A NON-TECHNICAL GUIDE TO THE PE MODELING PORTAL

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Abstract

In this working paper, we present a non-technical guide for users of the Partial Equilibrium (PE) Modeling Portal (`https://www.usitc.gov/data/pe_modeling/index.htm`). We describe the fundamental assumptions used in each model on the portal and present a series of steps that users can follow to choose the right model for their analysis. We also include data sources and elasticity academic literature to help guide model input choices.

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1 Introduction

Partial equilibrium (PE) models are useful tools for simulating the economic effects of a trade policy change on a specific industry. The models are grounded in economic theory and can be applied to a wide variety of industries and policy scenarios. The PE Modeling Portal (`https://www.usitc.gov/data/pe_modeling/index.htm`) is a research initiative by economists at the USITC to present easy-to-apply PE models for public use. The purpose of this working paper is to provide a non-technical how-to guide for users of the PE Modeling Portal. [1] This working paper will be updated regularly when additional models are added to the portal.

In Section 2, we describe how to select a model on the PE Modeling Portal. In Section 3, we list resources available for elasticity parameter values and data inputs. Then we provide a non-technical write-up of each of the models found on the portal in Section 4.

2 Selecting a Model

Some users of the PE Modeling Portal know the exact model they need before arriving at the site. Other users may have a specific research question in mind, but do not know what model to choose to address their research question. This section is for the latter group who need some direction when choosing a portal model. The list below contains questions to ask to help guide model choice.

1. What is the change in trade policy that you want to analyze?

    - The majority of models on the portal focus on a tariff increase or decrease. If the policy that is changing is a tariff, this question only slightly narrows down the list of choices. In this case, continue reading the questions below.
    - For a quota model, see the Binding Import Quota Model in Section 4.6.
    - For a model of foreign direct investment (FDI), see the FDI, Trade, and Pricing Model in Section 4.18.
    - For a model that analyzes changes in firm costs, like fixed costs of production or exporting, see Sections 4.11 and 4.12. For a model of offshoring tasks and wage changes, see Section 4.16.
    - For a model of changing intellectual property rights (IPRs), see Sections 4.14 and 4.15.

2. How concentrated is your industry? Are there a large number of suppliers (perfect competition), or a small number of firms with market power (imperfect competition)?

    - If market power is not an important feature of the industry under consideration, then choose one of the many perfect competition models.

[1] In addition to this document, there is technical documentation on the Portal that provide equations of the models.

- If market power is an important feature of your industry, then an imperfect competition model should be used. For an imperfect competition model with differentiated products where firms set prices to maximize profits, see the Bertrand model in Section 4.8. For an imperfect competition model with perfectly substitutable goods where firms set quantities to maximize profits, see the Cournot models in Section 4.9. If your market has a monopoly, see the monopoly tariff model in Section 4.10. For a Bertrand model with affiliated entities, see Section 4.18.

3. How willing are consumers to substitute or switch across products in response to a change in relative prices? There are several different ways that substitution between products is modeled on the portal:

   - The standard trade policy model is the constant elasticity of substitution (CES) tariff model in Section 4.1. This model has one substitution elasticity that describes substitutability across all sources of supply. If you would like more variety in substitution patterns, and wish to group your sources of supply, use the nested CES models described in Section 4.2 of this paper. This model has two substitution elasticities and allows users to group some sources of supply into a more substitutable nest. Modelers commonly nest all imported varieties in an industry and keep the domestic variety outside the nest, though other patterns are available. The imported varieties are given a higher elasticity value than the domestic-import substitution elasticity.[2]
   - There are also models that depart from standard CES preferences to offer greater flexibility in substitution patterns. The log-linear model in Section 4.7 is minimally restricted and most flexible. The translog model in Section 4.21 offers a theory-consistent model with greater variety in substitution patterns than the CES model but less than the log-linear model.

4. Do you need a long-run (static) model or a multi-period (dynamic) model with policy changes scheduled over time?[3] Do you need to capture inventory stockpiling or storage in anticipation of a tariff, long growth/build cycles, or other multi-period settings?

   - The portal currently has two multi-period dynamic models. The time to build tariff model in Section 4.19 should be chosen for products that have a production lag or take a long time to build or grow (e.g. agriculture). The stockpiling model in Section 4.20 is applicable in situations where the tariff change is announced before it enters into force, allowing producers to stockpile products ahead of the tariff imposition.

[2] Many modelers use the rule-of-two, where the substitution elasticity among imported varieties is twice as high as that between imports and domestic products. For many products, there is greater substitutability between imported varieties than there is between domestic and imported varieties.

[3] The static models are technically timeless, or silent about speed of adjustment. In the context of multi-period dynamic models, they are considered long-term.

- All other models on the portal are considered static. If you do not need a multi-period setting, then choose among the static models.

3 Data and Elasticities Sources

The models provided on the PE Modeling Portal were designed to minimize user data requirements and make the models practical to apply. In the sub-sections below, we list references to help the user find data for their model.

3.1 Elasticities

Users of these models must enter elasticity values that describe the reaction of supply and demand to price changes in the particular industry under consideration. The model descriptions in Section 4 list the elasticities required for each model with a brief model-specific definition. In general, the price elasticity of industry demand is a parameter that reflects the responsiveness of total industry demand to changes in the average price level. It is the percent change in total industry quantity demanded in response to a 1% change in the industry average price. The price elasticity of supply parameter is a similar concept but for the supply side of the market. It reflects responsiveness of quantity supplied to changes in prices from each source. For example, it captures how domestic supply responds to a 1% increase in the domestic price. The elasticity of substitution broadly represents the willingness of a consumer to substitute across varieties, or sources of supply, in response to a relative price change. For example, this parameter captures the relative quantity change of a domestic product if the price for the domestic product increases by 1% more than the imported product.

For the elasticity of substitution, there are several academic studies that provide econometrically-estimated elasticity values by sector or industry. As a resource for choosing an elasticity of substitution value for your industry, consider some useful publications below:

1. Broda and Weinstein (2006), "Globalization and Gains from Variety", estimated at the 10-digit HTS level.

2. Hertel, Hummels, Ivanic and Keeney (2007), "How Confident Can We Be of CGE-based Assessments of Free Trade Agreements?" at the GTAP sector level.

3. Soderbery (2015), "Estimating Import Supply and Demand Elasticities: Analysis and Implications," estimated at the 8- and 10- digit HTS level. Website link: `http://web.ics.purdue.edu/~asoderbe/Site/Elasticities_LIML.html`

4. Caliendo and Parro (2015), "Estimates of the Trade and Welfare Effects of NAFTA", estimated at the 2-digit ISIC Rev3 level.

5. Soderbery (2015), "Trade Elasticities, Heterogeneity, and Optimal Tariffs", estimated at the 4-digit HS level.

6. Ahmad and Riker (2019), Elasticity of Substitution Dataset for U.S. Manufacturing Industries, estimated at the 4- and 6-digit NAICS level. The full dataset can be found at the bottom of the PE modeling portal here: `https://www.usitc.gov/data/pe_modeling/index.htm`

3.2 Production data

Most models will ask for data on the value of domestic production or shipments, as well as imports. For U.S. production or shipments, the U.S. Census publishes official U.S. Shipment data from its Annual Survey of Manufactures, which can be found at `https://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml`. The USITC publishes U.S. import and export data on its Dataweb at `https://dataweb.usitc.gov/`. The Worldbank publishes global trade data on its World Integrated Trade Solution at `https://wits.worldbank.org/`.

3.3 Tariff data

The WTO's tariff analysis tool provides global tariff data on applied and bound rates. This information can be found at `https://tao.wto.org/`. The USITC publishes official U.S. tariff rates in the Harmonized Tariff Schedule. This information can be found at `https://www.usitc.gov/tata/hts/index.htm`.

4 Model Descriptions

4.1 CES Tariff Model

File name: Euler Method PE Tariff Model with Non-Nested CES and Three Sources of Supply

The constant elasticity of substitution (CES) model with perfect competition is the most common model in industry-specific trade policy analysis. It features one national market with three sources of supply.[4] Consumers choose to buy domestically-produced products, imports that are subject to the tariff change, or imports not subject to the tariff change. The policy change is an increase or decrease in an ad valorem tariff on subject imports. The model presents impacts on prices, quantities, and expenditures in the industry under consideration.[5] For example, this model would be appropriate for analyzing the price, quantity, and expenditure effects of a 10 percent tariff

[4] The industry may have many more sources of supply, but they are aggregated into three sources to simplify the model.

[5] The model does not estimate indirect effects or changes to general equilibrium conditions, such as economy-wide welfare.

increase on Chilean apples in a single market with one domestically-produced variety of apples and two imported varieties (subject Chilean imports and all other non-subject imports).

4.1.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits, there is unlimited entry and exit, and the new equilibrium is calculated by setting supply equal to demand.
- **Products differentiated by source:** Products are imperfectly substitutable across countries, and there is a different price for products originating from each of the three sources.
- **CES:** Demand is modeled using equations with CES functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.1.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input demand and supply elasticity values as described below:[6]

1. **Price elasticity of supply:** Represents the responsiveness of quantity supplied to changes in the price from an individual source. There is one price elasticity of supply for each of the sources of products. Typically, both subject and non-subject import sources have higher price elasticities of supply than the domestic source.
2. **Elasticity of substitution:** Describes substitutability, or the extent of product differentiation, across all three sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.[7]
3. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

[6] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

[7] If the industry exhibits more variety in substitution patterns, a nested CES model would be preferable to a non-nested model. Both variations are available on the PE Modeling portal.

4.1.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibrium. For the non-nested CES model with perfect competition, users enter:

- initial value of domestic shipments[8]
- initial value of subject imports
- initial value of non-subject imports
- initial tariff rate on the subject imports source
- new tariff rate on the subject imports source

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.1.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of the CES model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.2 CES Tariff Model with Nesting

Import nesting file name: Euler Method PE Model with Ad Valorem Tariffs and Nested CES Preferences
Domestic + subject import nesting file name: MEM PE Model with Nested Preferences (D+S Nest)
Domestic + non-subject import nesting file name: MEM PE Model with Nested Preferences (D+N Nest)

This model is a variant of the constant elasticity of substitution (CES) Tariff model described

[8] Users can enter market share data instead of values.

in section 4.1.[9] Similarly, this model features one national market with three sources of supply: domestically-produced products, imports not subject to the tariff change, and imports that are subject to the tariff change.[10] In contrast to the non-nested CES model, this model allows for more variety in substitution patterns. This is represented by a higher elasticity of substitution value between two sources, which make up the nest, as compared to the differing elasticity value between the nest and the third source. With slight variations, this model is compatible with any configuration of sources making up the nest: subject and non-subject imports, subject imports and domestic product, or non-subject-imports and domestic products. For example, this model would be appropriate for analyzing the price, quantity, and expenditure effects of a 10 percent tariff increase on Vietnamese t-shirts in a single market with one, high-quality domestically-produced variety of t-shirts and two imported varieties (subject Vietnamese imports and all other non-subject imports). The two imported varieties are generally of similar quality, therefore they are relatively more substitutable (nested) than the domestically-produced and composite imports.

4.2.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits, there is unlimited entry and exit, and the new equilibrium is calculated by setting supply equal to demand.
- **Products differentiated by source:** Products are imperfectly substitutable across countries, and there is a different price for products originating from each of the three sources.
- **Nested CES:** Demand is modeled using equations with CES functional forms. The model assumes a nested CES structure so the substitutability of the two nested sources of supply is represented by a higher elasticity value than the value used to represent the substitutability between the nest and the third source.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.2.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input demand and supply elasticity values as described below:[11]

[9] This section (4.2) serves as a description for three models on the PE Modeling Portal: the CES Tariff Model with Nesting of Subject and Non-Subject Imports .(xlsx), the CES Tariff Model with Nesting of the Domestic Product and Subject Imports (.xlsx), and the CES Tariff Model with Nesting of the Domestic Product and Non-Subject Imports (.xlsx).

[10] The industry may have many more sources of supply, but they are aggregated into three sources to simplify the model.

[11] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates

1. **Price elasticity of supply:** Represents the responsiveness of quantity supplied to changes in the price from an individual source. There will be one price elasticity of supply for each of the sources of products. Typically, both subject and non-subject import sources have higher price elasticities of supply than the domestic source.

2. **Elasticity of substitution:** There are two elasticity values that describe substitutability, or extent of product differentiation–one between the two nested sources, and one between the nest and the third source. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases. Some modelers use the rule-of-two, where the elasticity of substitution inside the nest is twice as high as the out-side elasticity of substitution.

3. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

4.2.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibrium. For the nested CES model with perfect competition, users enter:

- initial value of domestic shipments[12]
- initial value of subject imports
- initial value of non-subject imports
- initial tariff rate on the subject imports source
- new tariff rate on the subject imports source

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.2.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

for non-subject imports, and other market factors.

[12] Users can enter market share data instead of values.

All results are expressed in percent change form. One nice property of the CES model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.3 CES Tariff Model without a Domestic Industry

File name: Euler Method PE Tariff Model with Non-Nested CES and Two Sources of Supply

This model is a variant of the constant elasticity of substitution (CES) Tariff model described in section 4.1. Similarly, this model features one national market with two foreign sources of supply: imports not subject to the tariff, and imports that are subject to the tariff.[13] In contrast to the non-nested CES model, this model does not have a domestic source of supply and assumes that this will be the case even after the tariff change. This model presents impacts on prices, quantities, and expenditures of the two imported varieties in the industry under consideration. For example, this model would be appropriate for analyzing the price, quantity, and expenditure effects of a 10 percent tariff decrease on Japanese chemicals, such as mixtures of tungsten, in a single market with no domestically-produced variety of such chemicals, and two imported varieties (subject Japanese imports and all other non-subject imports).

4.3.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits and the new equilibrium is calculated by setting supply equal to demand.
- **Products differentiated by source:** Products are imperfectly substitutable across importing countries, and there is a different price for products originating from each of the foreign sources.
- **CES:** Demand is modeled using equations with CES functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

[13] The industry may have many more sources of supply, but they are aggregated into two sources to simplify the model.

4.3.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input demand and supply elasticity values as described below:[14]

1. **Price elasticity of supply:** Represents the responsiveness of quantity supplied to changes in the price from an individual source. There will be one price elasticity of supply for each of the sources of products. There is no price elasticity of supply value for the domestic source because no domestic product exists.

2. **Elasticity of substitution:** Describes substitutability, or the extent of product differentiation, across the two foreign sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.

3. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

4.3.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibrium. For the non-nested CES model with perfect competition and no domestic production, users enter:

- initial value of subject imports [15]
- initial value of non-subject imports
- initial tariff rate on the subject imports source
- new tariff rate on the subject imports source

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.3.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new

[14] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

[15] Users can enter market share data instead of values.

tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this CES model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.4 CES Tariff Model with Two or Three Countries

Two country file name: Euler Method PE Tariff Model with Two National Markets
Three country file name: Three Regions Tariff Model

This model[16] is a variant of the CES Tariff model described in section 4.1. The two country version of the model features two source countries that simultaneously serve as destination markets, whereas the three country version features three source countries that simultaneously serve as destination markets. Consumers in each destination market choose to buy either domestically-produced products or imports that may or may not be subject to tariffs.

In either version of the model, the policy change can vary by destination market as an increase or decrease in an ad valorem tariff on subject imports of source countries. For example, in a two country model, country A can increase the ad valorem tariff on subject imports from country B, or both country A and B can change the ad valorem tariff on subject imports from each other by different amounts, etc. Similarly, in the three country model, country A can change the ad valorem tariff on subject imports from countries B and C by different amounts, or countries B and C can change the tariff on subject imports from country A by different amounts, etc. The model presents impacts on prices, quantities, and expenditures in each of the destination markets under consideration. The two country version of this model is available on the PE Modeling Portal in a spreadsheet format, while the three country version (three sources of supply and three destination markets) is available as a Mathematica notebook file.

4.4.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in each destination market. This means that firms earn zero profits, there is unlimited entry and exit, and the new equilibrium is calculated by setting supply equal to demand for each country and product.

[16] This section (4.4) serves as a description for two models on the PE Modeling Portal: the constant elasticity of substitution (CES) Tariff Model with Two Countries (xlsx) and the CES Tariff Model with Three Countries or Regions (mathematica notebook).

- **Products differentiated by source:** Products are imperfectly substitutable across countries, and there is a different price for products originating from each of the sources.
- **CES:** Demand is modeled using equations with CES functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.4.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input demand and supply elasticity values as described below:[17]

1. **Price elasticity of supply:** Represents the responsiveness of quantity supplied to changes in the price from an individual source. Regardless of the model version, there will be one price elasticity of supply for each of the sources of products.
2. **Elasticity of substitution:** Describes substitutability, or the extent of product differentiation, across all sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases. Regardless of the model version, the chosen elasticity value is the same for each destination market under consideration.
3. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up. Regardless of the model version, there is one price elasticity of industry demand for each of the destination markets under consideration.

4.4.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibria. For the CES tariff model with two or three countries, users enter:

- initial value of domestic shipments in each destination market
- initial value of imports from each source of supply to each destination market
- initial tariff rates on imports from each source to each destination market

[17] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

- new tariff rates on the subject imports from each source to each destination market. If there is no change from the initial tariff rate for a unique source-destination combination, simply input 0.

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.4.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.5 Tariff Model with Intermediate Imports

File name: Partial Equilibrium Tariff Model with Imported Intermediates

This model includes two sources of final products supply and two sources of intermediate products supply to a single market. The two sources are domestic shipments and foreign subject imports. Intermediate inputs are combined with value added to produce a final good. Firms in the market choose: (1) levels of intermediate products or other production inputs, (2) levels of domestically-produced or imported intermediate products, and consumers can choose between buying either domestically-produced or imported final products. This model can simulate the effects of tariff changes for both intermediate products and final products on prices, quantities and volumes of production in the market.

4.5.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits, there is unlimited entry and exit, and the new equilibrium is calculated by setting supply equal to demand.
- **Products differentiated by source:** Products are imperfectly substitutable across countries, and there is a different price for products originating from each of the sources.

- **Perfectly elastic supply of inputs:** The model assumes supply of inputs is perfectly elastic, so wages and factor prices are determined outside of the model (exogenous) and do not vary.
- **CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.5.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input elasticity values as described below:[18]

1. **Elasticity of substitution:** There are three elasticity of substitution parameters, one between sources of final products, one between sources of intermediate products, and one between intermediates and other production inputs. The elasticity of substitution between final products describes substitutability, or the extent of product differentiation, between the two sources of final products. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases. The elasticity of substitution between intermediate products describes substitutability, or level of product differentiation, between the two sources of intermediate products. The elasticity of substitution between intermediates and other production inputs describes substitutability between inputs into production.

4.5.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the initial equilibrium. For the model with intermediate imports, users enter:

- initial tariff on intermediate products
- new tariff on intermediate products
- initial tariff on final products
- new tariff on final products
- share of imports in expenditure on final products

[18] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

- share of imports in expenditure on intermediate products
- cost share of intermediate products

4.5.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.6 Model with a Binding Import Quota

File name: Euler Method PE Quota Model with Nested Preferences

This variant includes three sources of supply to a single national market.[19] The model can simulate the effects of a binding quota on prices, quantities, and volumes of production in the market. For example, this model would be appropriate for analyzing the price, quantity, and expenditure effects of an increase in the quota for imports of agricultural products, such as Korean dairy products. In this case, buyers would choose between dairy products of a domestically-produced variety, a subject Korean variety, and non-subject variety.

4.6.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits, there is unlimited entry and exit, and the new equilibrium is calculated by setting supply equal to demand.
- **Products differentiated by source:** Products are imperfectly substitutable across countries, and there is a different price for products originating from each of the sources.
- **Supply of subject imports is perfectly inelastic:** The model fixes the level of subject imports to an exogenously-determined (outside the model) quota level.

[19] The industry may have many more sources of supply, but they are aggregated into three sources to simplify the model.

- **Nested CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a nested CES structure so the substitutability of the two nested sources of supply is represented by a higher elasticity value than the value used to represent the substitutability between the nest and the third source. If the industry being considered exhibits a non-nested CES structure rather than a nested CES structure, simply input the same elasticity of substitution values.
- **Unexpected policy change:** There is no schedule to policy changes. The model does not separately distinguish policy announcements and entry into force.

4.6.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input demand and supply elasticity values as described below:[20]

1. **Price elasticity of supply:** Represents the responsiveness of quantity supplied to changes in the price from an individual source. The higher the value, the more responsive the supplier is to a change in price. Note that there is no subject import supply elasticity because the new equilibrium quantity supplied is equal to the binding quota value.
2. **Elasticity of substitution:** This model assumes a nested CES structure. That means there are two elasticity of substitution parameters, the elasticity of substitution between the domestic and imported products, and the elasticity of subsitution between import varieties. This elasticity describes substitutability, or extent of product differentiation between varieties. The higher the value, the more willing consumers are to switch from domestic to imported (or visa versa) in response to a relative price increase. Some modelers use the rule-of-two, where the elasticity in the nest is twice that of the other.
3. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

4.6.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the initial equilibrium. For the binding import quota model, users enter:

- initial value of domestic shipments

[20] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

- initial value of subject imports
- initial value of non-subject imports
- value of the subject import binding quota

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.6.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.7 Tariff Model with Log-Linear Demand

File name: Tariff Model with Log-Linear Demand

This model is an alternative to the constant elasticity of substitution (CES) Tariff Model described in section 4.1. The model features one national market with three sources of supply.[21] Consumers choose to buy from the domestic source, from imports that are subject to the tariff policy change, and from non-subject imports. The policy change is an increase or decrease in an ad valorem tariff on subject imports. Instead of CES preferences, the model uses a more flexible system of log-linear demand equations. With a more flexible demand system, model users can input a wider variety of substitution patterns across the three sources of supply. This means that users of this model must input values for all nine elasticity parameters. The model simulates the effects of the tariff change on prices, quantities, and expenditures in the industry under consideration.

[21] The industry may have many more sources of supply, but they are aggregated into three sources to simplify the model.

4.7.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits, there is unlimited entry and exit, and the new equilibrium is calculated by setting supply equal to demand.
- **Products differentiated by source:** Products are differentiated by source country and there is a different price for each source of supply.
- **Log-Linear Demand:** Demand is modeled using a flexible log-linear demand system with constant own- and cross-price elasticities of demand.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.7.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input demand and supply elasticity values as described below:[22]

1. **Own and Cross Price Elasticities of Demand:** There is one price elasticity of demand for each combination of sources. For a three-source model, there are nine own- and cross-price elasticities of demand. Own-price elasticities describe how the quantity of good x changes in response to a price change in good x. Own-price elasticities of demand should be negative values, reflecting a downward sloping demand curve, so demand falls as prices go up. Cross-price elasticities of demand describe how the quantity demanded of good x changes with respect to a price change in good y. Cross-price elasticities of demand parameters that are positive reflect products that are substitutes.
2. **Price elasticity of supply:** Represents the responsiveness of quantity supplied to changes in the price from an individual source. There is one price elasticity of supply for each of the sources of products. Typically, both subject and non-subject import sources have higher price elasticities of supply than the domestic source.

4.7.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibrium. For the tariff model with log-linear demand, users enter:

- initial tariff rate on the subject imports source

[22] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

- new tariff rate on the subject imports source

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.7.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium outcomes, expressed in percent change form. The results are presented in green cells in the model spreadsheet.

4.8 Bertrand Differentiated Products Tariff Model

File name: Euler Method PE Model of Ad Valorem Tariffs and Bertrand Differentiated Products

This variant includes three sources of supply to a single, highly concentrated national market.[23] Firms in the concentrated industry can earn profits, at least in the short run while the number of firms in the industry is fixed, making this model useful for analyzing industries with high entry costs. Furthermore, firms maximize profits in a Bertrand-style competition. They choose their price, taking the equilibrium prices of their competitors as given. The model can simulate the effects of a tariff change on prices, quantities, and profits in the market.

4.8.1 Key Assumptions

- **Imperfect competition:** The model assumes suppliers operate under imperfect competition in the market. Firms adjust prices, taking the prices of their competitors as given. Cost differences between producers exist, and firms adjust prices and supply to maximize profits.
- **Products differentiated by source:** Products are differentiated by source country and there is a different price for each source of supply.
- **CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

[23] The industry may have many more sources of supply, but they are aggregated into three sources to simplify the model.

4.8.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input elasticity values as described below:[24]

1. **Elasticity of substitution:** Describes substitutability, or extent of product differentiation, across all three sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.

2. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

4.8.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the initial equilibrium. For the Bertrand model, users enter:

- initial value of domestic shipments[25]
- initial value of subject imports
- initial value of non-subject imports
- initial tariff rate on the subject imports source
- new tariff rate on the subject imports source

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.8.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to

[24] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

[25] Users can enter market share data instead of values.

one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.9 Cournot Tariff Model with 2 or 3 Firms

2-firm file name: Partial Equilibrium Tariff Model with Cournot Competition and 2 Firms
3-firm file name: Partial Equilibium Tariff Model with Cournot Competition with 3 Firms

This model includes two or three sources of supply to a highly concentrated national market, where each of the sources is a single firm. Firms maximize profits in a Cournot-style competition. They choose their quantity, taking the equilibrium quantities of their competitors as given. The model can simulate the effects of a tariff change on prices, quantities, and profits in the market.

4.9.1 Key Assumptions

- **Imperfect competition:** The model assumes suppliers operate under imperfect competition in the market. Firms choose production levels to maximize profits, taking the quantities of their competitors as given. Cost differences between producers exist, and firms adjust supply to maximize profits.
- **Perfect substitutes:** Products from each firm are perfectly substitutable. There is only one price in the market shared by all sources.
- **CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.9.2 Parameters

All parameter inputs that can be changed by the user are presented in orange. For this model there is only one parameter that requires input from the user.[26] The price elasticity of industry demand represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

[26] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

4.9.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the initial equilibrium. For the Cournot model, users enter:

- initial value of domestic shipments[27]
- initial value of subject imports
- initial value of non-subject imports
- initial tariff rate on the subject imports source
- new tariff rate on the subject imports source

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.9.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.10 Monopoly Tariff Model

File name: Euler Method PE Model with Domestic Monopoly and Foreign Competitive Fringe

This model includes a domestic monopoly and a foreign perfectly competitive supply of fringe firms that limit the monopolist market power. There are two sources of supply in the market: a domestic dominant monopoly firm and a foreign supply. The dominant monopolist sets its price to maximize profits. The trade policy change is a tariff on the foreign competitive fringe.

[27] Users can enter market share data instead of values.

4.10.1 Key Assumptions

- **Products differentiated by source:** Products are differentiated by source country and there is a different price for each source of supply.
- **Monopolist is profit maximizing:** The monopolist chooses a price to maximize profits, taking the price of the foreign supply as given. The model assumes constant marginal costs that are calibrated to initial market data entered by the user.
- **Competitive fringe are price-takers:** The foreign suppliers are price takers, operating under a perfect competition assumption.
- **CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.10.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input elasticity values as described below:[28]

1. **Elasticity of substitution:** Describes substitutability, or extent of product differentiation, across all three sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.
2. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

4.10.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the initial equilibrium. For the monopoly model, users enter:

- the expenditure on the product of the domestic monopolist
- the expenditure on imports

[28] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

- initial tariff rate on foreign supply
- new tariff rate on foreign supply

4.10.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.11 Model with Cross-Border Trade, Fixed Costs, Tariffs, and Firm Heterogeneity but No Foreign Affiliate Sales

File name: PE Model with Fixed Costs and Firm Heterogeneity

This model is a two-country Melitz-style model of international trade with firm heterogeneity.[29] The model estimates the effects of changes in tariffs, changes in fixed costs of exporting, and changes in fixed costs of production on the volume of trade and domestic shipments. This PE model is explained in more detail in Khachaturian and Riker (2016), and is especially useful when analyzing trade in services industries.

4.11.1 Key Assumptions

- **Firms are heterogeneous:** There is a continuum of firms with different productivities, drawn from Pareto distribution with shape parameter γ. This means that there are many different firms with different productivity levels, and a high proportion of the productivity levels are low values whereas only a few firms have very high productivity values.
- **Monopolistic competition:** Firms provide products/services that are differentiated from other firms offerings and they engage in monopolistic competition.
- **Non-tariff barriers to trade:** The model includes fixed costs of exporting and fixed costs of production as non-tariff barriers to trade.

[29] Based on Melitz (2003), Helpman, Melitz and Yeaple (2004), and Chaney (2008)

- **Factors of production:** Labor is the only factor of production and it is assumed that wages in each country are equalized by international trade in other sectors of the economy.
- **Unexpected policy change:** There is no schedule to policy changes. The model does not separately distinguish policy announcements and entry into force.

4.11.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input parameter values as described below:

1. **Elasticity of Substitution:** Describes substitutability, or extent of product differentiation, across all sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.
2. **Pareto Shape Parameter:** This is the shape parameter in the Pareto distribution of productivities. It must be a positive value, and must be larger than the elasticity of substitution for the model to solve properly. The larger the parameter value, the smaller the proportion of outlier firms. Said another way, a pareto shape parameter of 6 will have less high-value firm productivities than a pareto shape parameter of 3.

4.11.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibrium. For this model with cross-border trade, fixed costs, tariffs, and firm heterogeneity, users enter:

- initial value of domestic shipments
- initial value of imports
- initial tariff rate and revised tariff rate if tariff changes (can leave as 0 otherwise)
- change in fixed cost of exporting if exporting cost changes (can leave as 0 otherwise)
- change in fixed cost of domestic production if production cost changes (can leave as 0 otherwise)

4.11.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and adds in the policy change. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

4.12 Model with Foreign Affiliate Sales and Cross-Border Trade

File name: Model with Foreign Affiliate Sales and Cross-Border Trade

This model of multi-mode trade in services is a variant of the model presented in 4.11 that includes foreign affiliate sales. The model is based on the monopolistic competition firm heterogeneity framework in Helpman et al. (2004), adapted as a multi-mode PE model of trade in professional services as in Khachaturian and Riker (2019). There are two sources of services: the home country and a foreign country. The model simulates the effects on consumer expenditures on the different modes of supply from a change in the fixed and variable costs of trade.

4.12.1 Key Assumptions

- **Firms are heterogeneous:** There is a continuum of firms with different productivities, drawn from Pareto distribution with shape parameter γ. This means that there are many different firms with different productivity levels, and a high proportion of the productivity levels are low values whereas only a few firms have very high productivity values.
- **Monopolistic competition:** Firms provide products/services that are differentiated from other firms offerings and they engage in monopolistic competition.
- **Non-tariff barriers to trade:** The model includes the following non-tariff barriers to trade: fixed costs of exporting to domestic market, fixed costs of foreign affiliate production, fixed costs of domestic production, and cross-border trade costs.
- **Substitution across sources:** In a monopolistic competition model, the elasticity of substitution is the inverse of the markup of the domestic firm. Using this relationship, we do not require model users to enter an elasticity of substitution because it is calibrated with initial market data.
- **Unexpected policy change:** There is no schedule to policy changes. The model does not separately distinguish policy announcements and entry into force.

4.12.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The only parameter in this model is the shape parameter of the Pareto distribution of firm productivities. It must be a positive value. The larger the parameter value, the smaller the proportion of outlier firms. Said another way, a pareto shape parameter of 6 will have less high-value firm productivities than a pareto shape parameter of 3.

4.12.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibrium. For this model with foreign affiliate sales and cross-border trade, users enter:

- initial value of domestic shipments
- initial value of domestic industry cross-border exports
- domestic industry variable costs
- initial value of cross-border imports
- initial value of inbound foreign affiliate sales
- delivered cost of foreign product relative to domestic product
- applicable policy changes: percent change in cross-border trade costs, percent change in fixed costs of exporting to domestic market, percent change in incremental fixed costs of foreign affiliate production, and percent change in fixed costs of domestic production[30]

4.12.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and adds in the policy change. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

4.13 Model with Entry of a New Source of Imports

File name: PE Model with Entry of New Source of Imports

This model is appropriate for simulating the entry of a new source of imports, for example due to the reduction or elimination of prohibitive tariffs on imports from a new source. Essentially, it estimates the effects of changes in trade policy when there are no initial imports from a new supplier to the domestic market. However, the standard PE model is not equipped to estimate the effect of changes in trade policy when there are no initial imports from source countries subject to the tariff reduction. This model, on the other hand, predicts the increase in the volume of subject imports conditional on entry by using initial values from a reference group of imports that are already in the market. The choice of an appropriate reference group of imports is determined by the model user and will depend on the specific industry and market to which the model is applied.

[30] These can be set to 0 if they do not change or are not being analyzed in the scenario under consideration.

4.13.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits and the new equilibrium is calculated by setting supply equal to demand.
- **Products differentiated by source:** Products are imperfectly substitutable across countries and there is a different price for products originating from each source.
- **CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.13.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input elasticity values as described below:[31]

1. **Elasticity of substitution:** Describes substitutability, or extent of product differentiation, across all three sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.
2. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

4.13.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the initial equilibrium.

- initial value of domestic shipments[32]
- initial value of reference non-subject imports
- initial value of other non-subject imports

[31] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

[32] Users can enter market share data instead of values.

- initial tariff rate on reference non-subject imports
- initial tariff rate on other non-subject imports
- new tariff rate on the reference subject imports source
- new tariff rate on other non-subject imports
- new tariff rate on new subject imports

4.13.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and adds the policy change. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.14 Model of the Value of a Monopoly Created by Protecting IPR

File name: PE Model for Valuing the Creation of a Monopoly (e.g., by protecting IPR)

This model values the monopoly rents associated with protecting intellectual property rights (IPRs) in a market that initially operates under perfect competition. The model starts with perfect competition and no protection for IPRs. The policy change is a change in the protection of IPRs that leads to creation of a monopoly and a new market equilibrium. The model calculates the increase in profits, change in price and change in quantity as a result of protection of IPRs.

4.14.1 Key Assumptions

- **Market Structure:** The market initially operates under perfect competition and IPRs are not protected. This means that profits are competed to zero by infringing or imitating firms. Price initially equals marginal cost. Then the protection of IPRs creates a monopoly in the market and there are positive economic profits.
- **Linear Demand:** The model assumes a linear demand curve for products in the market. Because of the linear demand assumption, the model uses the price elasticity of industry demand to calibrate demand parameters.

- **Unexpected policy change:** There is no schedule to policy changes. The model does not separately distinguish policy announcements and entry into force.

4.14.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The only parameter input in this model is the initial price elasticity of industry demand. The price elasticity of industry demand represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

4.14.3 Model Data Requirements

The only data input in this model is the initial revenue in the market. This data input is used to calibrate marginal costs and demand curve parameters in the initial equilibrium.

4.14.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and adds in the protection of IPRs. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

4.15 Model of Trade and Innovation

File name: PE Model of Trade and Innovation

This model addresses how the protection of intellectual property rights (IPRs) affects incentives to innovate. It is based on models of trade, product diversity, and monopolistic competition as in Krugman (1980), and a simpler version of Grossman and Helpman (1989). The policy change is an increase in IPR protection and the model simulates the effects on the quantity and value of global innovation.

4.15.1 Key Assumptions

- **Market setup:** There are a number of national markets where IPRs are protected in the initial equilibrium. Within each market, there are a continuum of varieties. The laws that protect IPRs create a monopoly in the variety that would otherwise not exist. Unrestricted immitation and infringement would drive the mark-up to zero and eliminate the incentive to develop the variety.

- **Demand:** Consumers have symmetric constant elasticity of substitution (CES) preferences with constant elasticity of substitution between varieties. There are Cobb-Douglas preferences between industries, implying that the price elasticity of total industry demand is -1.
- **Firm setup:** There is a fixed cost to invent a new variety and constant marginal costs of production. Firms price their product at a constant markup over marginal cost. The blueprint for each variety is non-rival in its use in different countries, so there are global scale economies to innovation, as long as the returns to innovation are ensured by the protection of IPRs.
- **Unexpected policy change:** There is no schedule to policy changes. The model does not separately distinguish policy announcements and entry into force.

4.15.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The only parameter input in this model is the constant elasticity of substitution. This describes the substitutability, or level of product differentiation, across varieties. The higher the value, the more willing a consumer is to switch from one supplier to another when the relative price increases.

4.15.3 Model Data Requirements

The two data inputs in this model are the total industry revenue in the initial set of national markets with IPR protection, and the total industry revenue in the new set of national markets with IPR protection.

4.15.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and adds in the policy change. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

4.16 Model with Offshoring

File name: Model with Offshoring

This model of offshoring is based on the trade in tasks model in Grossman and Rossi-Hansberg (2008). The model has two types of workers: low-skilled and high-skilled. Each type of worker has a productivity level (one for low-skilled, one for high skilled). The two productivity parameters are calibrated in the model to intial data inputs. There are two countries, domestic and foreign, that employ the two types of workers. Wages are exogenous (determined outside the model).

The model quantifies the economic effects of exogenous changes in wage rates in the two countries and relative productivity of foreign workers in each skill type. The model calculates changes in the share of tasks offshored by skill level and domestic employment by skill level.

4.16.1 Key Assumptions

- **Trade in tasks:** There are two groups of tasks, low-skilled and high-skilled. Tasks within each group are complements. The two tasks groups are imperfect substitutes of each other. Each group of tasks is a continuum, where the cost of offshoring the two types of tasks is uniformly distributed between zero and one (all tasks within a group are equally likely).
- **Market structure:** The model assumes suppliers operate under perfect competition in the market. This means that firms earn zero profits and the new equilibrium is calculated by setting supply equal to demand.
- **Unexpected policy change:** There is no schedule to policy changes. The model does not separately distinguish policy announcements and entry into force.

4.16.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input parameter values as described below:

1. **Demand Elasticity for the Final Good:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.
2. **Elasticity of Substitution:** Describes substitutability, or level of product differentiation, across high- and low-skilled inputs in production. The higher the value, the more willing firms are to switch between high- and low-skilled workers.

4.16.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibrium. For this model with offshoring, users enter:

- total expenditure in the market
- foreign wage relative to domestic wage
- foreign share of employment in high-skill tasks
- foreign share of employment in low-skilled tasks

- cost share of low-skilled tasks
- unit labor requirements for high-skilled tasks
- unit labor requirements for low-skilled tasks
- applicable policy changes: changes in domestic wage, changes in offshoring wage, change in offshoring cost for high-skilled tasks, change in offshoring costs for low-skilled tasks

4.16.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and adds in the policy change. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

4.17 Extended Model with New Entry of Subject Imports

File name: Bertrand Model for New Entry of Subject Imports

This model is appropriate for simulating the entry of a new source of imports, for example due to the reduction or elimination of prohibitive tariffs on imports from a new source. The model is an extended version of Section 4.13. Essentially, it estimates the effects of changes in trade policy when there are no initial imports from a new supplier to the domestic market. However, the standard PE model is not equipped to estimate the effect of changes in trade policy when there are no initial imports from source countries subject to the tariff reduction. This model, on the other hand, predicts the increase in the volume of subject imports conditional on entry by using initial values from a reference group of imports that are already in the market and the comparable to the subject imports of interest in terms of their cost supplying the market. The marginal cost of this reference group is then imputed to the subject imports.

The choice of an appropriate reference group of imports is determined by the model user and will depend on the specific industry and market to which the model is applied. The goal is to find a reference group of imports that are currently in the market and are likely to have similar marginal costs as the subject imports in questions. Examples include similar imports from the same country that face different tariff rates or imports from countries at similar levels of economic development. See Riker (2019a) for more detail.

4.17.1 Key Assumptions

- **Imperfect competition:** The model assumes suppliers operate under imperfect competition in the market. Firms adjust prices to maximize profits, taking the prices of their competitors

as given. Cost differences between suppliers exist, and firms adjust prices and supply to maximize profits.

- **Products are differentiated by source:** Products are imperfectly substitutable across countries and there is a different price for products originating from each source.
- **CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.17.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. There is only one parameter input in this model.[33] The constant elasticity of substitution describes substitutability, or extent of product differentiation, across all three sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.

4.17.3 Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the initial equilibrium. For this model, users enter:

- initial value of domestic shipments[34]
- initial value of reference non-subject imports
- initial value of other non-subject imports
- initial tariff rate on reference non-subject imports
- initial tariff rate on other non-subject imports
- new tariff rate on reference non-subject imports
- new tariff rate on other non-subject imports
- new tariff rate on the new subject imports source[35]

[33] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

[34] Users can enter market share data instead of values.

[35] There is no need to enter tariff rates for non-subject imports because they are implicitly captured in the parameter calibration.

4.17.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rates. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.18 FDI, Trade, and Pricing Model

File name: FDI, Trade, and Pricing Model

This model quantifies the effects of Foreign Direct Investment (FDI) on trade, prices, and employment in a sector-specific oligopoly model. The model has three profit-maximizing firms supplying a single market: two of the firms produce products domestically and there is one foreign firm. The model considers three types of direct investment: a foreign acquisition of a domestic firm without a transfer of production technology, a foreign acquisition of a domstic firm with a technology transfer, and a greenfield investment by a foreign firm to establish transplant production in the domestic market. The model does not try to predict the causes of FDI or whether there will be new FDI in the industry, but instead estimates the effects of new FDI on prices and market shares. For an in-depth description of this model, see Riker (2019b).

4.18.1 Key Assumptions

- **Imperfect competition:** Firms maximize profits in a Bertrand-style imperfectly competitive market by choosing a profit-maximizing price.
- **Products differentiated by source:** Products are differentiated by source country and there is a different price for each source of supply.
- **CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value. The model assumes Cobb-Douglas preferences between products of different sectors, so the price elasticity of total sector demand is equal to -1.

- **Unexpected policy change:** There is no schedule to FDI policy changes. The model does not separately distinguish policy announcements and entry into force.

4.18.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input elasticity values as described below:[36]

1. **Elasticity of substitution:** Describes substitutability, or extent of product differentiation, across all sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.

2. **Tariff rate:** This is an ad valorem tariff on imports. Note that this is not a policy change, this is a parameter in the model.

4.18.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibrium. For this model with firm FDI, Trade and Pricing, users enter:

- initial value of expenditures for each of the domestic sources
- Initial expenditure of foreign source
- policy change - the model user can choose different FDI policy changes depending on their specific industry - a foreign acquisition of a domestic firm without a transfer of production technology, a foreign acquisition with a technology transfer, and a greenfield investment by a foreign firm. The policy change affects the ownership structure but the products remain distinct.

4.18.4 Understanding the Results

Marginal costs and demand parameters are calibrated using the inputted consumer expenditures and assumed functional forms. The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and adds the policy change. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

[36] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

4.19 Time to Build Model with Unanticipated Tariff Changes

File name: Time to Build and Unanticipated Tariff Changes

This model is appropriate if the product in question takes time to grow (e.g. agricultural products and certain manufacturing products with long production processes, such as airplanes). If unanticipated temporary tariffs enter into force, then producers have two choices: either sell their product at a lower price or store some product until a future period when the tariff is gone to partially offset the negative effects of the tariff. However, storage has costs (warehousing fees, perishable products going bad, etc.). This PE model takes this into consideration. The cost of storage, the magnitude of the tariff change, and the discount factor, all impact the decision to store goods to future periods.

The model has three sources of supply (domestic production, subject imports, and non-subject imports) and three periods.[37] In period 1, producers decide how much to produce for the period 2 market and begin growing their products. In period 2, an unexpected tariff enters into force and producers decide how much of their product to sell in the market and how much to store to period 3, subject to a storage cost. Producers also decide how much to produce for the period 3 market and begin growing those products. In period 3, producers sell their period 2 products, plus any stored products. See Schreiber (2019b) for more information.

4.19.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits, there is unlimited entry and exit, and the new equilibrium is calculated by setting supply equal to demand.
- **Supply:** Supply is fixed in the short-run and relatively more elastic in the long-run, capturing the lag time in production.
- **Products are differentiated by source:** Products are imperfectly substitutable across countries and there is a different price for products originating from each source.
- **CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

[37] The industry may have many more sources of supply, but they are aggregated into three sources to simplify the model.

4.19.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input elasticity values as described below:[38]

1. **Elasticity of substitution:** Describes substitutability, or extent of product differentiation, across all three sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.

2. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.

3. **Price elasticity of supply:** Represents the responsiveness of quantity supplied to changes in the price from an individual source. There will be one price elasticity of supply for each of the sources of products

4.19.3 Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the initial equilibrium. For the time to build model, users enter:

- initial value of domestic shipments[39]
- initial value of subject imports
- initial value of non-subject imports
- initial tariff rate on the subject imports source
- new tariff rate on the subject imports source
- time cost of money (interest rate)
- ad valorem storage costs

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

[38] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

[39] Users can enter market share data instead of values.

4.19.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.20 Import Stockpiling with Anticipated Tariff Changes

File name: Import Stockpiling and Anticipated Tariff Changes

This model is appropriate if tariff changes are anticipated and if the product in question can be stored indefinitely. For example, the potential stockpiling of auto parts after the announcement of future tariffs on these products. If tariffs are announced in a period prior to implementation, then importers have two choices: either import the product and sell in the period between announcement and implementation, or stockpile more of the product after the announcement and sell after the tariff enters into force at a higher price. However, storage has costs (warehousing fees, perishable products going bad, etc.). This PE model takes this into consideration. If the cost to stockpile (store) is less than the estimated future cost of the tariff, then we would expect a surge in imports with the announcement of a future tariff increase and a magnified decrease in imports after the tariff increase occurs, due to the stockpiling of imports in advance. However, if the cost to stockpile is more expensive than the estimated cost of the tariff, then we would expect no storage. See Riker (2019c) for more information.

The model has three sources of supply (domestic production, subject imports, and non-subject imports) and three periods.[40] Period 0 is the initial period prior to the announcement of the future tariff change. In period 1 the future tariff change is announced, and in the final period (period 2) the new tariff rate is imposed permanently.

4.20.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits, there is unlimited entry and exit, and

[40] The industry may have many more sources of supply, but they are aggregated into three sources to simplify the model.

the new equilibrium is calculated by setting supply equal to demand.

- **Products are differentiated by source:** Products are imperfectly substitutable across countries and there is a different price for products originating from each source.
- **CES:** Demand is modeled using equations with constant elasticity of substitution (CES) functional forms. The model assumes a non-nested, or flat, CES structure, so the substitutability between all sources of supply are represented by a single, common elasticity value.
- **Expected tariff change:** The model implicitly assumes that the tariff change is expected–the tariff is announced in one period and enters into force at a future date.

4.20.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input elasticity values as described below:[41]

1. **Elasticity of substitution:** Describes substitutability, or extent of product differentiation, across all three sources. The higher the value, the more willing consumers are to switch from one supplier to another when the relative price increases.
2. **Price elasticity of industry demand:** Represents the responsiveness of total industry demand to changes in the average price level. Model users should enter a negative value, so that total industry demand falls as all prices go up.
3. **Price elasticity of supply:** Represents the responsiveness of quantity supplied to changes in the price from an individual source. There will be one price elasticity of supply for each of the sources of products

4.20.3 Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the initial equilibrium. For the stockpiling model, users enter:

- initial value of domestic shipments[42]
- initial value of subject imports
- initial value of non-subject imports

[41] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

[42] Users can enter market share data instead of values.

- initial tariff rate on the subject imports source
- new tariff rate on the subject imports source
- time cost of money (interest rate)
- ad valorem storage costs

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.20.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

All results are expressed in percent change form. One nice property of this model is that the results are independent of the initial prices of the products, so the model sets initial prices equal to one for each source without loss of generality. If the model user wants to know the new price level or value, she or he can find initial price information separately and then multiply the initial price by the percent change result. The same is true for quantities.

4.21 Tariff Model with Translog Demand

File name: Translog Demand PE Model of Tariff Changes

This model is an alternative to the constant elasticity of substitution (CES) Tariff Model described in section 4.1 and the Tariff Model with Log-Linear Demand described in section 4.7. The model features one national market with three sources of supply.[43] Consumers choose to buy from the domestic source, from the imported source that is subject to the tariff policy change, and from the imported source not subject to the policy change. The policy change is an increase or decrease in an ad valorem tariff on subject imports. Instead of CES preferences, the model uses transcendental logarithmic (translog) preferences, originally proposed by Christensen, Jorgenson and Lau (1973) and made popular in recent times by Feenstra. This allows a greater variety in substitution patterns across sources of supply. The model simulates the effects of the tariff changes on prices and quantities in the industry under consideration.

[43]The industry may have many more sources of supply, but they are aggregated into three sources to simplify the model.

4.21.1 Key Assumptions

- **Perfect competition:** The model assumes that suppliers operate under perfect competition in the market. This means that firms earn zero profits, there is unlimited entry and exit, and the new equilibrium is calculated by setting supply equal to demand.
- **Products are differentiated by source:** Products are differentiated by source country and there is a different price for each source of supply.
- **Translog Demand:** Demand is modeled using a flexible translog demand system with constant own- and cross-price elasticities of demand.
- **Unexpected tariff change:** There is no schedule to tariff changes. The model does not separately distinguish tariff announcements and entry into force.

4.21.2 Parameters

All parameter inputs entered by the user are presented in orange cells in the model spreadsheet. The user must input elasticity values as described below:[44]

1. **Own and Cross Price Elasticities of Demand:** There is one price elasticity of demand for each combination of sources. For a three-source model, there are nine own- and cross-price elasticities of demand. Own-price elasticities of demand should be negative values, reflecting a downward sloping demand curve, so demand falls as prices go up. Cross-price elasticities of demand that are positive reflect products that are substitutes.
    - The model places several theoretical restrictions on the own- and cross-price elasticities to limit the number of parameter inputs. This limits the number of user inputs for the price elasticities of demand from nine down to three. See Schreiber (2019a) for more information on the restrictions placed on the model.
2. **Price elasticity of supply:** Represents the responsiveness of quantity supplied to changes in the price from an individual source. There will be one price elasticity of supply for each of the sources of products. Typically, both subject and non-subject import sources have higher price elasticities of supply than the domestic source.

4.21.3 Model Data Requirements

Model users must enter initial data so that the model has a baseline starting point from which to establish the new equilibrium. For the tariff model with translog demand, users enter:

[44] There are also additional demand and supply parameters in the model that are calibrated to the initial expenditure data entered by the model user. They are not model inputs. They implicitly capture market size, initial tariff rates for non-subject imports, and other market factors.

- initial value of domestic shipments, subject imports, and non-subject imports
- initial tariff rate on the subject imports source
- new tariff rate on the subject imports source

There is no need to enter tariff rates for non-subject imports because the model assumes they remain fixed and they are implicitly captured in the parameter calibration. See Section 3 for more information on where to find the data for this model.

4.21.4 Understanding the Results

The model takes in the parameter values and initial data entered by the user, assumes a set of modeling equations used to calculate the new equilibrium, and subjects the imports to the new tariff rate. The model then calculates a new set of equilibrium prices, quantities and expenditures. The results are presented in green cells in the model spreadsheet.

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