General Equilibrium Mechanisms and the Real Exchange Rate in the GTAP Model*

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1. Introduction

In Computable General Equilibrium (CGE) models the adjustments taking place in the economy through the interaction between variables are not always transparent since a change in one of the variables will have an impact in every aspect of the economy by virtue of the general equilibrium structure. Often, the economy-wide nature of the effects of a shock and the simultaneous adjustments in variables make it difficult to tease out the causality. This is especially true for shocks which have significant general equilibrium impacts. The objective of this paper is to discuss how three of the most critical inter-sectoral linkages work their way through the economy and influence the ultimate outcome with respect to key sectoral variables such as output and employment.

Individual sectors in the economy are connected with each other such that a shock to one sector affects every other sector. These inter-sectoral linkages can be traced using the Input-Output (IO) structure that underlies the CGE model. These linkages have a high degree of explanatory power, but they do not encapsulate the entire story. They ignore changes in factor prices and incomes that may be significant when seeking to analyze economy-wide shocks, such as trade reforms. To understand how these general equilibrium effects work it is helpful to understand the driving forces that restore internal consistency in the model, in terms of both internal and external equilibrium. Since these forces are driven by basic economic relationships, such as Factor Market Clearing (FMC) and Balance of Payments (BP) equilibrium, bringing them to account also improves our ability to analyze the results of the model.

In this paper, we will distinguish between Internal and External Equilibrium. Internal Equilibrium refers to the domestic factor market interactions between sectors through factor reallocations in response to a policy shock. On the other hand, External Equilibrium refers to the interactions between the domestic economy and the world economy. By using this distinction we will develop a tool that enables the user to isolate the channel through which a policy shock affects each sector. Since it now becomes possible to pinpoint the repercussions of a policy shock on different sectors, a set of experiments can be defined to separate the predicted impact on the targeted sectors without distorting production in other sectors.

The paper begins by explaining the inter-sectoral linkages in Section 2 using the IO mechanisms. Section 3 focuses on the macroeconomic linkages by decomposing the General Equilibrium into the Internal and External Equilibria. The theoretical background established in the previous sections paves the way to an applied analysis reinforcing the General Equilibrium mechanisms at play. In that sense, Section 4 discusses the steps to do a simulation analysis that focus on the internal and external equilibrium changes. The simulation focuses on the elimination of all tariffs on exports from all regions to the European Union (EU) using the GE3×3 aggregation[1] and this paper shows how these decomposition techniques can aid in understanding the more complex aspects of CGE analyses of economy-wide shocks. Having introduced the decomposition technique in Section 5 we will focus on how the impact of tariff elimination is reversed when the capital account response to the shock is more prominent by introducing a new aggregation using

[1] The aggregation is similar to ACORS3×3 in the sense that it has three regions SSA, EU and the Rest of the World (ROW) and three commodities food, manufactures (mnfcs) and services (svces). The only difference is that in ACRS3×3r1, RORDELTA=1 is used instead of RORDELTA=0. Refer to the Footnote 34 for more information on RORDELTA and see Hertel and Tsigas (1997) for a more comprehensive discussion.

GTAP 8 Data Base[2]. The simulation focuses on the elimination of all tariffs on exports from the EU to China using the GEINV3×3 aggregation. Section 6 concludes the paper.

2. Inter-Sectoral Linkages

This section analyzes the connection between different sectors through a discussion about how a shock on sector i affects sector j. One of the tools utilized in economics to explain the interaction between sectors is the IO analysis. This method provides an explanation about the interdependencies between economic variables through direct and indirect linkages. There are three concepts that can fall under the category of direct input-output linkages, namely backward quantity linkages, forward price linkages and sideways linkages. We discuss each of these, in turn.

Backward quantity linkages explain the direct relationship between input and output quantities in industries. In order to increase the production of a good, the industry requires more of the inputs that are used in the production process. Thus, an increase in output of a certain good results in an increase in the demand for the input it uses. For instance, coal is used as an input in the production of electricity. Suppose that there is an increase in the production of electricity. This will raise the input demand of the firm leading to an increase in the quantity supplied of coal in the electricity production. Thus, the backward quantity linkage shows how an increase in output brings about an increase in the supply of input it uses.

Forward price linkages capture the relationship between the input and output prices. Given our assumptions about perfect competition, the output prices are determined by zero profit conditions (Hertel and Tsigas, 1997). In fact, the price of a product is a simple function of the price of inputs since the cost of production is what specifies the price of output. Following the electricity example, assume that the price of coal increases. Since coal is used as an input in the production of electricity an increase in the price of coal means that there is an increase in the cost of production in electricity. If the cost of producing electricity increases, the price of electricity also rises given the zero profit conditions. In short, the forward price linkage shows how an increase in the price of an input brings about an increase in the price of the output.

Sideways linkages connect the price changes to the quantity changes through substitutability or complementarity of inputs. If two goods are substitutable inputs in the production of a good, then the price change in one of the inputs will bring about a change in the demand of the other good through substitution. For instance, gas and coal can be thought of as substitutable inputs in the production of electricity. If the price of coal rises, the firm will switch to the less costly input in order to minimize its cost. In that sense the demand for coal goes down and the demand for gas goes up raising the production of gas. Thus, the sideways linkage shows how an increase in the price of an input brings about an increase in the quantity demanded of the other input.

In addition to the aforementioned direct linkages, there are also some indirect linkages that can explain the interactions taking place between sectors. For example, aluminum production uses electricity as an input and electricity uses coal as an input. If there is an increase in the demand for aluminum, then the demand for electricity will increase, as well since the increased production of aluminum requires more

[2] See Aguiar, M^{c}Dougall and Narayanan (2012) for further information about GTAP 8 Data Base.

inputs. By the same token, as the demand for electricity production rises, there will also be a rise in the demand for coal. This indirect linkage between sectors is like an extended backward quantity linkage.

Now that we are familiar with the IO linkages, we can use this tool to explain how a shock on sector i affects sector j. Suppose that the import tariff on food from SSA to EU declines. The simulation results in the ACRS3×3r1 version show that the output in the services sector rises as a result of this tariff cut[3]. A decline in agricultural tariffs means that there is a decline in the price of imported agricultural products in the EU. If we think of agricultural products as inputs in the production of services, then based on the forward price linkage we can claim that the decline in the price of agricultural products will bring about a decline in the price of services. However, agricultural products do not constitute a big share of the inputs that are used in services. In fact, the input-output mechanism has limited explanatory power in examining the impact of a tariff cut on other sectors in this case. Suppose that merchandise tariff on imports from SSA to EU declines. The results show that this would lead to an expansion in the manufacturing sector which constitutes a puzzle. Based on the IO linkage explanation, merchandise tariff cut reduces the price of imported intermediates which leads to a decline in the price of manufactures through forward price linkages. In turn, lower price of manufactures stimulates an increase in net exports which is not a very satisfying explanation. Since it is insufficient as an explanatory tool, IO mechanism must be supplemented by other tools to offer more satisfying analysis of the sectoral linkages from a large shock such as this. This observation encourages us to search for additional tools in CGE Analysis, which brings us to the next section.

3. Macroeconomic Linkages

The impact of a shock on economic variables is not always apparent in a model. Given that inter-sectoral linkages are limited in explaining the impact of a shock on equilibrium, we need additional explanatory tools. This section discusses the Macroeconomic Linkages through the General Equilibrium (GE) Analysis as a more compact and transparent tool. These linkages show that a change in one of the sectors will have an impact in every aspect of the economy. In a macroeconomic sense every variable is linked with every other variable which leads to an interdependency in all agent activities in the economy. Contrary to the input-output mechanism, a shock on sector i does not only have an impact on sector j, but it also creates a domino effect which leads to changes in all sectors through indirect linkages. This chain reaction occurs simultaneously which makes it difficult to track the GE mechanisms. In order to simplify the analysis and to make these macroeconomic linkages more intelligible we will decompose the general equilibrium into two equilibria, namely the Internal Equilibrium and the External Equilibrium.

The Internal and External Equilibrium may be discussed through the relationship between aggregate real consumption (*C*) and the relative factor returns (*w*). The factor returns ratio is the price index of primary factors (`pfactor`) in the region where the reforms are taking place, evaluated relative to the global primary factor price index. This relative price functions as a real exchange rate in the model. Before we begin with the discussion of Internal and External Equilibrium, it is informative to talk about the real exchange rate in the GTAP model since adjustments in this macroeconomic variable will be the key to our analysis of External Equilibrium. The concept of real exchange rate can be discussed by utilizing 3 commonly used definitions:

[3] See Pearson et al. (2010) for a more detailed analysis of the same shock with ACORS3×3 aggregation.

1. Price of non-tradables relative to tradables.
2. Price of exports relative to imports.
3. Price of domestic factors relative to foreign factors.

Each of these definitions captures the same basic concept, but from a different perspective. Hence they imply one another. In the multi-region open economy model, GTAP, the third definition is adopted to capture the real exchange rate impact on the economy. Through the zero profit conditions, we can see that the third definition implies the second definition. If the price of a domestic factor of production changes relative to foreign factor prices, then through forward price linkages we expect that there is a change in the price of domestically produced goods relative to international goods. Since domestically produced goods and international goods constitute export goods and import goods, respectively, the third definition is linked to the second one. The relation between definition 3 and definition 1 comes from the assumptions in the GTAP model that primary factors are treated as the only non-tradable commodities in the system[4]. Thus, a change in domestic factor prices implies a change in the price of non-tradables. This means that a change in the price of domestic factors relative to foreign factors, which underpin the prices of tradable commodities in the model, relates to a change in the price of non-tradables relative to tradables. Hence is the link between definition 3 and definition 1.

Since we have a variable that functions as a real exchange rate in the model, we can talk about real depreciation or appreciation for a given region. In GTAP, a change in the real exchange rate is brought about by factor price adjustment. For instance, a decline in `pfactor` (denoted here by *w*) means that domestic factors are cheaper relative to foreign factors and therefore acts in the same manner as a real depreciation. That is because when the relative factor prices decline, the relative price of exportable goods declines with respect to the price of importable goods through the link between definitions 3 and 2. Thus, there is an adjustment in terms-of-trade (TOT) which transmits into adjustments in exchange rate. In short, a decline in *w* is associated with a real depreciation in this paper.

While we can talk about a real exchange rate in this context, the GTAP model does not say anything about nominal exchange rates. The choice of not having a nominal exchange rate in the model is associated with the underlying framework. The model does not discuss absolute price levels. In other words, all prices are relative to a numeriare so that changing only the nominal values will not be effective. Moreover, the demand functions are homogeneous of degree zero in prices which means that following a nominal exchange rate shock, there will be no change in quantity demanded[5]. Hence in order to examine the impact of a nominal exchange rate shock in the GTAP model other variables should be used to modify the closure rule so as to generate qualitatively similar results of such a shock[6].

[4] See Hertel and Tsigas (1997) for further information about the tradable and non-tradable commodities in GTAP.
[5] See M^{c}Dougall (2003) for a comprehensive discussion on the new final demand system.
[6] For example, if the interest is to analyze the implications of the Asian financial crisis, the focus should be on the reasons behind the change in the real exchange rate. In particular, the increase in the risk premium that has been experienced can be generated in this model by a positive shock to the slack variable, `cgdslack`, which causes investment to fall. Given that savings are fixed, a reduced investment requires a rise in net exports to satisfy the external balance which brings about real exchange rate depreciation.

Having talked about how the real exchange rate is used in this analysis we can start discussing the External and Internal Equilibrium by looking at the relationship between aggregate real consumption (*C*) and the relative factor returns (*w*).

3.1. External Equilibrium

External Equilibrium manages the activities in the economy that involve interacting with the rest of the world. It maintains balance of payments equilibrium by ensuring any trade deficit or surplus is offset by capital flows. For instance, if there is an increase in imports, the economy has to find a way to pay for these additional imports. Stimulating exports is a way to afford the increased expenditure. However, if exports are not high enough, there is a trade deficit that must be offset by international savings (i.e. borrowing from abroad).

In order to put the intuition in an algebraic context two macroeconomic equations are used. The aggregate demand identity is

$$Y = C + I + X - M \tag{1}$$

where Y is aggregate income, C is aggregate consumption which is composed of private and public consumption, I is aggregate investment, X is exports and M is imports. In addition to that, there is a second equation that decomposes income into consumption and saving.

$$Y = C + S \tag{2}$$

where Y is aggregate income, C is aggregate consumption and S is aggregate savings. If Equation (2) is substituted into Equation (1), the balance of payments equality condition is derived.

$$Y = C + I + X - M \tag{3}$$

$$C + S = C + I + X - M \tag{4}$$

$$S = I + X - M \tag{5}$$

$$\underbrace{\underbrace{(X - M)}_{BoT} + \underbrace{(I - S)}_{BoKA}}_{BOP} = 0 \tag{6}$$

which shows that net trade is identically equal to the capital flows. The balance of trade (BoT) together with the balance of capital account (BoKA) makes up the balance of payments which should always be balanced out. [7] This paper will refer to the External Equilibrium as the Balance of Payments (BP) Equilibrium.

A graphical representation of the BP equilibrium can be obtained by looking at the relationship between aggregate real consumption (*C*) and the relative factor returns (*w*). If there is an increase in consumption, the economy grows which raises the demand for imports. The increase in imports, in turn, reduces net trade distorting the balance of payments equilibrium. There are three changes that can take place in the

[7] See Hertel and Tsigas (1997) for further information on this closure in the GTAP model.

BOP identity to restore equilibrium. An increase in exports or investment is capable of generating an improvement in BOP such that the increase in imports is eliminated. Alternatively, a decline in savings which is of the same magnitude as imports will bring about the BOP balance. The main engine that restores external equilibrium is determined by the type of shock imposed on the economy in question. With regards to the initial example of agricultural tariff cut in the EU, the change in (*I*-*S*) is very small since on the one hand *I* is determined by relative rates of return across regions which are only minimally affected by an agricultural tariff cut; and on the other hand *S* changes very little as it is proportional to income (M^{c}Dougall, 2003). As a result, agricultural tariff cut generates a very small change in BoKA which allows us to focus our attention on the changes taking place in trade balance. The fact that *I* and *S* moves in tandem in this specific example does not necessarily imply that the response of BoKA will be the same in other scenarios. Depending on the type of shock and the economy, the change in BoKA might be the driving force in maintaining BOP equilibrium. These issues will be addressed in subsequent sections of this paper.

In the agricultural tariff cut example, the increase in imports will be offset by an increase in exports since the change in BoKA is not sufficient to eliminate the trade deficit. The increase in exports is brought about by a real depreciation. As is explained above, a real depreciation in this setting is a decline in the relative factor return (*w*). Hence the increase in consumption brings about a decline in relative factor returns which implies a negative relationship between *C* and *w* resulting in a downward sloping BP curve as shown in Figure 1.

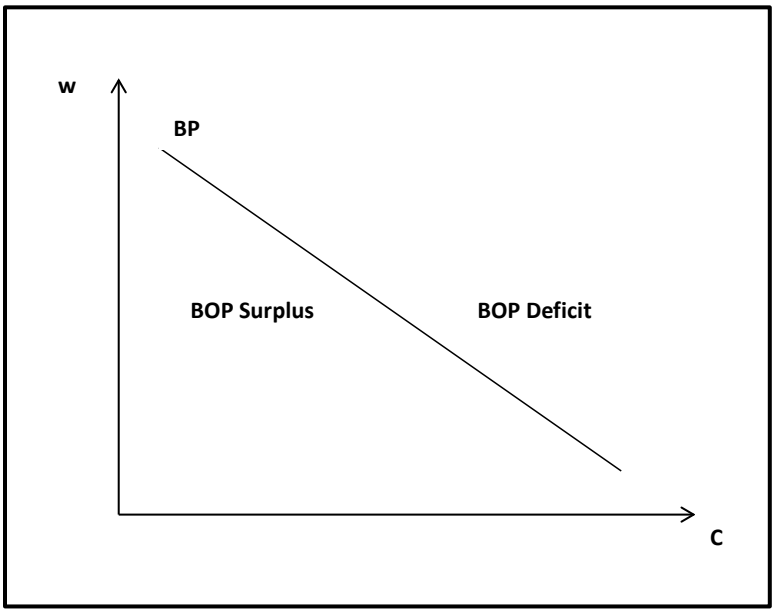

Figure 1. Balance of Payments Curve

A movement along the BP curve shows how exports and imports are balanced out to ensure that the BOP condition holds given that the change in capital account is roughly unnoticeable. If the (*C*,*w*) pair is above the BP curve, the real exchange rate is too high to encourage exports given a constant consumption level. A high real exchange rate makes imported goods more attractive for domestic consumers which stimulates imports and causes a trade deficit. Thus, the points above the BP curve are associated with BOP deficit in the economy. In contrast, if the (*C*,*w*) pair is below the BP curve, the real exchange rate is

too low leading to a high demand for exports and a low demand for imports given the constant consumption level; thereby, resulting in trade surplus. Hence, the points below the BP curve are associated with BOP surplus.

3.2. Internal Equilibrium

Internal Equilibrium encompasses the reallocation of factors across sectors following a shock based on the factor market clearing conditions. In the standard closure of the GTAP model it is assumed that there is full employment in the economy which means that the total employment is fixed (Hertel and Tsigas, 1997).[8] Thus, if labor demand in one sector declines, the labor demand in other sectors must increase in order to ensure full employment in the economy. In other words, the excess labor released from a sector should be absorbed by other sectors so that the Internal Equilibrium is restored. Since this Internal Equilibrium captures the full employment assumption of the model, this paper will refer to it as the Full Employment (FE) Equilibrium.

Similar to the BP equilibrium, a graphical representation of the FE equilibrium can be obtained by looking at the relationship between *C* and *w*. If there is an increase in consumption, it means that there is a higher demand for the products in the economy. The higher demand stimulates production which requires more inputs. Thus, as consumption increases there will be an associated increase in the demand for factors of production leading to higher factor returns. Hence there is a positive relationship between *C* and *w* resulting in an upward sloping FE curve as shown in Figure 2.

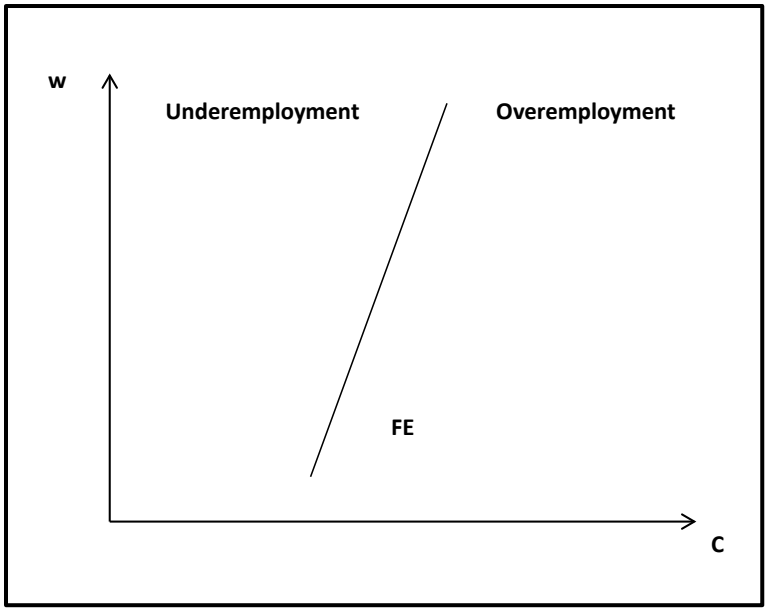

Figure 2. Full Employment Curve

A movement along the FE curve generates factor reallocation across sectors such that the full employment condition is satisfied. Given the consumption level, if the (*C*,*w*) pair is above the FE curve, the relative factor return is too high to absorb all the labor in the economy. Thus, a point above the FE

[8] The standard closure in GTAP is neoclassical which assumes that all markets are in equilibrium. See Section 4.1 for a more detailed analysis on the closure rule used in this paper.

curve is associated with underemployment. In contrast, if the (*C*,*w*) pair is below the FE curve, the relative factor return is too low which means that factor demand is high in the economy. Hence, a point below the FE curve is associated with overemployment.

3.3. General Equilibrium

The FE and BP curves are brought together to build up the Macroeconomic General Equilibrium (GE) which is presented in Figure 3. General Equilibrium is achieved when there is both an Internal and an External equilibrium in the economy. The (*C*,*w*) pair that is associated with such a GE occurs when the FE and BP curves intersect. At the GE equilibrium, *w* is such that the exchange rate balances net trade and capital flows. The same *w* also ensures that the factors are allocated among sectors in such a way that full employment condition is satisfied.

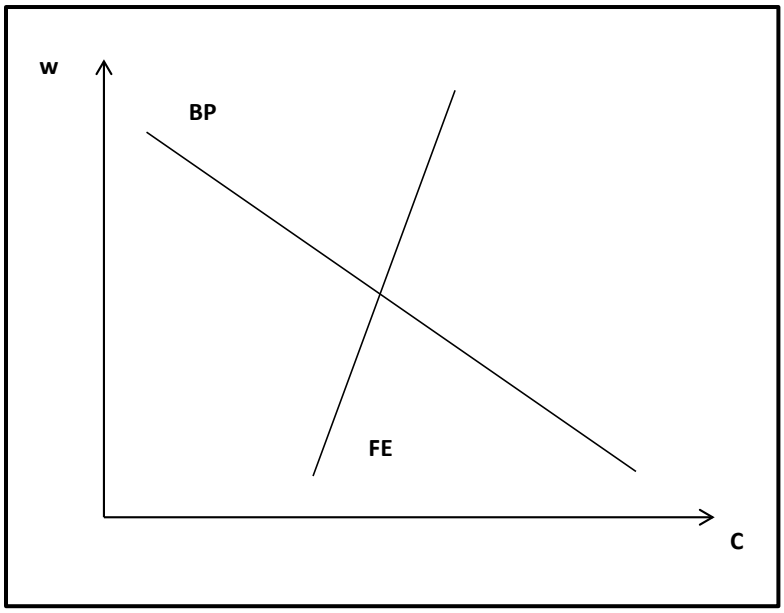

Figure 3. General Equilibrium

Having discussed the mechanics of General Equilibrium, we can use this tool to explain the initial example about how the tariff cut on food in EU leads to an expansion in services. Since the IO study was insufficient in explicitly showing the mechanics in restoring equilibrium, we will decompose the GE mechanism into its FE and BP effects to provide a more detailed analysis of the results.

The agricultural tariff cut in the EU leads to a decline in the price of imported agricultural goods which makes the domestic agricultural products relatively more expensive compared to imports. Thus, consumers substitute away from domestic goods in favor of imported agricultural goods. The impact of this substitution will be analyzed under two headings. To achieve internal equilibrium the changes that take place in domestic production should be considered. The decline in demand for domestic agricultural goods leads to a contraction in the agricultural sector. Lower production reduces the use and thereby the demand for factors of production which leads to a decline in factor returns. At this point, recall that full employment should be restored in the economy. Thus, market clearing conditions ensure that the decline in labor demand in agriculture must be accommodated for by other sectors. In this case, the services

sector absorbs the majority of the unskilled labor that leaves agriculture. As a result of the increase in factors, services and manufacturing sectors expand. Thus, an agricultural tariff cut leads to an expansion in the services sector to restore internal equilibrium.

To achieve external equilibrium we need to think about the activities that connect the domestic market to the international market. Recall that with tariff reduction, the import price of agricultural products is now relatively lower which stimulates imports. The rise in imports causes a trade deficit resulting in a BOP disequilibrium shown by Equation (7).

$$\underbrace{\underbrace{(X-M)}_{BoT}+\underbrace{(I-S)}_{BoKA}}_{BOP}<0 \tag{7}$$

The changes that will restore the balance of payments equilibrium will come either from the BoT or the BoKA. The balance of trade can be improved with an increase in exports or a decline in imports. The other option is a change in the balance of capital account through an increase in investment or a decline in savings. In the agricultural tariff cut experiment the change in BoKA is very small[9]; therefore, the balance in BOP will be restored by the changes taking place in trade as discussed in Section 3.1. The increase in imports is balanced out by an increase in exports which is brought about by real exchange rate depreciation. If the relative price of exportable goods is lower than the imported goods, then the foreign countries would find the EU products cheaper and they would be encouraged to buy more. Thus, EU exports will increase with a simultaneous decline in *w*. This decline would also induce domestic consumers to buy less of imported products which leads to a reduction in imports. These two forces will offset the initial increase in imports restoring the external equilibrium.

Consequently, an agricultural tariff cut brings about a contraction in the agricultural sector, an expansion in the services sector, a real depreciation and a decline in the domestic factor returns relative to foreign factor returns. The FE and BP tool provides a more explicit and intuitive analysis of the impact of a shock on sectors, in particular and on the economy, in general. As a result, the GE analysis paves the way for a more thorough understanding of how the macroeconomic linkages work which broadens the limited explanatory power of the IO study.

4. Simulation: Tariff Liberalization

Section 3 focused on how the economy restores equilibrium following a policy shock by discussing two mechanisms: internal equilibrium and external equilibrium. Using a simple example, we demonstrated how conventional IO explanations fail to explain some of the key results of a CGE model, because they do not consider the return to equilibrium effect on variables. While the illustrative example used was relatively intuitive, most policy simulations are much more complex and the two adjustments occur simultaneously, making it difficult to analyze and explain. In those cases, distinguishing between the disequilibrium effects and the adjustment to equilibrium effects provides an effective method to trace out

[9]This specific experiment examines an agricultural tariff cut on the imports from SSA to EU which does not lead to a very significant change in imported capital goods and hence there will be little change in the rate of return and investment. The behavior of investment in the model also depends on the binary parameter RORDELTA which is a mechanism to manage the allocation of investment across regions (Hertel and Tsigas, 1997). See Footnote 34 for a discussion on the role of RORDELTA in this paper.

the changes in variables on the path to equilibrium. In particular, after imposing a shock on the system we can allow for disequilibrium in the economy to reveal the conventional linkages between variables. Then, an accompanying shock is imposed to restore equilibrium which isolates the changes in variables that occur during the adjustment to equilibrium process. This section outlines a procedure to decompose the general equilibrium into conventional linkages effects and adjustment to equilibrium effects by discussing the impact on BOP and FE equilibrium. In particular, we will focus on a simulation that shows the impact of eliminating all EU merchandise tariffs by using GE3×3 aggregation. In this simulation, all tariffs on exports from all regions to the EU are eliminated on all commodities.

The impact of tariff liberalization on the trade balance of each sector is presented in Figure 4. The figure shows that trade balance in the food sector declines, while that of the manufacturing and services sectors increase. The immediate expectation from the tariff cut is an increase in imports in all sectors based on the lower import prices. However, the observed changes in the manufacturing and services sectors are not in line with the conventional reasoning which is only capable of explaining the response of the food sector.

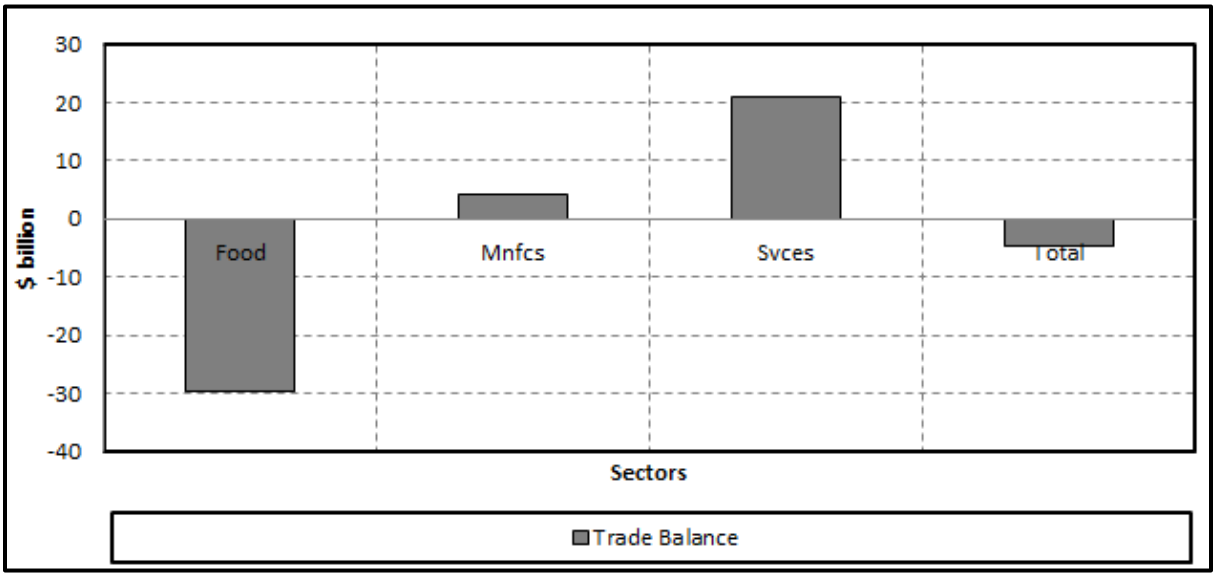

Figure 4. Trade Balance in the EU

In order to explain the driving force behind the increase in net exports in the manufacturing and services sectors, the GE mechanism is analyzed in two steps. The first step examines the response of variables (in this case *C* and *w*) to tariff shock if we allow for disequilibrium in the economy by giving reference to the post-shock changes in BOP and FE conditions. The second step isolates the effect of adjustments in key variables that restores general equilibrium by taking the BOP and FE responses into account.

This decomposition technique requires that we make some modifications to the standard way we use the GTAP model and closure. The original model is modified in order to allow for alternative closures that make a decomposition analysis possible. The following section discusses the modifications made to the model and explains why those changes are required. Then, the FE and BP curves specific to this simulation are drawn paving the way to the decomposition analysis that examines the macro impact of eliminating all tariffs.

4.1. The Closure

The closure refers to how the user chooses to close the model. It ensures that there is a mathematical solution to the model, which is consistent with the underlying accounting relations, but it also allows the user to include their own views about how economies work. From a mathematical perspective, the closure rule distinguishes the exogenous and endogenous variables in the model in order to assure that the number of equations is equal to the number of unknowns so that the system of equations has a solution (Hertel and Tsigas, 1997). This variable classification depends on the economic problem at hand, should be in line with the policy objective, and should make economic sense. The 'standard' closure in GTAP is neoclassical and it ensures that all markets are in equilibrium, all firms earn zero profits, and that the regional household lies on its budget constraint, although users are free to alter this closure.

This section discusses how we modify the standard closure to allow for changes in the classification of exogenous and endogenous variables, making it possible to trace out the FE and BP curves.[10] In order to do this we add a couple of additional variables and equations, which are outlined below.

The first new equation to focus on is the factor endowments equation which captures the impact of internal equilibrium (FE) on output change. GEMPACK code of the equation is given as:

```
Equation FACTENDOW
#Expand endowment closure swap options.#
(all,i,ENDW_COMM)(all,r,REG)
qo(i,r) = qocom(i) + qoreg(r) + qoall(i,r);
```

This equation defines `qo(i,r)`, the percentage change in the quantity of endowment commodity *i* in region *r*, endogenously determined by these three new 'endowment change shifters', which would normally be exogenous in the standard GTAP closure: `qocom(i)`, `qoreg(r)` and `qoall(i,r)`. The addition of this new equation and the endowment shifters makes isolating the FE effect easier. `qocom(i)` is the percentage change in the quantity of endowment commodity *i*, `qoreg(r)` is the percentage change in the quantity of endowment in region *r*, `qoall(i,r)` is the percentage change in the quantity of endowment *i* in region *r*.

The second new equation introduces a new closure variable, aggregate real per capita consumption (`uc`) as the aggregation of private and government expenditure. The addition of the new variable (`uc`) and an equation defining it would mean that `uc` would typically be endogenous in the standard GTAP closure.

```
Equation REALCONSUMPTION
#aggregate real per capita consumption#
(all,r,REG)
AGGEXPEND(r) * uc(r) = PRIVEXP(r) * up(r) + GOVEXP(r) * ug(r);
```

There are three absorption indexes which are `uc(r)`, `up(r)` and `ug(r)`. `uc(r)` is the per capita utility from private and government consumption in region *r* which is decomposed into `up(r)`, per capita

[10] See Appendix 1 for a list of closure rules used in this paper.

utility from private expenditure in region *r*, and `ug(r)`, per capita utility from government expenditure in region *r*. In order to isolate the FE and BP curves, the variable `uc(r)` is used.

The remaining two variables affected in the alternative closure are already defined in the model. `dpsave(r)` represents the fraction of income that is being saved and affects the distribution of savings in region *r* through the `SAVING` equation. A change in `dpsave` has an impact on the savings-investment balance through which we will capture BOP disequilibrium.

```
Equation SAVING
#saving#
(all,r,REG)
psave(r) + qsave(r) - y(r) = uelas(r) + dpsave(r);
```

The second variable is `pfactor(r)` which represents the real exchange rate in the model. Note that real depreciation in this paper is captured by a decline in `pfactor`. Bringing all the pieces together, we will be focusing on `pfactor`, `uc`, `qoreg` and `dpsave` in modifying the closure rule in order to trace out the FE and BP curves. In the standard closure of this model `qoreg` and `dpsave` are classified to be exogenous variables, while `pfactor` and `uc` are defined as endogenous.

Following the same method in Section 3, the FE and BP curves are analyzed by looking at the relationship between aggregate real consumption (*C*) and the relative factor returns/real exchange rate (*w*). This requires that *w* and *C* be exogenous, which requires exogenizing `pfactor("EU")` and `uc("EU")` in the model.

The tariff cut in EU leads to a shift in the FE and BP curves resulting in internal and external disequilibrium at the initial (*C,w*) pair. The disequilibria are captured by two variables, `qoreg(r)` and `dpsave(r)`, respectively. The variable `qoreg(r)`is used to modify the closure in drawing the FE curve. If there is a change in the endowment of a factor then the FE curve will shift distorting the internal equilibrium at the initial (*C,w*) pair which is captured by the endowment shifting parameter, `qoreg`. If the endowment level stays the same, then the economy is moving along the same FE curve. On the other hand, the variable `dpsave(r)`is used to modify the closure in drawing the BP curve. If there is a change in aggregate savings, then there will be a shift in the BP curve causing balance of payments disequilibrium at the initial (*C,w*) pair which is captured by the saving distribution parameter, `dpsave`. If aggregate savings stays the same, this leads to a movement along the BP curve. In order to allow for these adjustments in the model we need to modify the closure rule so that the shifting parameters are endogenous.[11] In particular, `qoreg("EU")` and `dpsave("EU")` will be endogenized using the swap operator so that the alternative closure is achieved by adding the following to the standard closure:

```
swap uc("EU") = dpsave("EU");
swap pfactor("EU")= qoreg("EU");
```

The swap function makes `uc("EU")` exogenous while endogenizing `dpsave("EU")`which enables the model to have changes in aggregate savings. The second swap statement makes `pfactor("EU")`

[11]The comparison between the standard closure and the alternative closure are presented in Table 10 in Appendix 1.

exogenous while endogenizing qoreg("EU") which allows for changes in endowment levels. Now that the closure rule is modified to capture the internal and external equilibria we can use the FE and BP curves to show the impact of tariff liberalization in EU.

4.2. Drawing the Initial Curves

Before proceeding to the decomposition itself it might be helpful to draw the BP and FE curves to show the relationship between *w* and *C* in the simulation. In order to do this, a shock is imposed on either *w* or *C* to observe the changes in the other given that everything else that might affect the curve is constant (ceteris paribus). There are two options. Either uc is treated as an exogenous variable and the changes in pfactor are obtained or we can treat pfactor as an exogenous variable and obtain the changes in uc. Both of these options will give us the same *w* and *C* relationship along the BP and FE curves.

In this paper uc is chosen to be treated as an exogenous variable. Hence we will observe how shocks on uc affect pfactor along the curves. In order to trace out the FE curve, qoreg is required to be constant so that an FE disequilibrium caused by a uc shock can be offset by a change in pfactor instead of a change in qoreg[12]. Hence the alternative closure outlined in Section 4.1 is modified by the following swap operation to allow for a movement along the FE curve.

```
swap qoreg("EU")= pfactor("EU");
```

Using this closure the impact of nine uc shocks are calculated. The results are given in Table 1[13] and the corresponding FE curve is given in Figure 5. As can be seen, the resulting FE curve is upward sloping capturing the positive relationship between uc and pfactor along the curve. In other words, if aggregate consumption in the country increases, then EU experiences a real appreciation of domestic factor prices relative to foreign factor prices. In order to see the macroeconomic linkage in this positive relationship between uc and pfactor think about the internal equilibrium. Under the alternative closure, an increase in aggregate consumption means that there is a higher demand for the products in the economy. The higher demand stimulates production which brings about an increase in the demand for inputs. If we allow qoreg to be endogenous, there will be an increase in endowments to keep the economy in full employment so that internal equilibrium is restored. However, this would cause factor reallocation that generates allocative efficiency which would shift the FE curve. Since we want to see how pfactor balances out the increase in uc, we need to consider the modified closure and keep qoreg exogenous to draw the FE curve. In that case, higher production leads to an increase in factor demand which calls for higher returns for the factors. This causes an offsetting reduction in employment which, in turn, restores internal equilibrium. Hence the increase in pfactor as a consequence of an increase in uc represents a movement along the upward sloping FE curve.

Given the FE curve, we now turn back to the closure rule to trace out the BP curve. In order to capture the specific impact of uc shock on pfactor, we need to keep other variables in the BOP equation constant.

[12] See Table 10 in Appendix 1for a list of closure rules.

[13] To see the impact of each shock, use the following cmf files respectively: fe_0.cmf, fe_1.cmf, fe_2.cmf, fe_3.cmf, fe_4.cmf, fe_5.cmf, fe_6.cmf, fe_7.cmf and fe_8.cmf.

That is, dpsave is required to be constant so that a BOP disequilibrium caused by a uc shock can be offset by a change in pfactor instead of a change in dpsave. The alternative closure outlined in Section 4.1 is modified by the following swap operation to trace out the BP curve[14]

```
swap dpsave("EU")= pfactor("EU");
```

The results of the uc shocks imposed are listed in Table 1[15] and the corresponding BP curve is presented in Figure 5. As can be seen, the resulting BP curve is downward sloping so that an increase in uc generates a decline in pfactor. In other words, an increase in aggregate consumption reduces the real exchange rate which means that EU experiences a real depreciation of domestic factor prices relative to foreign factor prices. In order to see the macroeconomic linkage in this negative relationship between uc and pfactor think about the external equilibrium. Recall that the external equilibrium is achieved by the BOP identity.

$$\underbrace{\underbrace{(X-M)}_{BoT}+\underbrace{(I-S)}_{BoKA}}_{BOP}=0 \tag{8}$$

An increase in aggregate consumption boosts imports generating trade deficit. This causes a BOP disequilibrium which can be remedied by an improvement in the balance of capital account or in the balance of trade. The former requires an increase in investment or a decline in savings. In the standard closure a decline in savings is capable of offsetting the increase in imports and restoring the external equilibrium. However, in the BP closure we exogenized dpsave and endogenized pfactor. Thus, the remedy comes from the changes in pfactor instead of a change in dpsave. In this case, the BP equilibrium is restored by a real depreciation. In other words, a decline in pfactor encourages exports and discourages imports compensating for the initial increase in imports restoring the external equilibrium. The decline in pfactor as a consequence of an increase in uc represents a movement along the downward sloping BP curve.

Table 1. Changes in uc and pfactor along the FE and BP curves in the EU[16]

Case	uc	pfactor-FE	pfactor-BP
0	-8.2996	-4.7708	1.2204
1	-6.2916	-3.6613	0.9109
2	-4.2397	-2.4983	0.6044
3	-2.1428	-1.2788	0.3008
4	0	0	0
5	2.1897	1.3410	-0.2980
6	4.4274	2.7471	-0.5932
7	6.7140	4.2211	-0.8856
8	9.0508	5.7657	-1.1754

[14]See Table 10 in Appendix 1 for a list of closure rules.
[15]To see the impact of each shock, use the following cmf files in the same order: bp_0.cmf, bp_1.cmf, bp_2.cmf, bp_3.cmf, bp_4.cmf, bp_5.cmf, bp_6.cmf, bp_7.cmf and bp_8.cmf.
[16] The decimal places of the values are kept throughout the analysis in order to improve the accuracy in results.

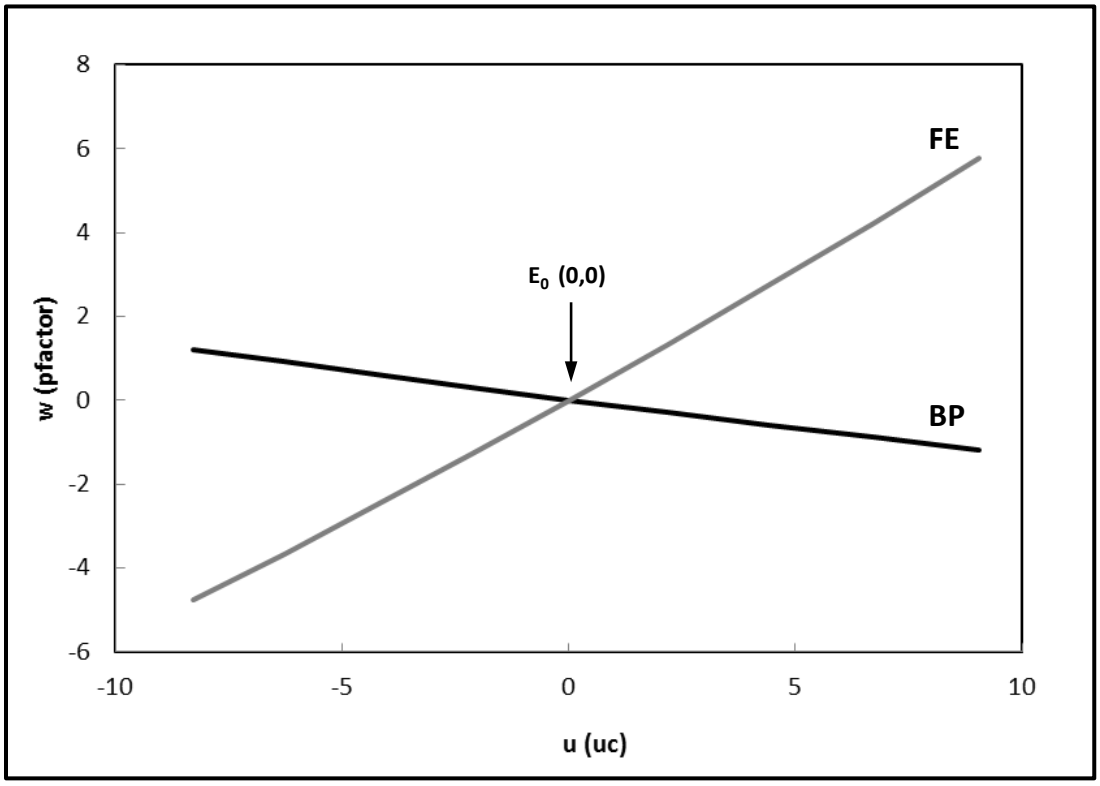

Figure 5. Initial Equilibrium in the EU

As is seen in Figure 5, the FE curve is upward sloping and the BP curve is downward sloping substantiating the theoretical discussions about their slopes in the previous section. The intersection of the two curves gives the General Equilibrium, E_0, which ensures that the EU has both internal and external equilibrium. The (*C*,*w*) pair at E_0 represents the starting macroeconomic equilibrium for our simulation.

4.3. Tariff Liberalization

Now we turn to the trade liberalization shock itself and discuss how to isolate the impact of internal and external equilibrium. Assume that at E_0 we eliminate all tariffs on imports from all regions to the EU in each sector. The tariff cut will be introduced by a `tms(TRAD_COMM,REG,"EU")` shock the amount of which is shown in Table 2[17].

Table 2. Tariff Liberalization in the EU

Sectors	SSA	EU	ROW
Food	-11.537	0	-13.057
Mnfcs	-1.854	0	-3.440
Svces	-0.024	0	-0.033
Total	-13.416	0	-16.530

[17]In order to obtain accurate results and reduce the error in simulations, we will carry all the decimal places on the parameter and variable values throughout the analysis.

The tms shock will cause adjustments in the internal equilibrium through endowment changes and in the external equilibrium through changes in the BOP equation. These changes will shift the FE and BP curves causing disequilibrium at the initial point which is captured by the variables `qoreg` and `dpsave` as long as they are endogenous. Thus, we will use the alternative closure rule defined in Section 4.1.

The tariff cut reduces the price of imported products in the EU. This stimulates imports in EU, increasing demand for imported goods, and resulting in a reduction in net trade for the EU. If we focus on the Internal Equilibrium, an increase in the demand for imported products means that the domestic consumers find the price of domestic products relatively more expensive. Hence the demand for domestic products declines causing a reduction in domestic production. Since the tariff cut is higher in the agricultural sector, it is the most affected sector in this scenario. The contraction forces the factors of production employed in the agricultural sector to be released. Recall that we have the full employment assumption which should hold in order to achieve internal equilibrium. This condition ensures that the factors released from the agricultural sector are absorbed by other sectors in the economy. The reallocation of factors among sectors that takes place in the EU will increase allocative efficiency which leads to a rightward shift in the FE curve (as depicted through the endogenous response in `qoreg("EU")`). If we turn to the external equilibrium, we see that the increase in the demand for imports causes net trade to decline which means that there is BOP deficit in the economy. The higher imports will create a trade deficit shifting the BP curve downwards given the endogenous `dpsave("EU")`.

Thus, in theory the `tms` shock leads to a rightward shift in the FE curve and a downward shift in the BP curve causing a macroeconomic disequilibrium at the initial point. In order to see whether this is the case in application, we will follow the same method in drawing the FE and BP curves that we used in the Section 4.2 but with the `tms` shock included in this case. The closure rule is again modified to allow for a movement along the FE curve and then a movement along the BP curve as discussed above. The same `uc` shocks are introduced to obtain the changes in `pfactor`.[18] The resulting shifts in the FE and BP curves are presented in Figure 6.

[18]In order to obtain the FE curve, use the tms_fe.cmf files for nine different uc shocks. In order to obtain the BP curves, use the tms_bp.cmf files for nine different uc shocks.

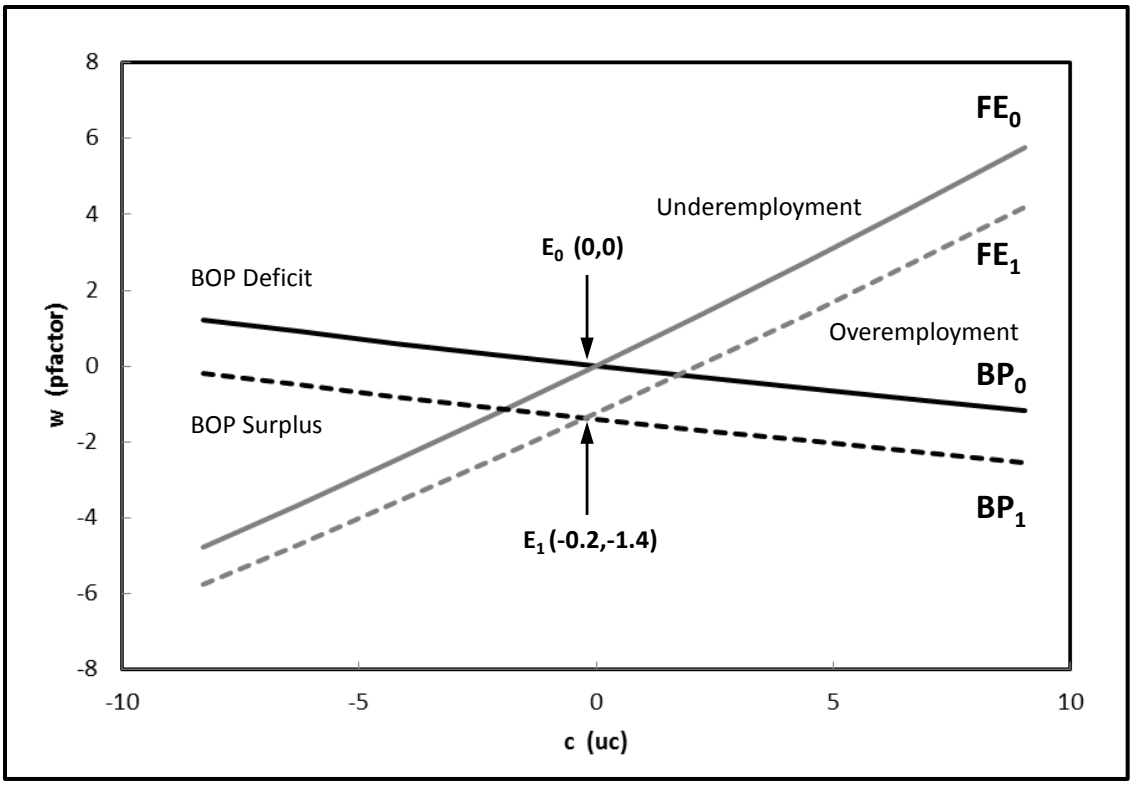

Figure 6. Change in Equilibrium in the EU

The initial macroeconomic equilibrium is observed at E_0. Given the shifts in the curves following tariff elimination, E_0 is no longer an equilibrium allocation. It represents a macroeconomic disequilibrium since at that (*C*,*w*) pair we have unemployment and BOP deficit. Notice that E_0 is above FE_1 which means that it is associated with unemployment. Given the `tms` shock, the relative domestic factor returns are too high to absorb all the labor released from domestic sectors. Thus, the full employment condition is not satisfied which means that the allocation of labor and the relative factor prices at E_0 does not maintain the internal equilibrium anymore. Unless there is a change in allocative efficiency captured by changes in `qoreg`, there will be unemployment in the economy and thereby macroeconomic disequilibrium.

From the external equilibrium perspective, notice that E_0 is also above BP_1 which means that there is balance of payments deficit in the economy. Given tariff liberalization, the real exchange rate is too high which means that imported products are relatively cheaper than the domestic products. This encourages imports and discourages exports causing a trade deficit and therefore a BOP deficit. With this deficit, E_0 no longer satisfies external equilibrium. Since neither internal equilibrium nor external equilibrium is satisfied by the (*C*,*w*) pair at E_0, it is associated with a macroeconomic disequilibrium following tariff liberalization. In order to see that this is, in fact, the case we will take a look at the results of the simulation given in Table 3.[19]

[19]These results are obtained by using the tms_macro.cmf file.

Table 3. The Impact of Tariff Cut on the Closure Variables in the EU

Regions	uc	pfactor	qoreg	dpsave
SSA	0.255	1.021	0	0
EU	0	0	-1.752	-19.816
ROW	0.006	-0.016	0	0
Total	0.261	1.005	-1.752	-19.816

Since `uc("EU")` and `pfactor("EU")` are defined as exogenous variables in the alternative closure they do not change which is why they are zero. Thus, the (`uc, pfactor`) pair is at the E_0 level. Given this, we see that `qoreg("EU")` is `-1.752` which means that there is a decline in the endowments employed in in EU. In other words, there is not enough absorption in the economy to employ all the factors released from contracting sectors which creates underemployment. We also see that `dpsave("EU")`is `-19.816` which means that there is a decline in the savings distribution parameter in EU. Recall that the BOP equation states that the balance of trade should be identically equal to the balance of capital account. In this case, the decline in the saving distribution parameter shows that there is deterioration in BOP. Thus, there is not enough activity in the capital account to compensate for the high real exchange rate in the economy which means that the EU is not able to cover all of its import expenditure. Hence, there is a BOP deficit at E_0.

Now that the initial equilibrium E_0 represents a macroeconomic disequilibrium given tariff liberalization we should find a way to restore the general equilibrium. The BOP deficit should be eliminated to obtain external equilibrium and the absorption in the economy should be increased to obtain the internal equilibrium. What we need is a change in `dpsave("EU")` and `qoreg("EU")` to allow for a movement from E_0 to E_1. In order to eliminate the internal and external deficits at the same time we need to have Δ`dpsave("EU")= 19.816` and Δ`qoreg("EU")= 1.752`. Recall that in the alternative closure `qoreg` and `dpsave` are defined as endogenous variables. Thus, we cannot generate the required change by simply imposing a shock on them. What we can do is to impose a shock on the exogenous variables which will then generate the required amount of change in `dpsave` and `qoreg` through the GE mechanism. The exogenous variables that are going to be shocked are `uc` and `pfactor`. In order to obtain the amount of shock that needs to be imposed on these variables we will work with General Equilibrium elasticities.

4.4. General Equilibrium Elasticities

The GE elasticities show the amount of change in the endogenous variables given a percentage change in the exogenous variables[20]. In order to find the elasticity of `uc` and `pfactor` with respect to `dpsave`, the following shock should be imposed under the standard closure[21]

```
shock dpsave("EU")= 1;
```

[20] For more information on equilibrium elasticities in GTAP, see Hertel et al (1997).
[21]Use the dpsave.cmf file to find the elasticity of `uc` and `pfactor` with respect to `dpsave`.

With this shock, the increase in savings brings about BOP deficit. In order to restore the equilibrium, there should be either an increase in exports or a decline in imports. If consumption declines it will bring about a decline in imports that will offset the initial increase in savings. Thus, when dpsave increases uc is expected to decline which is in line with the negative elasticity observed. On the other hand, when pfactor declines it means that the real exchange rate depreciates which will result in an export increase. Hence the balance of payments equilibrium will be restored which shows that there is a negative relationship between dpsave and pfactor.

In order to find the elasticity of uc and pfactor with respect to qoreg, the following shock should be imposed under the standard closure[22]

```
shock qoreg("EU")= 1;
```

In this case, the growth in endowments causes an internal disequilibrium because the current employment is not enough to absorb the increase in factors. Since the factor endowments are now higher, factor prices start to decline implying a negative relationship between qoreg and pfactor. On the other hand, since endowments are increasing, consumption is expected to be higher in order to absorb the higher supply of goods which implies a positive relationship between qoreg and uc. The GE elasticities observed in this simulation are summarized in Table 4.

Table 4. GE Elasticities in the EU

	uc	pfactor
dpsave	-0.098	-0.059
qoreg	0.975	-0.134

Given these elasticties we will find how much we need to shock uc and pfactor to generate the required changes in dpsave and qoreg using Equations (9) and (10)[23].

$$uc(\text{“}EU\text{”}) = dpsave(\text{“}EU\text{”}) \times \varepsilon_{\texttt{uc,dpsave}} + qoreg(\text{“}EU\text{”}) \times \varepsilon_{\texttt{uc,qoreg}} \tag{9}$$

$$pfactor(\text{“}EU\text{”}) = dpsave(\text{“}EU\text{”}) \times \varepsilon_{\texttt{pfactor,dpsave}} + qoreg(\text{“}EU\text{”}) \times \varepsilon_{\texttt{pfactor,qoreg}} \tag{10}$$

where $\varepsilon_{\texttt{uc,dpsave}}$ is the elasticity of uc with respect to dpsave, $\varepsilon_{\texttt{uc,qoreg}}$ is the elasticity of uc with respect to qoreg, $\varepsilon_{\texttt{pfactor,dpsave}}$ is the elasticity of pfactor with respect to dpsave and $\varepsilon_{\texttt{pfactor,qoreg}}$ is the elasticity of pfactor with respect to qoreg.

Using the GE elasticities it can be seen that the general equilibrium is restored by reducing consumption by -0.227% and depreciating the real exchange rate by -1.404%. These changes also confirm the initial discussion about the shifts required in the FE and BP curves to restore the equilibrium after the tms shock. Regarding the internal equilibrium, the reallocation of factors in the EU brings about a decline in

[22]Use the qoreg.cmf file to find the elasticity of uc and pfactor with respect to qoreg.

[23] Note that these equations are not from the GEMPACK code. The changes in uc and pfactor are found by this calculation the result of which correspond to the simulation results.

the domestic factor prices relative to foreign factors while absorbing all the factors released from agriculture. Thus, pfactor declines to restore the FE equilibrium. Regarding the external equilibrium, the increase in imports in EU requires the real exchange to depreciate if the BOP deficit is to be eliminated. Consequently, the shocks that should be introduced to restore the macroeconomic equilibrium are

```
shock uc("EU") = -0.227;
shock pfactor("EU")= -1.404;
```

Recall that the tariff cut under the standard closure automatically generates these adjustments. However, the decline in uc and pfactor occur simultaneously following the shock; therefore, their impacts are not isolated. The decomposition generates the need to impose these shocks artificially to restore the equilibrium which allows for their isolated impact to be observed. Overall, the resulting uc and pfactor in the new macroeconomic equilibrium are, in fact, almost the same as the ones we obtain under the standard closure. [24]

Note that the changes in uc and pfactor both include the BP and FE effects each. A more detailed analysis can be obtained by further decomposing the shock on uc and pfactor into the internal and external equilibrium effects. This is carried out by separating the impact of dpsave and qoreg in Equation (9) and (10) . Focusing on the BP effect we have

$$\begin{aligned} ucBP(\text{“}EU\text{”}) &= dpsave(\text{“}EU\text{”}) \times \varepsilon_{\texttt{uc,dpsave}} \\ pfactorBP(\text{“}EU\text{”}) &= dpsave(\text{“}EU\text{”}) \times \varepsilon_{\texttt{pfactor,dpsave}} \end{aligned} \tag{11}$$

It should be noted that dpsave captures how far off the initial equilibrium is from the new BP curve keeping the initial FE curve constant. Hence it represents a movement from E_0 to the intersection of BP_1 and FE_0 in Figure 6. In that sense the change in dpsave together with the GE elasticities gives us an approximation of the BP effect of tariff liberalization. By the same token, if we focus on the FE effect we have

$$\begin{aligned} ucFE(\text{“}EU\text{”}) &= qoreg(\text{“}EU\text{”}) \times \varepsilon_{\texttt{uc,qoreg}} \\ pfactorFE(\text{“}EU\text{”}) &= qoreg(\text{“}EU\text{”}) \times \varepsilon_{\texttt{pfactor,qoreg}} \end{aligned} \tag{12}$$

In this case, note that qoreg captures how far off the initial equilibrium is from the new FE curve keeping the BP curve constant. Similar to the discussion above, the change in qoreg together with the GE elasticities gives us an approximation of the FE effect.

[24] The tms shock under the standard closure generates the values pfactor("EU")=-1.363 and uc("EU")= -0.216. They are quite close to the percentage changes found using GE elasticities. The small difference stems from the loss in precision based on the decimal places used in calculations and it is captured by the error term.

4.5. Results

Isolating the FE and BP effects of trade liberalization therefore calls for decomposition and a detailed analysis which is laid out below. First, the final result of the tariff cut under the standard closure is separated into the impact of the `tms` shock under the alternative closure (first-round change), the `uc` shock and the `pfactor` shock (equilibration), and the error. Then we further analyze the results of the simulation to determine if the impact of ensuring equilibrium is due to the FE or BP equilibrium.

The portion '`tms` shock under the alternative closure' shows the impact on output of the tariff shock assuming that we do not have to return to internal and external equilibrium: one might say the first-round effects. The sum of the `uc` and `pfactor` portions then show the impact on output of returning to equilibrium, since these shocks are introduced to eliminate the macroeconomic disequilibrium caused by the `tms` shock under the alternative closure. The percentage change in output in each sector can be decomposed into these effects using the GE elasticities. The results are presented in Figure 7 [25].

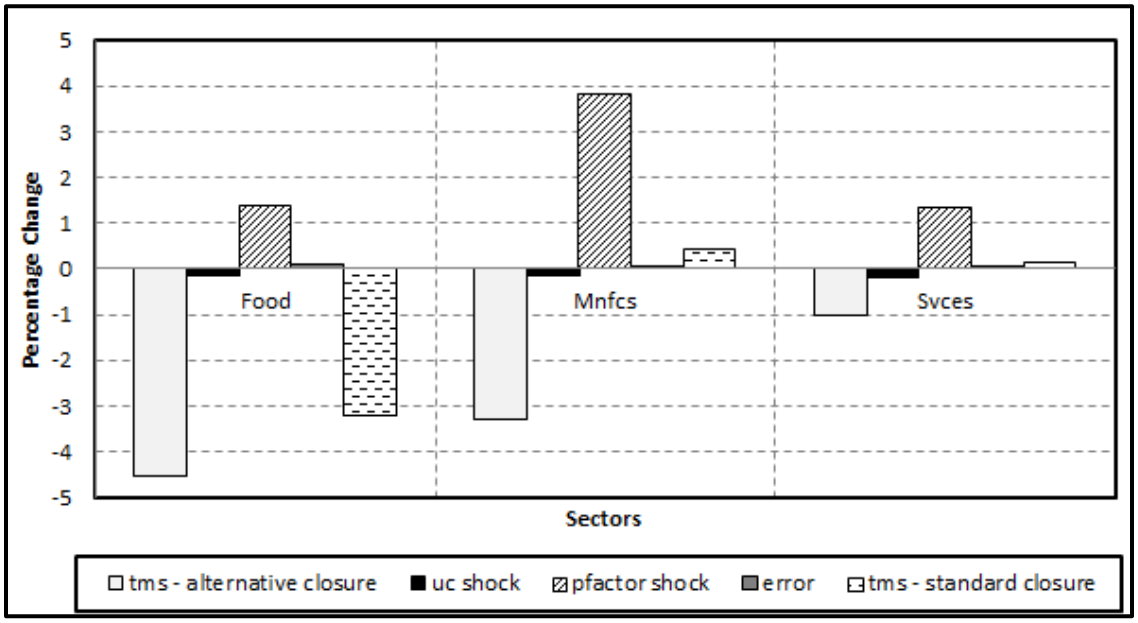

Figure 7. Percentage Change in Output in the EU

In Figure 7, 'tms – alternative closure' corresponds to the `tms` shock under the alternative closure.[26] In this closure we have the tariff shock; however, the economy is prevented from returning to equilibrium:

[25] The percentage change in output given the `tms` shock under the alternative closure together with `uc` and `pfactor` shocks will give an approximation to the percentage change in output given the `tms` shock under the standard closure with an error. The calculation can be represented by the following equation

$$\text{tms under the alternative closure} + \text{uc shock} + \text{pfactor shock} = \text{tms under the standard closure} - \text{error}$$

[26] The change in output (`qo`) is found by using the tms_macro.cmf file.

unemployment and an external deficit result. The tariff cut leads to an increase in imports which replaces domestic production and this results in a contraction across all sector. The food sector experiences the highest output drop since the tariff cut on food prices is the highest.

As discussed in Section 4.4, in order to bring the economy back to macroeconomic equilibrium, two shocks should be imposed on the model. The first one we will examine is the `uc` shock[27]. The reduction in `uc` leads to a reduction in aggregate expenditure hence it causes a decline in domestic demand for all goods produced in EU. This causes a contraction in all sectors. Note that a decline in real consumption implies that savings are increasing which leads to an increase in net trade and a deficit in the capital account. The second shock is the `pfactor` shock.[28] The real decline in pfactor results from a) the real depreciation (which brings about an expansion in each sector); and b) the decline in real wages required to remove unemployment (which brings about expansions in all sectors). The manufacturing sector experiences the highest output expansion following the `pfactor` shock since most of the EU's trade with other countries is in manufacturing. These two shocks need to be added together to obtain the impact of returning to internal and external equilibrium: through a fall in unemployment and a rise in exports.

Given the impact of `uc` and `pfactor` shocks on sectoral output, 'tms – standard closure' in Figure 7 represents the final change.[29] The results are found by imposing the same tariff cut under the standard GTAP closure. In this final case, the macroeconomic equilibrium is restored in such a way that the tariff cut generates a contraction in the food sector and an expansion in manufacturing and services. Note that, the error term shows how much the results differ from those obtained using the decomposition.

Figure 7 therefore shows that, for the food sector the first-round effects outweigh any increase in output due to increased exports or access to unemployed factors. Hence the overall result is a contraction in food production. On the other hand, both the manufacturing and services sectors experience an expansion in their output. For those sectors, the driving force is the increase in trade balance caused by the real depreciation and the reallocation of unemployed factors into their production.

Even though, each sector experiences similar changes from the real depreciation (BP) and the removal of unemployment (FE) which impact will dominate and whether they will offset the first-round effects depends on the sector. In order to see which effect is the greatest in determining the output growth in each

[27]The shock that is imposed, in this case, is `uc("EU")=-0.227`. The change in output following this shock is found by using the GE elasticities. The first step is to use the uc.cmf file to find the elasticity of `qo` with respect to `uc` by imposing the shock `uc("EU")=1`. The second step is to multiply this elasticity by -0.227 to find how much the `uc` shock changed `qo`. The calculation can be represented by the following equation

$$qo(\text{“}TRAD\_COMM, EU\text{”}) = uc(\text{“}EU\text{”}) \times \varepsilon_{qo,uc}$$

[28]The shock that is imposed, in this case, is `pfactor("EU")=-1.404`. The change in output following this shock is found by using the GE elasticities similar to the previous case based on the pfactor.cmf file. The calculation can be represented by the following equation

$$qo(\text{“}TRAD\_COMM, EU\text{”}) = pfactor(\text{“}EU\text{”}) \times \varepsilon_{qo,pfactor}$$

[29]In this case, the change in output can be found by using tms.cmf file. This gives the total impact of the initial tms shock, the uc shock and the pfactor shock together with the error. Recall that the total impact is the final effect of tariff liberalization.

sector, we need to look more closely at the results. For instance, we could decompose the output growth into domestic sales and export sales. The results are summarized in Table 5. [30]

Table 5. Output Growth in the EU

	Food	Mnfcs	Svces
e1_SHRDM	-2.186	-0.297	-0.081
e1_SHRST	NA	NA	0.042
e1_SHRXMD	-1.005	0.753	0.155
tradslack	0	0	0
Total	-3.191	0.456	0.116

When `qo` in the EU is decomposed into share weighted domestic sales and share weighted export sales, it can be seen that the domestic sales decline in all three sectors. However, the export sales only decrease in the agricultural sector, while it increases in the manufacturing and the services sectors. Note that in this case the `pfactor` and `uc` shocks are accompanied by a tariff cut which causes a reduction in the export sales in the food sector.

Table 5 shows that the increase in the percentage change of manufacturing output is driven by the increase in export sales. Thus, the final result in the manufacturing sector is due to the BP effect. If `qxs` is decomposed into its components, it can be seen that the bulk of the increase in exports in each sector comes from the substitution effect rather than the expansion effect. Thus, the real depreciation creates the change in relative prices in favor of the EU so that exports increase in each sector with the `pfactor` shock.

Figure 8 shows the decomposition of trade balance in each sector.[31] As can be seen, the `pfactor` shock affects the manufacturing sector the most, because the export of manufacturing products from the EU to all regions has the highest share compared to food and services. In contrast, trade liberalization causes a contraction in the food sector which brings about a decline in factor demand and generates a reduction in factor returns. In order to restore the internal equilibrium, the factors released from the food sector should be absorbed by other sectors. The factor reallocation observed as a result of the tariff cut is shown in Figure 9.

[30]The results are found by using tms.cmf file.

[31]The change in trade balance in each case is found by following the same steps we followed in examinig the change in output.

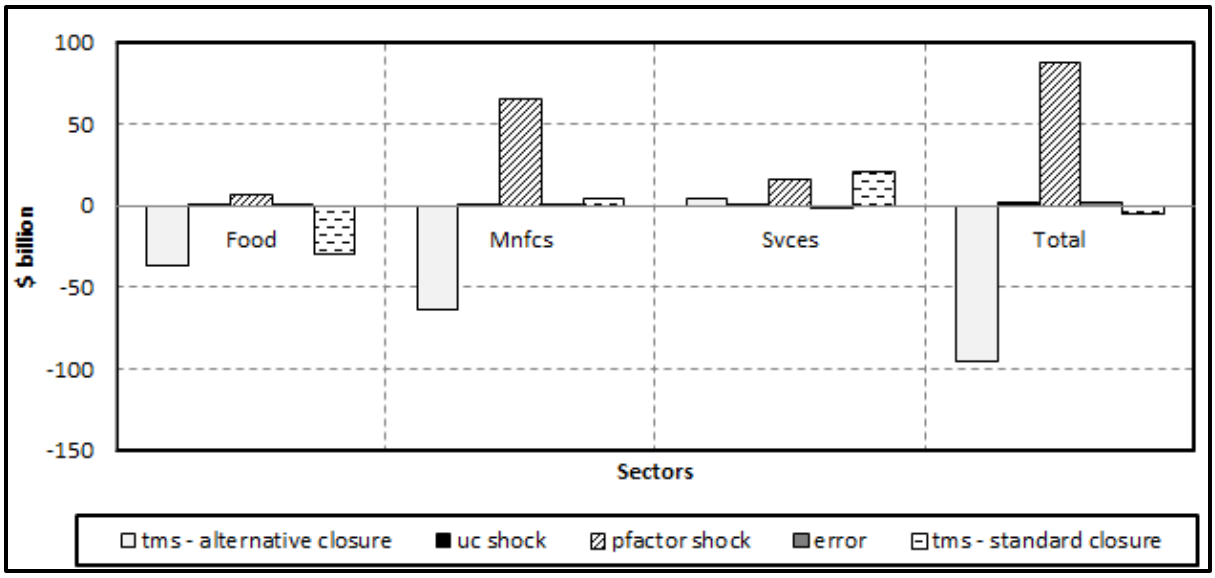

Figure 8. Change in Trade Balance in the EU

In this case, the bulk of the unskilled and skilled labor released from the food sector is employed in the manufacturing sector. The manufacturing sector absorbs most of the factors due to the positive impact of real depreciation on exports. Both these effects are captured in the `pfactor` shock, which is why it generates such a huge expansion in manufacturing production.

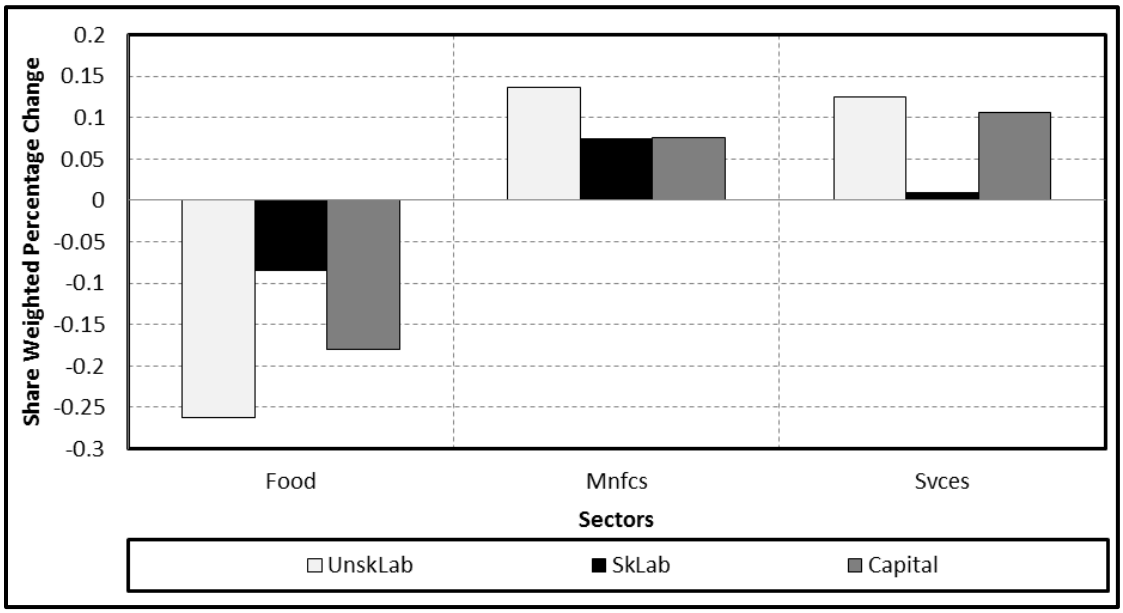

Figure 9. Effects of Tariff Liberalization on Factor Demand in the EU[32]

[32] The reported results are the changes in share weighted factor demand found by using the tms.cmf file. In particular, we looked at `SHREM(ENDWM_COMM,PROD_COMM,EU)*qfe(ENDWM_COMM,PROD_COMM,EU)` to calculate the share-weighted percentage change.

The decomposition of share-weighted percentage change in unskilled labor is given in Figure 10. The movement of the unskilled labor from the food sector to the manufacturing and services sectors improves the allocative efficiency and restores the internal equilibrium.

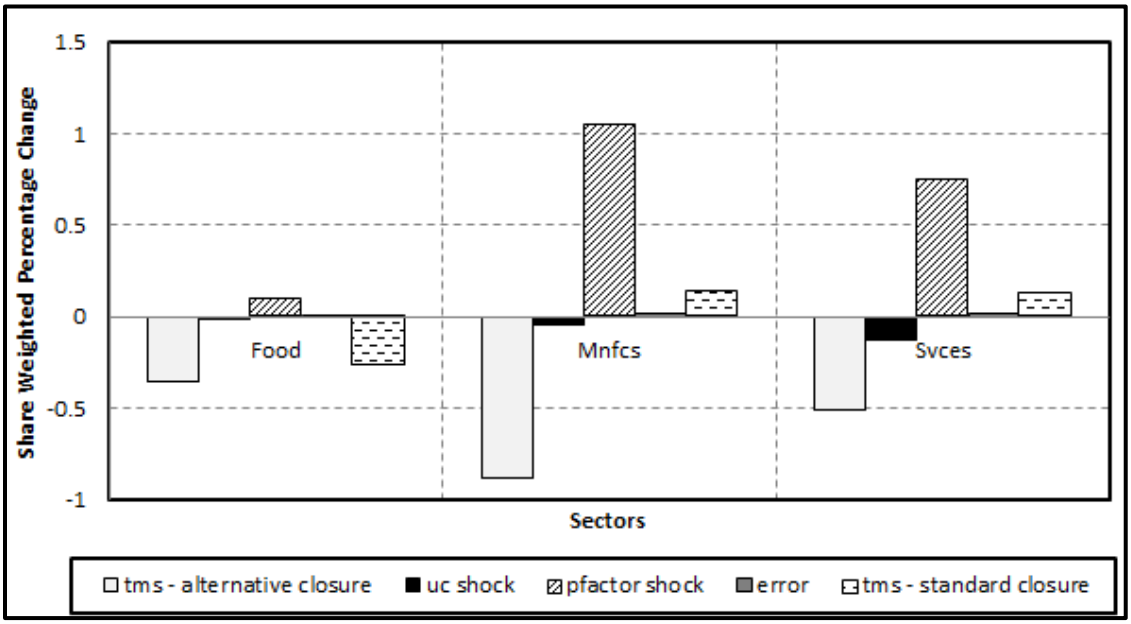

Figure 10. Share-weighted Percentage Change in Unskilled Labor in the EU

The decomposition of the GE mechanisms shows that the food sector's response to the shock is dominated by the first-round effects, while that of the manufacturing and services sectors are dominated by the equilibration effects. Hence the channel through which the policy shock affects the sector differs across sectors depending on which effects dominate.

5. Changes in the Balance of Capital Account

Section 4 analyzed a tariff liberalization scenario which required us to focus more on the trade balance in order to restore the external equilibrium. However, there are other scenarios whose impact on investment generates a prominent change in the balance of capital account as well as the balance of trade. In this context, this section will examine one such scenario by introducing a new aggregation. We will work with a 3×3 aggregation GEINV3×3 which has three regions; namely, China (CHN), EU and the Rest of the World and three sectors; namely, food, manufactures and services. The simulation we will focus on is the elimination of all tariffs on exports from the EU to China in each sector. The distinct feature of this experiment is that it shows how the impact of tariff elimination on the economy is reversed when investment changes significantly as a response to the shock.

The simulation in this section will be carried out by using the same decomposition method as in Section 4.3. In that sense we will isolate the changes taking place in the BP and FE curves by discussing the

internal and external equilibrium responses to the `tms` shock. The amount of the tariff cut in each sector for this scenario is presented in Table 6.

Table 6. Tariff Liberalization in CHN

Sectors	`tms` Shock
Food	-10.971
Mnfcs	-13.822
Svces	0
Total	-24.793

Tariff liberalization leads to adjustments in the external equilibrium through its impact on the balance of trade (BoT) and the balance of capital account (BoKA) such that BOP is always balanced.

$$\underbrace{\underbrace{\left(X-M\right)}_{BoT}+\underbrace{\left(I-S\right)}_{BoKA}}_{BOP}=0 \tag{13}$$

The tariff cut leads to a decline in the price of imported goods relative to the domestic goods; therefore, imports in CHN have gone up. Note that in this scenario the generated import increase is much higher than that of the previous simulation. This difference stems from the fact that China imports a significant amount of investment goods from the EU. With higher imports, BoT deteriorates causing disequilibrium in the balance of payments. While imports are going up, income in China is going down which leads to a decline in savings.[33] Even though lower savings offset part of the increase in imports, it is not enough to eliminate it as can be seen in Table 7.

Table 7. BOP Variables in China under the Standard Closure

	% Change in Volume	Change in Volume	Change in Value
Net Savings	0.16817	2293.111	-6732.177
Net Investment	0.71299	2622.958	2622.958
Imports	6.06931	60047.273	59163.961
Exports	4.73348	59620.387	49863.5

So far the changes taking place in BOP variables are similar to the previous scenario. However, the response of investment is reversed compared to the first simulation results. This reversal becomes decisive in the adjustment of exports to restore the BOP equilibrium. Following the tariff cut, the price of imported investment goods goes down which means that the price of capital goods in China is decreasing. Lower price of capital goods raises the current rate of return to capital which then induces investment. The fact that investment goods constitute a high portion of imported goods in China and those imports, mainly manufactures, experience larger declines in tariffs (compare Table 6 and Table 2) lead to an increase in the current rate of return that is more prominent than in the previous experiment. This is why the investment response to this `tms` shock is the opposite of the first simulation.

[33] The relationship between savings and income is determined by the Cobb-Douglas function such that if income declines, savings go down, as well. See M^{c}Dougal (2003) for a more comprehensive analysis on demand.

Higher investment together with lower savings leads to an increase in the balance of capital account generating a BoKA surplus. Given the deterioration in BoT and the surplus in BoKA, exports must decline in order to restore BOP equilibrium. In fact, the BP curve shifts upward reflecting the fact that the initial real exchange rate is too low to bring the economy back to external equilibrium. Hence the disequilibrium in BOP is eliminated by a real exchange rate appreciation and a resulting decline in exports. The final change is such that the decline in BoT is offset by the increase in BoKA as is summarized in Table 8. Consequently, the BOP equilibrium is restored on the new BP curve with a higher real exchange rate. Note that Table 7 shows that exports have increased instead of declining despite the fact that there is a real exchange rate appreciation. Even though this result seems to be contradictory with our explanation, it is, in fact, one such puzzle that can be solved by the decomposition method which we will examine later in this section.

Table 8. Final Change in BOP in China

	Change in Volume	Change in Value
ΔBoT	-426.886	-9300.461
ΔBoKA	329.848	9355.135

While tariff liberalization generates a BP surplus, there are also some changes taking place in the internal equilibrium. Tariff liberalization leads to adjustments in the internal equilibrium through factor reallocation across sectors. Due to high investment, there is an excess demand in the economy which results in overemployment. The tariff liberalization brings about a contraction in food and manufacturing, while it leads to an expansion in services. Hence the factors that are released from food and manufacturing are absorbed by services. As this happens the FE curve shifts leftward leaving the initial equilibrium point off the FE curve which distorts the internal equilibrium. In fact, at the initial equilibrium the relative factor returns are too low to eliminate the overemployment. A rise in relative factor returns is then necessary to offset the rise in demand and to bring the economy back to internal equilibrium on the new FE curve.

Consequently, the `tms` shock leads to an inward shift in the FE curve and an upward shift in the BP curve causing a macroeconomic disequilibrium given the initial point. In order to see whether this is the case in this application, we will follow the same method that we used in Section 4.3 to draw the FE and BP curves using the same modifications in the closure. In other words, the same `uc` shocks are introduced to obtain the changes in `pfactor`. The movement in the economy following the `tms` shock can be seen in Figure 11.

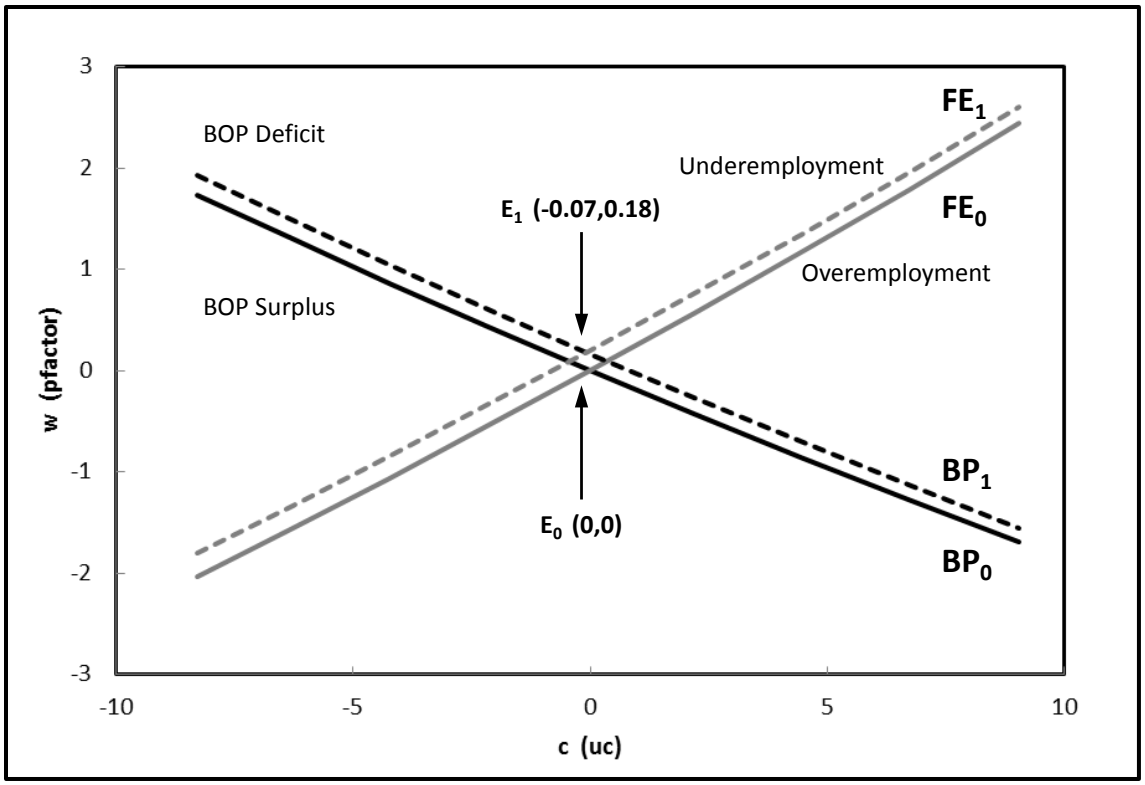

Figure 11. Change in Equilibrium in China

Examining Figure 11 it can be seen that tariff liberalization leads to an inward shift in the FE curve and an upward shift in the BP curve leaving the initial equilibrium combination of (*C*,*w*) with a balance of payments surplus and an overemployment. At E_0 the real exchange rate is too low to offset the BOP surplus hence it increases until the external equilibrium is restored at E_1. Similarly, at E_0 the relative factor returns are too low to eliminate the overemployment. Therefore, *w* increases bringing the economy back to the external equilibrium at E_1. At E_0 neither the internal equilibrium, nor the external equilibrium are satisfied. Hence it is associated with a macroeconomic disequilibrium where the economy experiences an overemployment and a BOP surplus. This result is also confirmed by the changes taking place in the closure variables following the `tms` shock which is summarized in Table 9.

Table 9. The Impact of Tariff Cut on the Closure Variables in China

Regions	uc	pfactor	qoreg	dpsave
CHN	0	0	0.482	0.810
EU	0.174	0.695	0	0
ROW	-0.035	-0.281	0	0
Total	0.139	0.414	0.482	0.810

As expected, there is no change in the exogenous variables, uc and pfactor, that is why they are zero. On the other hand, the endogenous variables, qoreg and dpsave, have increased. Note that qoreg("CHN") is 0.482 which means that there is an increase in factor employment following the tariff cut leading to an overemployment in China. In addition, the tariff cut generates a balance of payments surplus which is captured by the fact that dpsave("CHN") increases by 0.81 %.

Note that the change in closure variables and the movement of both curves are reversed in this scenario compared to the simulation in Section 4. In the first simulation, qoreg and dpsave were both negative capturing the underemployment and BOP deficit experienced at the initial equilibrium following the tariff cut which results in real exchange rate depreciation in the EU. Even though the same type of tariff liberalization shock is analyzed in the second simulation, China experiences a BOP surplus and overemployment at E_0 leading to real exchange rate appreciation instead of a depreciation. This reversal can be traced back to the change in the response of investment. In the first simulation, net investment declines together with savings causing the change in BoKA to be ineffective in BOP. On the other hand, in the second scenario net investment increases as opposed to a decline in savings. This time the change in BoKA is too substantial that it drives the results in the balance of payments; thereby, reversing the real exchange rate response.[34]

The general equilibrium is restored by the same method used in Section 4.4. Using the GE elasticities for China we can find how much we should shock uc and pfactor to generate the required changes in dpsave and qoreg so that the economy moves from E_0 to E_1. The shock that should be introduced to restore general equilibrium is

```
shock uc("CHN")     =-0.078;
shock pfactor("CHN")= 0.183;
```

The adjustments in uc and pfactor as a response to the tms shock are isolated by this method which paves the way to decompose the impact of tariff liberalization. As is explained above the tariff cut distorts the external equilibrium by generating BOP surplus which is eliminated by real exchange rate appreciation and a resulting decline in exports. Recall that despite the real exchange rate appreciation, exports seemed to have increased as presented in Table 7. Even though it seems contradictory, the decomposition in Figure 12 shows that the tariff cut stimulates exports before uc and pfactor shocks return the global economy back to internal and external equilibrium. Hence the rise in exports is the result of the conventional linkages.

[34] The behavior of investment in GTAP depends both on the type of shock that is imposed as well as the binary parameter RORDELTA which is a mechanism to manage the allocation of investment across regions (Hertel and Tsigas, 1997). Specifically, if RORDELTA=1, expected rate of returns are equalized across regions through the allocation of investment. On the other hand, if RORDELTA=0, investment allocation is proportional to the existing composition of capital stock (Huff et al, 1997). In this paper, RORDELTA is assumed to be 1 in both experiments. Note that the shock imposed in the first simulation is elimination of all tariffs from SSA to EU which does not lead to a significant change in the response of investment if we switch to RORDELTA=0 as opposed to RORDELTA=1 since it does not induce a big change in the current rate of return. In contrast, eliminating all tariffs from EU to China leads to a noticeable increase in the current rate of return making the choice of RORDELTA effective. If RORDELTA is assumed to be 0, there will not be a noticeable change in BoKA hence the results will be similar to the first experiment. Table 11 in Appendix 2 compares the changes in BOP variables when RORDELTA is 0 and 1 in each simulation. See Hertel (1997) for further information on RORDELTA.

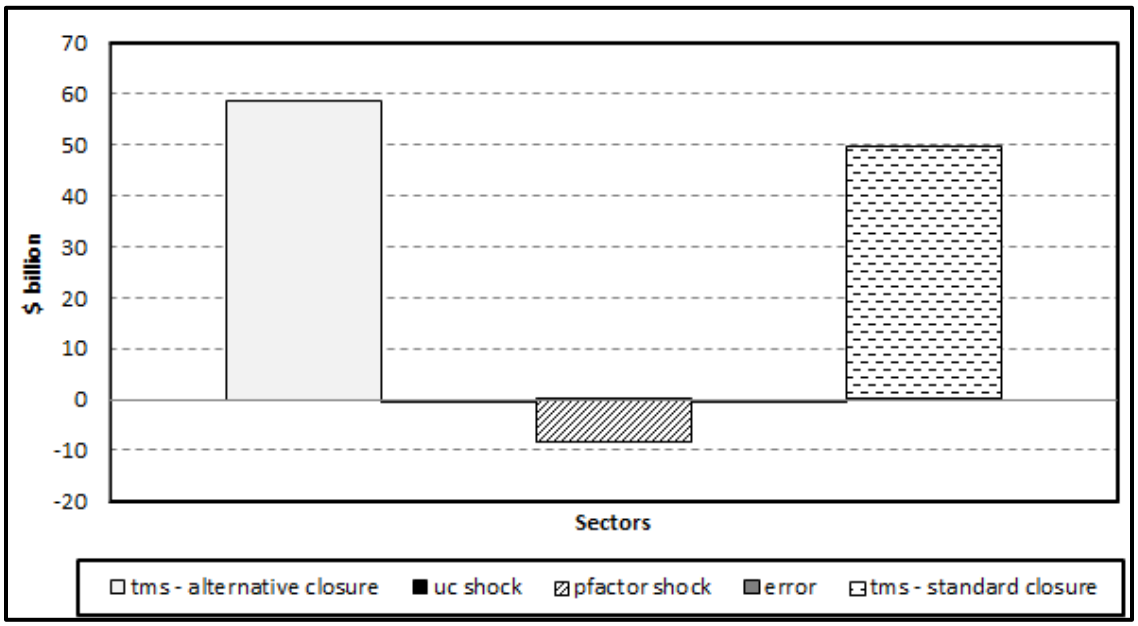

Figure 12. Change in Exports in China

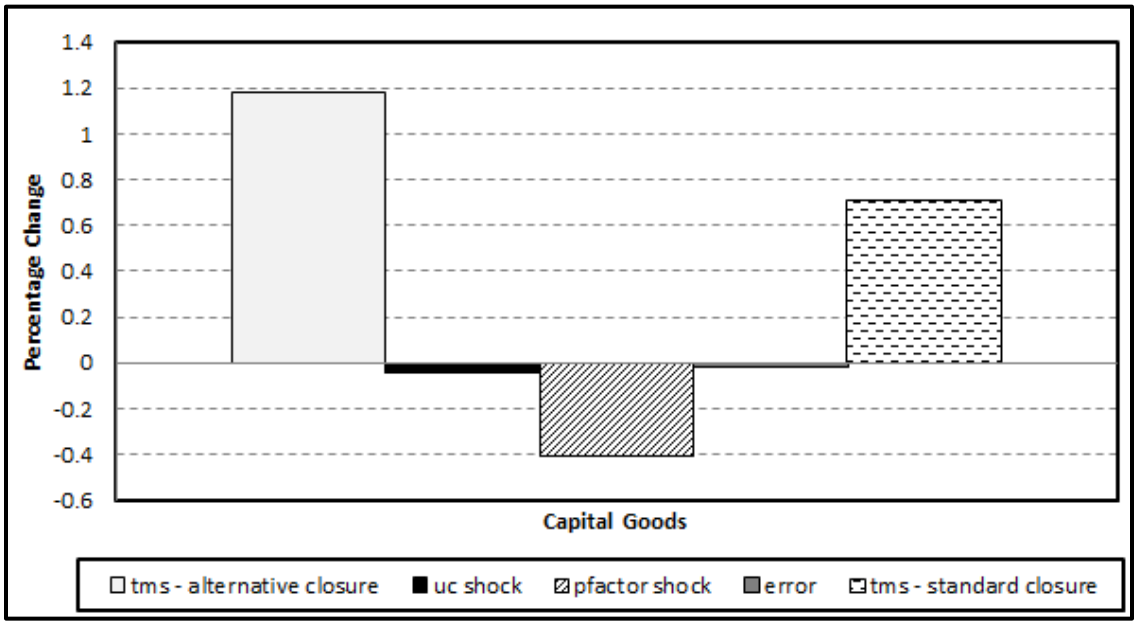

Figure 13. Change in Capital Goods in China

Since tariff cut reduces the price of imported goods, there is a significant increase in investment good imports which are used as intermediate inputs in production. It also leads to higher investment and an associated increase in capital goods which is shown in Figure 13. The lower input prices generate cost savings which are, then, reflected in commodity prices leading to a decline in the relative price of exports in China. Hence the tariff cut not only induces imports, but it also leads to an increase in exports thanks to cheap intermediate inputs. Part of the increase in exports is offset by real exchange rate appreciation as

shown by the pfactor shock in Figure 12. However, the initial increase in exports drives the final result of the tms shock. Note that the uc shock does not generate a noticeable change in exports.

The change in trade balance in each sector is shown in Figure 14. The initial impact of the trade liberalization is a deterioration in the trade balance of food and manufacturing sectors. As opposed to the less noticeable trade decline in the food sector, the manufacturing sector experiences a significant deterioration in its trade balance since the highest tariff cut is observed in the manufacturing sector and most of the trade in China is in manufactures. Even though exports are increasing, they are not enough to offset the increase in imports due to the amount of imported investment goods used in manufacturing. In contrast, there is an improvement in the trade balance of services which is partly because the tariff cut in services is zero. Since imports are not as attractive as they are in other sectors, the increase in exports dominates the change in trade balance in the services sector.

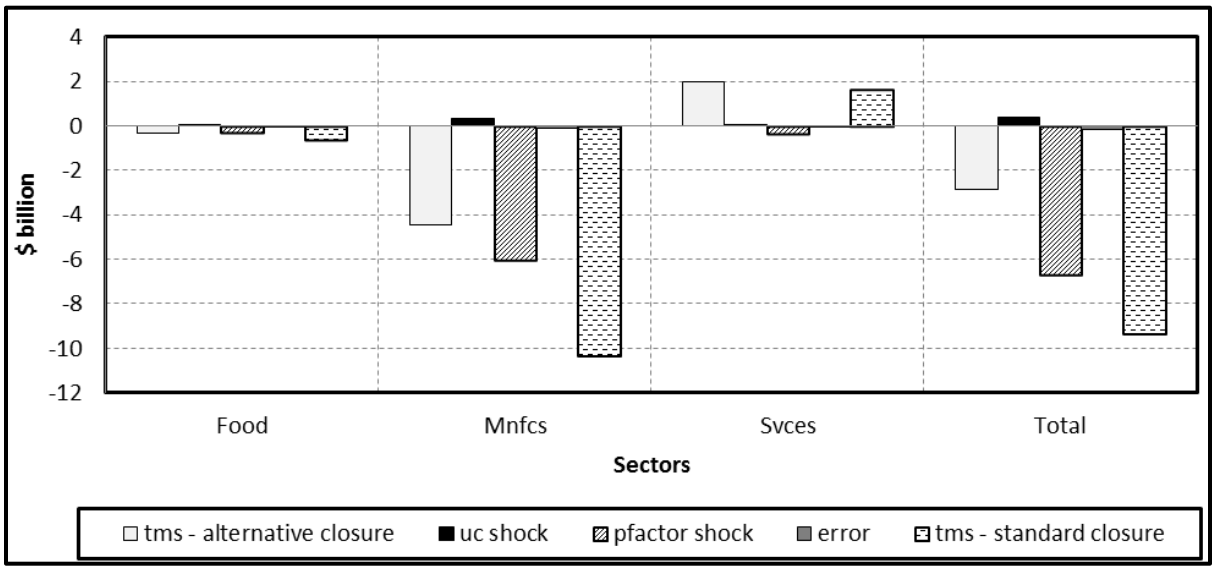

Figure 14. Change in Trade Balance in China

With the uc shock, domestic demand declines which leads to a reduction in imports and an associated improvement in the balance of trade in each sector. However, the impact of the pfactor shock generates the opposite effect and distorts each sector's trade balance. The biggest impact of exchange rate appreciation is observed in the manufacturing sector due to declining exports. The overall change in trade balance mimics that of the manufacturing sector since the bulk of trade is carried out over manufacturing commodities. The total effect shows that the real exchange rate appreciation is the main engine of the deterioration in overall trade balance compared to the uc shock.

Given the changes in trade balance, the decomposition of production in each sector is presented in Figure 15. Tariff liberalization initially leads to an expansion in all sectors due to increasing exports which are stimulated by initial cost savings. The increase in investment is also a contributing factor to the expansion of manufacturing sector. Since there is zero tariff cut in services sector, it does not face too much foreign

competition; therefore, the highest expansion is in the services sector. The decline in demand generated by the uc shock leads to a contraction in all sectors. Real appreciation causes further contraction which is mostly felt in the manufacturing sector. As a result, the overall effect of tariff liberalization is a contraction in food and manufacturing as opposed to an expansion in services sectors. It also means that the factor reallocation is such that the factors which are released from food and manufacturing are employed by the services sector maintaining the full employment condition on the new FE curve.

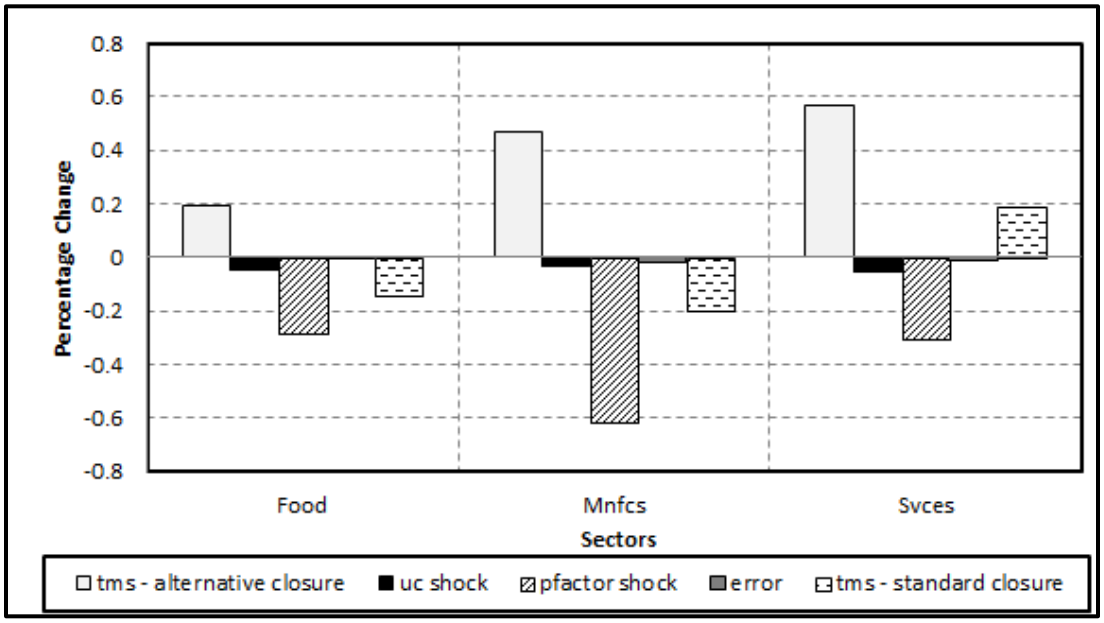

Figure 15. Change in Output in China

Note that the initial impact of tariff liberalization on each sector is the opposite of the first simulation carried out in Section 4.5. Even though, each sector expands under the alternative closure in this scenario, they all contracted in the first simulation. This difference stems from the fact that there is a significant intermediate input effect in China following the tariff cut resulting in lower export prices which stimulates exports and thereby production in each sector. The overall production effect is similar in the food and services sectors, while it differs in the manufacturing sector. While the manufacturing sector expands in the first simulation, it contracts in the second one due to the response of real exchange rate. The real depreciation of the first simulation is the main engine of expansion in the first simulation as opposed to the contraction effect of the real appreciation in the second scenario.[35]

6. Conclusion

This paper focuses on the General Equilibrium Mechanisms that restore equilibrium in the economy following tariff liberalization. The main objective of the paper is to isolate the driving forces behind the

[35] See Table 11 in Appendix 2 for a comparison of the change in BOP in each scenario.

equilibrium to understand the economy-wide impacts of a shock. The simultaneous adjustment of the economic variables makes it difficult to trace out the channels through which each sector responds to the shock. In order to distinguish the experiences of each sector and to make the causality more transparent, the GE mechanisms are decomposed into two effects: Internal Equilibrium and External Equilibrium. This analysis enables the modeler to distinguish the changes taking place in domestic production resulting from an allocative efficiency from the changes resulting from net trade and international capital flows. Since these two effects differ across sectors, the decomposition method can be a powerful tool in policy making.

The immediate results of a policy shock are not always intuitive because of the economy-wide impacts and simultaneous adjustment of the variables. In order to improve the analysis the decomposition procedure is carried out in two simulation experiments. The first simulation focused on is the elimination of all tariffs on exports from all regions to the EU using GE3×3 aggregation. The results show that the tariff cut leads to a contraction in the food sector, while the manufacturing and services sectors expand in the EU. The factor allocation in EU also supports this point since the share weighted factor demand for mobile factors such as skilled labor, unskilled labor and capital are declining in the agricultural sector while they are increasing in the manufacturing and services sectors. Thus, there has been a factor reallocation from the food sector to manufacturing and services.

The decomposition shows that the response of the food sector to the tariff cut is driven by the first-round effects. The factors in the economy are reallocated after the shock in order to restore the internal equilibrium the impact of which dominates the equilibration effects in the food sector. In contrast, the driving force behind the response of the manufacturing sector is the equilibration effects. The economy experienced a real exchange rate depreciation following the shock to restore the external equilibrium which improved net trade in all products. Moreover the decline in real wages reduces unemployment and restores internal equilibrium through the reallocation of factors some of which are employed by the manufacturing sector. The services sector also absorbs the factors released from the food sector but not as much as the manufacturing sector does since the rise in net exports of services falls short of that of the manufacturing sector. Hence the dominant channel through which the policy affects the variables differs across sectors.

The second simulation is the elimination of all tariffs on exports from the EU to CHN in a GEINV3×3 aggregation of the GTAP 8 Data Base. The results show that the impact of tariff liberalization on equilibrium is reversed when the capital account response to the shock is more prominent. Compared to the first simulation, tariff cut leads to an initial BOP surplus and overemployment which are eliminated by real exchange rate appreciation. This reversal can be traced back to the change in the response of investment. In the first simulation, net investment declines together with savings causing the change in BoKA to be ineffective in BOP. On the other hand, in the second scenario net investment increases as opposed to a decline in savings. This time the change in BoKA is too substantial that it drives the results in the balance of payments; thereby, reversing the real exchange rate response. Hence the decomposition method not only provides an explanation for the different responses of each sector to a policy shock, but it has the potential to provide an explanation for the reversal of the impact of the same policy shock in a different setting when the response of a variable, in this case investment, changes depending on the economy.

The GE mechanism provides a powerful tool in economic analysis and policy making since it shows how the FE and BP effects can differ across sectors and economies. Since it becomes possible to pinpoint the repercussions of a policy shock on different sectors, the policy can be adjusted so that it has the predicted impact on the targeted sectors without distorting production in other sectors.

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Appendix 1

Table 10. Closure Rules

Variable	Standard Closure	Alternative Closure	FE Closure	BP Closure
dpsave("REG")	Exogenous	Endogenous	Endogenous	Exogenous
qoreg("REG")	Exogenous	Endogenous	Exogenous	Endogenous
uc("REG")	Endogenous	Exogenous	Exogenous	Exogenous
pfactor("REG")	Endogenous	Exogenous	Endogenous	Endogenous

where "REG" is EU in the first simulation and "CHN" in the second simulation.

Appendix 2

Table 11. The Impact of RORDELTA

	Sim. 1: EU Section 4.5		Sim. 2: CHN Section 5	
	RORDELTA=0	RORDELTA=1	RORDELTA=0	RORDELTA=1
Δ Net Savings	-11060	-10892	-8860	-6732
Δ Net Investment	-8494	-6185	-8369	2622
Δ Imports	6333	7355	56945	59163
Δ Exports	3796	2710	56444	49863
rorc	0.31	0.32	1.12	1.18
pfactor	-1.39	-1.36	0.04	0.18
Δ BoKA	2566	4707	491	9355
Δ BoT	-2537	-4644	-500	-9300

The root of the difference between the results obtained in Section 4.5 and Section 5 can be traced back to the relative impact of the shock on investment and exports in driving the BP effect which is presented in Table 11. In Section 5 an example was shown where the current rate of return increased much more which brought about the investment increase (rorc is 1.18 in CHN compared to 0.32 in EU). It was shown in Section 5 that these investment effects can have a significant impact on the results and how exports rise to ensure BOP equilibrium. One way to turn off these investment effects on the BOP is to set RORDELTA equal to zero. When RORDELTA=0, investment does not respond to changes in the rates of return and hence any large investment effects are nullified or dampened (compare Sim. 2, RORDELTA=0 and RORDELTA=1). However, there should be a word of warning about this approach. Note that when the link between investment and regional rates of return is broken, it says that investment will not be positively affected by the trade liberalization shock, instead investment in all countries moves up or down together with global savings.

In Sim. 1 from Section 4.5 the weight of investment goods in the imports of EU from SSA was much smaller than that of CHN from the EU, hence rates of return did not rise significantly and the trade liberalization did not affect rates of return and investment. As such changing from RORDELTA=1 to RORDELTA=0 has only a minor impact on the results.