=
```
qpape0 = 37,556;(*kg*)
```

In[ ]:=
```
qcape0 = 5,239,167 shrca;(*kg*)
```

In[ ]:=
```
qcbpe0 = 5,239,167 (1 - shrca);(*kg*)
```

## 2.5 Catch Limits

### Alaskan Pollock

*Source: National Oceanic and Atmospheric Administration. National Marine Fisheries Service (NOAA Fisheries). "Alaska Groundfish Harvest Specifications." Accessed November 19, 2020. https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/alaska-groundfish-harvest-specifications.*

In[ ]:=
```
qpwcap = 2,762,265,000; (*kg*)
```

### Atlantic Pollock

*Source: National Oceanic and Atmospheric Administration. National Marine Fisheries Service (NOAA Fisheries). "Northeast Multi-*

*species (Groundfish); Fishing Year 2018 Regulations," April 30, 2018. https://www.fisheries.noaa.gov/bulletin/northeast-multispecies-groundfish-fishing-year-2018-regulations.*

In[ ]:=
```
qpacap = 38,204,000;(*kg*)
```

### Pacific Cod

*Source: National Oceanic and Atmospheric Administration. National Marine Fisheries Service (NOAA Fisheries). "Alaska Groundfish Harvest Specifications." Accessed November 19, 2020. https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/alaska-groundfish-harvest-specifications.*

In[ ]:=
```
qcbcap = 242,721,000;(*kg*)
```

### Atlantic Cod

*Source: National Oceanic and Atmospheric Administration. National Marine Fisheries Service (NOAA Fisheries). "Northeast Multi-species (Groundfish); Fishing Year 2018 Regulations," April 30, 2018. https://www.fisheries.noaa.gov/bulletin/northeast-multispecies-groundfish-fishing-year-2018-regulations.*

In[ ]:=
```
qcacap = 2,185,000;(*kg*)
```

## 2.6 Import Market Share Statistics

Imports percent in market for unprocessed pollock

In[ ]:=
```
N[100 qput0 / (qput0 + (qpad0 - qpae0 - cr qpapd0) + (qpwd0 - qpwe0 - cr qpwpd0))]
```

Out[ ]= 0.165426

Imports percent in market for unprocessed cod

In[ ]:=
```
N[100 qcut0 / (qcut0 + (qcad0 - qcae0 - cr qcapd0) + (qcbd0 - qcbe0 - cr qcbpd0))]
```

Out[ ]= 4.38749

Imports percent in market for processed pollock

In[ ]:=
```
N[100 qppt0 / (qppt0 + (qpwpd0 - qpwpe0) + (qpapd0 - qpape0))]
```

Out[ ]= 44.7161

Imports percent in market for processed cod

In[ ]:=
```
N[100 qcpt0 / (qcpt0 + (qcapd0 - qcape0) + (qcbpd0 - qcbpe0))]
```

Out[ ]= 74.5706

# 3. Calibration

Baseline values of unprocessed and processed apparent consumption and imports

In[ ]:=
```
vput0 = qput0 pput0;
```

In[ ]:=
```
vcut0 = qcut0 pcut0;
```

```
vpwd0 = (qpwd0 - qpwe0 - cr qpwpd0) ppwd0;
vpad0 = (qpad0 - qpae0 - cr qpapd0) ppad0;
vcbd0 = (qcbd0 - qcbe0 - cr qcbpd0) pcbd0;
vcad0 = (qcad0 - qcae0 - cr qcapd0) pcad0;
vppt0 = qppt0 pppt0;
vcpt0 = qcpt0 pcpt0;
vpwpd0 = (qpwpd0 - qpwpe0) ppwpd0;
vpapd0 = (qpapd0 - qpape0) ppapd0;
vcapd0 = (qcapd0 - qcape0) pcapd0;
vcbpd0 = (qcbpd0 - qcbpe0) pcbpd0;
```

## 3.1 Supply Parameters

$$\text{ecad} = N\left[\text{eca}\,\frac{\text{qcad0}}{(\text{qcacap} - \text{qcad0})}\right];$$

$$\text{ecbd} = N\left[\text{ecb}\,\frac{\text{qcbd0}}{(\text{qcbcap} - \text{qcbd0})}\right];$$

$$\text{epad} = N\left[\text{epa}\,\frac{\text{qpad0}}{(\text{qpacap} - \text{qpad0})}\right];$$

$$\text{epwd} = N\left[\text{epw}\,\frac{\text{qpwd0}}{(\text{qpwcap} - \text{qpwd0})}\right];$$

$$\text{acad} = (\text{qcacap} - \text{qcad0})\,\text{pcad0}^{\text{ecad}};$$

$$\text{acbd} = (\text{qcbcap} - \text{qcbd0})\,\text{pcbd0}^{\text{ecbd}};$$

$$\text{apad} = (\text{qpacap} - \text{qpad0})\,\text{ppad0}^{\text{epad}};$$

$$\text{apwd} = (\text{qpwcap} - \text{qpwd0})\,\text{ppwd0}^{\text{epwd}};$$

## 3.2 Demand Parameters

$$\text{bcbd} = \frac{\text{vcbd0}}{\text{vcad0}}\left(\frac{\text{pcbd0}}{\text{pcad0}}\right)^{\text{sigmacu}-1};$$

$$\text{bcut} = \frac{\text{vcut0}}{\text{vcad0}}\left(\frac{\text{pcut0}}{\text{pcad0}}\right)^{\text{sigmacu}-1};$$

$$\text{Pcu0} = \left(\text{pcad0}^{1-\text{sigmacu}} + \text{bcbd}\,\text{pcbd0}^{1-\text{sigmacu}} + \text{bcut}\,\text{pcut0}^{1-\text{sigmacu}}\right)^{\frac{1}{1-\text{sigmacu}}};$$

$$\text{bpwd} = \frac{\text{vpwd0}}{\text{vpad0}}\left(\frac{\text{ppwd0}}{\text{ppad0}}\right)^{\text{sigmapu}-1};$$

$$\text{bput} = \frac{\text{vput0}}{\text{vpad0}}\left(\frac{\text{pput0}}{\text{ppad0}}\right)^{\text{sigmapu}-1};$$

$$Ppu0 = \left(ppad0^{1-sigmapu} + bpwd\ ppwd0^{1-sigmapu} + bput\ pput0^{1-sigmapu}\right)^{\frac{1}{1-sigmapu}};$$

$$bpu = \frac{vpad0 + vpwd0 + vput0}{vcad0 + vcbd0 + vcut0}\left(\frac{Ppu0}{Pcu0}\right)^{betau-1};$$

$$Pu0 = \left(Pcu0^{1-betau} + bpu\ Ppu0^{1-betau}\right)^{\frac{1}{1-betau}};$$

$$bcpt = \frac{vcpt0}{vcapd0}\left(\frac{pcpt0}{pcapd0}\right)^{sigmacp-1};$$

$$bcbpd = \frac{vcbpd0}{vcapd0}\left(\frac{pcbpd0}{pcapd0}\right)^{sigmacp-1};$$

$$Pcp0 = \left(pcapd0^{1-sigmacp} + bcbpd\ pcbpd0^{1-sigmacp} + bcpt\ pcpt0^{1-sigmacp}\right)^{\frac{1}{1-sigmacp}};$$

$$bppt = \frac{vppt0}{vpapd0}\left(\frac{pppt0}{ppapd0}\right)^{sigmapp-1};$$

$$bpwpd = \frac{vpwpd0}{vpapd0}\left(\frac{ppwpd0}{ppapd0}\right)^{sigmapp-1};$$

$$Ppp0 = \left(ppapd0^{1-sigmapp} + bpwpd\ ppwpd0^{1-sigmapp} + bppt\ pppt0^{1-sigmapp}\right)^{\frac{1}{1-sigmapp}};$$

$$bpp = \frac{vpapd0 + vpwpd0 + vppt0}{vcapd0 + vcbpd0 + vcpt0}\left(\frac{Ppp0}{Pcp0}\right)^{betap-1};$$

$$Pp0 = \left(Pcp0^{1-betap} + bpp\ Ppp0^{1-betap}\right)^{\frac{1}{1-betap}};$$

$$ku = \frac{qcut0\ Pu0^{-etau-betau}\ Pcu0^{betau-sigmacu}\ pcut0^{sigmacu}}{bcut};$$

$$kp = \frac{qcpt0\ Pp0^{-etap-betap}\ Pcp0^{betap-sigmacp}\ pcpt0^{sigmacp}}{bcpt};$$

# 4. New Equilibrium Calculation

$$Pcu = \left(pcad^{1-sigmacu} + bcbd\ pcbd^{1-sigmacu} + bcut\ pcut^{1-sigmacu}\right)^{\frac{1}{1-sigmacu}};$$

$$Ppu = \left(ppad^{1-sigmapu} + bpwd\ ppwd^{1-sigmapu} + bput\ pput^{1-sigmapu}\right)^{\frac{1}{1-sigmapu}};$$

$$pcapd = \frac{pcad\ pcapd0}{pcad0};$$

$$pcbpd = \frac{pcbd\ pcbpd0}{pcbd0};$$

$$ppapd = \frac{ppad\ ppapd0}{ppad0};$$

$$ppwpd = \frac{ppwd\ ppwpd0}{ppwd0};$$

```
In[•]:= Pu = (Pcu^(1-betau) + bpu Ppu^(1-betau))^(1/(1-betau));

In[•]:= Pcp = (pcapd^(1-sigmacp) + bcbpd pcbpd^(1-sigmacp) + bcpt pcpt^(1-sigmacp))^(1/(1-sigmacp));

In[•]:= Ppp = (ppapd^(1-sigmapp) + bpwpd ppwpd^(1-sigmapp) + bppt pppt^(1-sigmapp))^(1/(1-sigmapp));

In[•]:= Pp = (Pcp^(1-betap) + bpp Ppp^(1-betap))^(1/(1-betap));
```

### Equilibrium equations

Supply (landings) of Atlantic cod = exports + consumer demand for unprocessed fish + consumer demand for processed fish

```
In[•]:= E1 = qcacap - acad pcad^-ecad == cr qcape0 + qcae0 +
      ku Pu^(betau+etau) Pcu^(sigmacu-betau) pcad^-sigmacu + cr kp Pp^(betap+etap) Pcp^(sigmacp-betap) pcapd^-sigmacp;
```

Supply (landings) of Pacific cod = exports + consumer demand for unprocessed fish + consumer demand for processed fish

```
In[•]:= E2 = qcbcap - acbd pcbd^-ecbd == cr qcbpe0 + qcbe0 + ku bcbd Pu^(betau+etau) Pcu^(sigmacu-betau) pcbd^-sigmacu +
      cr kp bcbpd Pp^(betap+etap) Pcp^(sigmacp-betap) pcbpd^-sigmacp;
```

Supply (landings) of Atlantic pollock = exports + consumer demand for unprocessed fish + consumer demand for processed fish

```
In[•]:= E3 = qpacap - apad ppad^-epad == cr qpape0 + qpae0 +
      ku bpu Pu^(betau+etau) Ppu^(sigmapu-betau) ppad^-sigmapu + cr kp bpp Pp^(betap+etap) Ppp^(sigmapp-betap) ppapd^-sigmapp;
```

Supply (landings) of Alaskan pollock = exports + consumer demand for unprocessed fish + consumer demand for processed fish

```
In[•]:= E4 = qpwcap - apwd ppwd^-epwd == cr qpwpe0 + qpwe0 + ku bpwd bpu Pu^(betau+etau) Ppu^(sigmapu-betau) ppwd^-sigmapu +
      cr kp bpp bpwpd Pp^(betap+etap) Ppp^(sigmapp-betap) ppwpd^-sigmapp;
```

Supply of imported unprocessed product = Demand for imported unprocessed product

```
In[•]:= E5 = qcul0 + replcu qcui0 == ku bcut Pu^(betau+etau) Pcu^(sigmacu-betau) pcut^-sigmacu;

In[•]:= E6 = qpul0 + replpu qpui0 == ku bput bpu Pu^(betau+etau) Ppu^(sigmapu-betau) pput^-sigmapu;
```

Supply of imported processed product = Demand for imported processed product

```
In[•]:= E7 = qcpl0 + replcp qcpi0 == kp bcpt Pp^(betap+etap) Pcp^(sigmacp-betap) pcpt^-sigmacp;

In[•]:= E8 = qppl0 + replpp qppi0 == kp bppt bpp Pp^(betap+etap) Ppp^(sigmapp-betap) pppt^-sigmapp;

In[•]:= FindRoot[{E1, E2, E3, E4, E5, E6, E7, E8}, {pcad, pcad0}, {pcbd, pcbd0}, {ppad, ppad0},
      {ppwd, ppwd0}, {pcut, pcut0}, {pput, pput0}, {pcpt, pcpt0}, {pppt, pppt0}]

Out[•]= {pcad → 4.90224, pcbd → 1.02972, ppad → 1.73776, ppwd → 0.296148,
      pcut → 4.72171, pput → 2.5614, pcpt → 8.31757, pppt → 2.92315}

In[•]:= pcad1 = pcad /. %;

In[•]:= pcbd1 = pcbd /. %%;

In[•]:= ppad1 = ppad /. %%%;
```

```
In[ ]:= ppwd1 = ppwd /. %%%%;

In[ ]:= pcut1 = pcut /. %%%%%;

In[ ]:= pput1 = pput /. %%%%%%;

In[ ]:= pcpt1 = pcpt /. %%%%%%%;

In[ ]:= pppt1 = pppt /. %%%%%%%%;

In[ ]:= pcapd1 = (pcad1 pcapd0)/pcad0;

In[ ]:= pcbpd1 = (pcbd1 pcbpd0)/pcbd0;

In[ ]:= ppapd1 = (ppad1 ppapd0)/ppad0;

In[ ]:= ppwpd1 = (ppwd1 ppwpd0)/ppwd0;

In[ ]:= Pcu1 = (pcad1^(1-sigmacu) + bcbd pcbd1^(1-sigmacu) + bcut pcut1^(1-sigmacu))^(1/(1-sigmacu));

In[ ]:= Ppu1 = (ppad1^(1-sigmapu) + bpwd ppwd1^(1-sigmapu) + bput pput1^(1-sigmapu))^(1/(1-sigmapu));

In[ ]:= Pu1 = (Pcu1^(1-betau) + bpu Ppu1^(1-betau))^(1/(1-betau));

In[ ]:= Pcp1 = (pcapd1^(1-sigmacp) + bcbpd pcbpd1^(1-sigmacp) + bcpt pcpt1^(1-sigmacp))^(1/(1-sigmacp));

In[ ]:= Ppp1 = (ppapd1^(1-sigmapp) + bpwpd ppwpd1^(1-sigmapp) + bppt pppt1^(1-sigmapp))^(1/(1-sigmapp));

In[ ]:= Pp1 = (Pcp1^(1-betap) + bpp Ppp1^(1-betap))^(1/(1-betap));

In[ ]:= qcad1 = qcacap - acad pcad1^(-ecad);

In[ ]:= qcbd1 = qcbcap - acbd pcbd1^(-ecbd);

In[ ]:= qpad1 = qpacap - apad ppad1^(-epad);

In[ ]:= qpwd1 = qpwcap - apwd ppwd1^(-epwd);

In[ ]:= qcut1 = qcul0 + replcu qcui0;

In[ ]:= qput1 = qpul0 + replpu qpui0;

In[ ]:= qcpt1 = qcpl0 + replcp qcpi0;

In[ ]:= qppt1 = qppl0 + replpp qppi0;

In[ ]:= qcapd1 = qcape0 + kp Pp1^(betap+etap) Pcp1^(sigmacp-betap) pcapd1^(-sigmacp);

In[ ]:= qcbpd1 = qcbpe0 + kp bcbpd Pp1^(betap+etap) Pcp1^(sigmacp-betap) pcbpd1^(-sigmacp);

In[ ]:= qpapd1 = qpape0 + kp bpp Pp1^(betap+etap) Ppp1^(sigmapp-betap) ppapd1^(-sigmapp);

In[ ]:= qpwpd1 = qpwpe0 + kp bpp bpwpd Pp1^(betap+etap) Ppp1^(sigmapp-betap) ppwpd1^(-sigmapp);
```

# 5. Results

### Atlantic Cod

Percent change in domestic price of unprocessed Atlantic cod

In[ ]:=
$$\frac{(\text{pcad1} - \text{pcad0})\ 100}{\text{pcad0}}$$

Out[ ]= 0.158091

Percent change in quantity of domestic Atlantic cod landings

In[ ]:=
$$\frac{(\text{qcad1} - \text{qcad0})\ 100}{\text{qcad0}}$$

Out[ ]= 0.78732

Percent change in price of processed Atlantic cod

In[ ]:=
$$\frac{(\text{pcapd1} - \text{pcapd0})\ 100}{\text{pcapd0}}$$

Out[ ]= 0.158091

Percent change in quantity of processed Atlantic cod

In[ ]:=
$$\frac{(\text{qcapd1} - \text{qcapd0})\ 100}{\text{qcapd0}}$$

Out[ ]= 4.68659

Change ($) in operating income, unprocessed product

```
In[ ]:= N[ (1 / sigmacu) (pcad1 (qcad1 - qcae0 - cr qcapd1) - pcad0 (qcad0 - qcae0 - cr qcapd0)) ]
```

Out[ ]= 850.07

Change ($) in operating income, processed product

```
In[ ]:= N[ (1 / sigmacp) (pcapd1 (qcapd1 - qcape0) - pcapd0 (qcapd0 - qcape0)) ]
```

Out[ ]= 14 237.

Change in landings (in kg)

```
In[ ]:= N[qcad1 - qcad0]
```

Out[ ]= 7684.24

### Pacific Cod

Percent change in domestic price of unprocessed pacific cod

In[ ]:=
$$\frac{(\text{pcbd1} - \text{pcbd0})\ 100}{\text{pcbd0}}$$

Out[ ]=
```
0.166902
```

Percent change in quantity of domestic pacific cod landings

In[ ]:=
$$\frac{(\text{qcbd1} - \text{qcbd0})\ 100}{\text{qcbd0}}$$

Out[ ]=
```
0.758949
```

Percent change in price of processed pacific cod

In[ ]:=
$$\frac{(\text{pcbpd1} - \text{pcbpd0})\ 100}{\text{pcbpd0}}$$

Out[ ]=
```
0.166902
```

Percent change in quantity of processed pacific cod

In[ ]:=
$$\frac{(\text{qcbpd1} - \text{qcbpd0})\ 100}{\text{qcbpd0}}$$

Out[ ]=
```
4.65093
```

Change ($) in operating income, unprocessed product

In[ ]:=
```
N[ (1 / sigmacu) (pcbd1 (qcbd1 - qcbe0 - cr qcbpd1) - pcbd0 (qcbd0 - qcbe0 - cr qcbpd0)) ]
```

Out[ ]=
```
33,582.6
```

Change ($) in operating income, processed product

In[ ]:=
```
N[ (1 / sigmacp) (pcbpd1 (qcbpd1 - qcbpe0) - pcbpd0 (qcbpd0 - qcbpe0)) ]
```

Out[ ]=
```
708,906.
```

Change in landings (in kg)

In[ ]:=
```
N[qcbd1 - qcbd0]
```

Out[ ]=
$$1.76515 \times 10^{6}$$

### Atlantic Pollock

Percent change in domestic price of unprocessed Atlantic pollock

In[ ]:=
$$\frac{(\text{ppad1} - \text{ppad0})\ 100}{\text{ppad0}}$$

Out[ ]=
```
0.222859
```

Percent change in quantity of domestic Atlantic pollock landings

In[ ]:=
$$\frac{(\text{qpad1} - \text{qpad0})\ 100}{\text{qpad0}}$$

Out[ ]=
```
1.11251
```

Percent change in price of processed Atlantic pollock

In[ ]:=
$$\frac{(\text{ppapd1} - \text{ppapd0})\ 100}{\text{ppapd0}}$$

Out[ ]=
```
0.222859
```

Percent change in quantity of processed Atlantic pollock

In[ ]:=
$$\frac{(\text{qpapd1} - \text{qpapd0})\ 100}{\text{qpapd0}}$$

Out[ ]=
```
9.84008
```

Change ($) in operating income, unprocessed product

In[ ]:=
```
N[ (1 / sigmapu) (ppad1 (qpad1 - qpae0 - cr qpapd1) - ppad0 (qpad0 - qpae0 - cr qpapd0)) ]
```

Out[ ]=
```
-1500.82
```

Change ($) in operating income, processed product

In[ ]:=
```
N[ (1 / sigmapp) (ppapd1 (qpapd1 - qpape0) - ppapd0 (qpapd0 - qpape0)) ]
```

Out[ ]=
```
23,899.8
```

Change in landings (in kg)

In[ ]:=
```
N[qpad1 - qpad0]
```

Out[ ]=
```
34,198.7
```

### Alaskan/Pacific Pollock

Percent change in domestic price of unprocessed Alaskan pollock

In[ ]:=
$$\frac{(\text{ppwd1} - \text{ppwd0})\ 100}{\text{ppwd0}}$$

Out[ ]=
```
0.151365
```

Percent change in quantity of domestic Alaskan pollock landings

In[ ]:=
$$\frac{(\text{qpwd1} - \text{qpwd0})\ 100}{\text{qpwd0}}$$

Out[ ]=
```
0.752732
```

Percent change in price of processed Alaskan pollock

In[ ]:=
$$\frac{(\text{ppwpd1} - \text{ppwpd0})\ 100}{\text{ppwpd0}}$$

Out[ ]=
```
0.151365
```

Percent change in quantity of processed Alaskan pollock

In[ ]:=
$$\frac{(\text{qpwpd1} - \text{qpwpd0})\ 100}{\text{qpwpd0}}$$

Out[ ]=
```
3.55515
```

Change ($) in operating income, unprocessed product

In[ ]:=
$$\text{N}\left[\left(1 / \text{sigmapu}\right)\ \left(\text{ppwd1}\ \left(\text{qpwd1} - \text{qpwe0} - \text{cr}\ \text{qpwpd1}\right)\ -\ \text{ppwd0}\ \left(\text{qpwd0} - \text{qpwe0} - \text{cr}\ \text{qpwpd0}\right)\right)\right]$$

Out[ ]=
```
86,388.9
```

Change ($) in operating income, processed product

In[ ]:=
$$\text{N}\left[\left(1 / \text{sigmapp}\right)\ \left(\text{ppwpd1}\ \left(\text{qpwpd1} - \text{qpwpe0}\right)\ -\ \text{ppwpd0}\ \left(\text{qpwpd0} - \text{qpwpe0}\right)\right)\right]$$

Out[ ]=
$$1.88894 \times 10^{6}$$

Change in landings (in kg)

In[ ]:=
$$\text{N}[\text{qpwd1} - \text{qpwd0}]$$

Out[ ]=
$$1.14856 \times 10^{7}$$

### Cod Imports

Percent change in price of unprocessed cod imports

In[ ]:=
$$\frac{(\text{pcut1} - \text{pcut0})\ 100}{\text{pcut0}}$$

Out[ ]=
```
1.08911
```

Percent change in quantity of unprocessed cod imports

In[ ]:=
$$\frac{(\text{qcut1} - \text{qcut0})\ 100}{\text{qcut0}}$$

Out[ ]=
```
-4.26382
```

Percent change in price of processed cod imports

In[ ]:=
$$\frac{(\text{pcpt1} - \text{pcpt0})\ 100}{\text{pcpt0}}$$

Out[ ]=
```
2.45513
```

Percent change in quantity of processed cod imports

In[ ]:=
$$\frac{(\text{qcpt1} - \text{qcpt0})\ 100}{\text{qcpt0}}$$

Out[ ]=
```
-4.95157
```

**Pollock Imports**

Percent change in price of unprocessed pollock imports

In[ ]:=
$$\frac{(\text{pput1} - \text{pput0})\ 100}{\text{pput0}}$$

Out[ ]=
```
0.713169
```

Percent change in quantity of whole unprocessed pollock imports

In[ ]:=
$$\frac{(\text{qput1} - \text{qput0})\ 100}{\text{qput0}}$$

Out[ ]=
```
-6.16589
```

Percent change in price of processed pollock imports

In[ ]:=
$$\frac{(\text{pppt1} - \text{pppt0})\ 100}{\text{pppt0}}$$

Out[ ]=
```
2.041
```

Percent change in quantity of processed pollock imports

In[ ]:=
$$\frac{(\text{qppt1} - \text{qppt0})\ 100}{\text{qppt0}}$$

Out[ ]=
```
-9.92424
```

### Percent change in price indexes

In[ ]:=
$$\left\{\frac{(\text{Pcu1} - \text{Pcu0})\ 100}{\text{Pcu0}}, \frac{(\text{Ppu1} - \text{Ppu0})\ 100}{\text{Ppu0}}, \frac{(\text{Pu1} - \text{Pu0})\ 100}{\text{Pu0}}, \frac{(\text{Pcp1} - \text{Pcp0})\ 100}{\text{Pcp0}}, \frac{(\text{Ppp1} - \text{Ppp0})\ 100}{\text{Ppp0}}, \frac{(\text{Pp1} - \text{Pp0})\ 100}{\text{Pp0}}\right\}$$

Out[ ]=
```
{0.321034, 0.159675, 0.208838, 2.2262, 0.916093, 1.76114}
```