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CGE experiments based on the GTAP database and two TiVA-based databases [1]

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Abstract

This paper aims to examine the implications of using the GTAP database and three databases containing information from trade in value-added (TiVA) datasets for computable general equilibrium (CGE) experiments. A comparison of experiments based on the GTAP data and on USITC research on global value chains (GVC) illustrates that a CGE model specified in such a way as to better reflect the trade linkages found in modern global supply and value chains can produce substantial differences in macro level impacts and also reflect the realities of specific product chain relationships. Our comparison would expand to include TiVA datasets from the WIOD project and OECD/WTO.

[1] Draft prepared for presentation in an Organized Session titled "An in-depth discussion of three global trade datasets and their implications for economic analysis" in the *16th Annual Conference on Global Economic Analysis*, June 12-14, 2013, Shanghai Institute of Foreign Trade, Shanghai, China.

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CGE experiments based on the GTAP database and two TiVA-based databases

Recent research has examined trade statistics from a value-added perspective and it has traced global value chains (GVC) through countries' domestic production, exports and imports. Research by Koopman et al., (2010 and 2012), Johnson and Noguera (2012), Timmer, ed., (2012), and OECD/WTO (2013) has made clear that our understanding of trade linkages based on statistics in gross values can be very different from our understanding of trade based on value-added terms. In this paper we examine how using information contained in these new datasets on trade in value-added (TiVA) in a computable general equilibrium (CGE) trade model can influence results from experiments. Our results suggest that the new data sets could improve empirical information used to support policy making.

We first build a version of the now standard computable general equilibrium (CGE) trade model, using a GTAP framework (Hertel, 1997; Narayanan, et al., 2012) and another CGE model that uses information derived from the USITC global value chains work. We then run two hypothetical comparative-static experiments to illustrate two alternative mechanisms that could result in a rebalancing in U.S.-Asia trade flows using the GTAP model and the GVC model – an additional U.S. tariff placed on imports from China aimed at offsetting the effect of a low exchange rate on U.S. imports from China, and a second scenario of an appreciation of the renminbi. In particular, the first hypothetical scenario is that the United States applies additional duties on imports from China at the rate of 27.5 percent. The second scenario is that the national savings rate in China declines from 44 percent to 36 percent. These two experiments are not calibrated to produce the same effect for any particular variable; thus differences in a particular effect across the two experiments do not imply that one change is more effective than the other change. We compare the results of this global value chains (GVC) based model with results from the standard GTAP model and find that the GVC trade model has quite important differences that more clearly illustrate how global value and supply chains work through the global economy and how they can cause some unexpected effects within and across economies.

A GVC CGE modeling framework

The economic theory of the GVC CGE model discussed in this draft is similar to the theory of the GTAP model (Hertel, 1997) except for two differences which are discussed below. Both the GVC and the GTAP models have a focus on the United States and China as well as their top trade partners. Twenty six regions and 41 production sectors in each region are specified to represent the world economy (**table 1**). The first difference between the GVC model and the GTAP model is that in the GVC model, China and Mexico have export processing zones and these zones are modeled as separate economies. Thus the total number of economies in the GVC model is 28.

Figure 1 illustrates the GVC model linkages between the processing trade economy in China, the rest of China, and a third economy, Japan. Figure 1 shows that there is two-way trade between Japan and the two Chinese economies; Japanese products enter the Chinese processing zone duty free; the rest of the Chinese economy exports products to its processing zone but does not import any products from it; finally, it is assumed that labor and capital can move freely between the Chinese export processing zone and the rest of the economy in China. The same linkages apply to Mexico and its processing zone in the GVC model. In the standard GTAP model trade is only specified bilaterally between Japan and China, as China processing is subsumed in China, and similarly with respect to the Mexico component.

For each economy in the GVC model we specify a utility function for its representative household and production functions for its producing sectors. Subject to transportation costs, the representative household and producing sectors engage in commodity and services trade with households and producing sectors in all other regions in the model. The representative household represents private and government expenditures.

All economic agents are price-takers and their demands for commodities and primary factor services are based on cost minimizing and utility maximizing behavior subject to production function and budget constraints. Producing sectors produce a single commodity. Intermediate and final demand users of commodities and services are assumed to differentiate a commodity and services by its region of origin, i.e., the *Armington specification* is applied (Armington 1969a and 1969b).

On the final demand side of the model, households purchase commodities and services and they save part of their income, which consists of returns to primary factors and net tax collections. In each region, aggregate investment in new capital goods is represented by the output of a "capital goods" sector. Globally, the sum of household savings is equal to the sum of investment expenditures. Commodity and services prices in each region are determined by market clearing through international trade.

Welfare and household demands. It is assumed that preferences are separable, which allows expressing total utility as a function of sub-utilities, which in turn have deeper subgroupings within them. At the top of the utility tree, regional welfare is derived from private household expenditures, government expenditures, and savings. It is assumed that the simulations do not change the distribution of regional income across private and government expenditures, and savings. This assumption is implemented by applying a Cobb-Douglas function to describe substitutions between the three components of welfare. Currently, there is no economic mechanism that links government expenditures to government revenues. Household demands for composite commodities are specified with Cobb-Douglas functions in the GVC model.

Industrial sector demands. Producing sectors demand two types of inputs: primary factors and intermediate inputs. The primary factor composite is a CES aggregate of unskilled labor, skilled labor, and capital. The elasticity of substitution between primary factors is industry specific. There is no substitution between the primary factor composite and intermediate inputs, i.e., a Leontief technology is assumed.

International trade. The main features of the model treatment of trade are the Armington assumptions discussed earlier. In the GVC model the determination of the sourcing of imports is placed at the producer and consumer level instead of at the national level. Thus in this model we have substituted the standard GTAP assumption that affects bilateral trade (i.e., sourcing of imports for the economy as a whole) with a micro-based determination of bilateral trade (i.e., sourcing of imports at the agent level). Placing the sourcing of imports at the agent level reduces the power of the terms-of-trade effects. Our database differentiates the sourcing of imports for producers from the sourcing of imports for households.

There are two additional mechanisms in the model that affect the international linkages in the model. The specification of both of these mechanisms draws on the GTAP model (Hertel and Tsigas). First, a global sector demands services from each regional transportation services sector, to provide a composite service which is used for shipping commodities across regions. In value terms, each region’s relative contribution to the global transportation sector does not change due to the simulation performed. It is also assumed that shipping services are required in fixed proportions with the quantity of a particular commodity shipped along a particular route.

The second global sector intermediates between regional savings and regional investment. This global sector has a portfolio of regional net investments which are offered to regional households to satisfy their demand for savings. Regarding the regional composition of net investment, the model assumes that there is a negative relationship between the (expected) regional rate of return on capital and the amount of investment undertaken in a region.

Primary factor mobility. Each region has fixed endowments of skilled and unskilled labor, and capital. Labor services and services from existing capital stock are assumed to be intersectorally perfectly mobile, but region specific. This implies that all sectors, in a region, face the same market price for labor services and the same market price for capital services. It is assumed that labor and capital can move freely between the export processing zone and the rest of the economy in China and Mexico.

Data used in the GVC CGE model

Trade flows in both models are represented by gross trade figures. The global value chain aspect of current international trade is reflected in the GVC model via the particular implementation of the Armington specification. In both the GTAP and the GVC model, commodities (and services) are assumed to be differentiated by their region of origin, i.e., the Armington specification is applied (Armington 1969a and 1969b). The two models, however, implement the Armington assumption in different ways.

Because of the lack of necessary data, the Armington assumption is implemented in two levels in the GTAP model: producers and consumers distinguish the domestic variety of a good from its imported variety without regard to the country of origin of the imported input; the sourcing of imported goods is placed at the border of an economy. **Figure 2** illustrates the implementation of the Armington specification in the GTAP model. The left-hand side of Figure 2 sketches substitution possibilities in the production process of particular sector. At the top level, valued added, a composite of labor and capital, can be substituted with intermediate inputs. At the second level, the domestic variety of a particular intermediate input can be substituted with its imported variety; this is the first component of the Armington assumption. The GTAP model incorporates similar substitution possibilities for household demands. The left-hand side of Figure 2 shows that the sourcing of imported goods, i.e., how much to import from particular countries, is modeled for the economy as a whole; this is the second component of the Armington assumption. We can visualize the economic mechanisms incorporated in Figure 2 as follows: for each economy and for each good, there is an importing firm which imports the good from other countries; the sourcing of imports changes as the relative prices change. This importing firm blends the country varieties of the particular good and supplies the blended imported good to producers and consumers.

Because of additional data work done for the development of the GVC data, it is possible to place the sourcing of imports in the GVC model at the agent level as shown in **figure 3**. This is the second difference between the GTAP model and the GVC model. Figure 3 shows that in the GVC model, a particular producer decides not only how much to import of a particular good, but also where to source these imports from. Thus in the GVC model we have potentially established tighter linkages between sectors located in different economies than the linkages contained in the GTAP model. We have also substituted an aggregate mechanism that determines bilateral trade, i.e., sourcing of imports for the economy as a whole in the GTAP model, with a micro-based mechanism of bilateral trade, i.e., sourcing of imports at the agent level.

The GVC database. We have constructed a 2007 IO table based on version 8 of the GTAP database (Narayanan, et al., 2012) and processing trade information from China and Mexico. This database is discussed in detail in Tsigas, Wang, and Gehlhar, 2012. The initial allocation of bilateral trade flows in the GTAP database into intermediate and final uses is based on the UN BEC (Broad Economic Categories) method. We use China's expanded IO table with a separate account for processing exports from Koopman, Wang and Wei (2008) and the 2003 Mexico IO table with separate domestic and Maquiladora accounts from the Instituto Nacional de Estadística, Geografía e Informática (INEGI).[1] We integrate China and Mexico's IO tables with version 8 of the GTAP database by a quadratic mathematical programming model to minimize the deviation between the resulting new data set and the original GTAP data.

Simulated hypothetical scenarios and effects

In this section we examine the potential effects of two U.S.-Asia rebalancing hypothetical scenarios using two different CGE models and databases.[2] We compare selected results from the GTAP global trade CGE model (Hertel, 1997; Narayanan, et al., 2012) with results from the GVC global trade model:

(1) the United States applies additional duties on imports from China at the rate of 27.5 percent; and

[1] For more details about the Mexican data see De La Cruz, J.; R. B. Koopman; Z. Wang; and S. J. Wei, 2011.

[2] Additional but not yet analyzed experiments of an appreciation of the renminbi approximate the U.S. tariff effect on U.S. imports from China.

(2) the national savings rate in China declines from 44 percent to 36 percent. In particular, a negative shock is applied to the $dpsave_{China}$ parameter (the savings distribution parameter) in the GTAP model (see p. 21 in McDougall, 2003).

In **figure 4** we present GDP results from the two rebalancing scenarios in the GTAP and GVC models. [Regular GTAP results are in blue and GVC results are in red in figures 4–7.] We can see that country level GDP effects are sensitive to the model chosen, despite identical parameterization and experimental shocks. In the savings experiment the GVC model produces a smaller impact on China's GDP than in the traditional model, while many other countries experience larger GDP effects. In the tariff experiment the GDP effects on China are muted in the GVC model compared to the GTAP model, and the other countries experience large differences in impacts with particularly big differences for Mexico, Malaysia, Singapore, Thailand, Taiwan, and Vietnam. Clearly, at the GDP level in the models, the GVC model produces quite different results from the traditional GTAP model. GDP is a much aggregated measure of model impacts and can be complicated to explain the various factors driving its change. Thus we now turn to some sectoral examples that highlight more clearly the impact of a GVC based model compared to a traditional GTAP model.

Figure 5 presents the change in U.S. imports of electronic equipment in the two savings rate experiments. The two experiments show almost exactly the same decline in imports from China (-15 percent), but results for other suppliers differ widely, depending on their roles in the electronics value chain. For example, Mexico experiences the largest export gain because its exports of electronics to the United States contain very little Chinese content. In fact, China had a lower market penetration in Mexico for imported intermediate inputs in 2007 than it did in any other country in our dataset. Hence, when Chinese exchange rates rise, driving up the cost of Chinese intermediate inputs, prices of electronics from Mexico rise less than electronics from its competitors. Vietnam has a very different role in the electronics supply chain. In 2007, Vietnam was largely an assembler of Chinese intermediates, with little production of its own intermediates. Hence, it is quite negatively affected by the rise in price of Chinese intermediates. For other countries, the two models showed much smaller differences. Particularly for East Asia, results are similar because these countries are both upstream and downstream, exporting intermediates to China and receiving intermediates from it.

Figure 6 presents Chinese imports of electronic equipment in the two experiments. The GVC model shows substantial deviations from the standard GTAP model, particularly for countries outside of East Asia. In many cases, countries have higher exports in the GVC experiment. In both models, the resulting rise in China's real exchange rate causes substitution away from Chinese sourcing of electronics inputs. Only the GVC model, however, captures the important differences between Chinese processing and non-processing imports. In this model, Chinese non-processing imports rise, but Chinese processing imports fall. Even though these imports fall by 10 – 20 percent for many countries, processing zones become relatively less reliant on domestic sourcing because of the even greater (42 percent) decline in domestic inputs. Hence, the overall change in Chinese imports from a particular source depends on how involved that source is in Chinese processing trade. For many countries in East Asia, the declines in processing imports dominate the rise in non-processing imports, and so overall Chinese imports from these sources decline.

Figure 7 presents Chinese imports of iron and steel in the two experiments. As with Chinese imports of electronics, the two experiments present different pictures of the results of a rise in the real Chinese exchange rate. In Figure 7, however, the deviation is more consistent across countries, with higher imports in the GVC experiment for 19 of 26 countries. As with electronics, the exchange rate rise causes substitution away from Chinese sourcing, with a rise in processing imports and a fall in non-process imports. Results are more uniformly positive for the GVC experiment because export suppliers are much less involved in processing trade for steel. In 2007, processing trade constituted 90 percent of overall electronics imports but only 17 percent of iron and steel imports. Processing trade for iron and steel come mostly from specific East Asian suppliers (e.g., Taiwan, Japan, Korea), which were the most negatively affected suppliers in figure 7.

Summary and conclusions

These experiment results illustrate that a CGE model specified in such a way as to better reflect the trade linkages found in modern global supply and value chains can produce substantial differences in macro level impacts and also reflect the realities of specific product chain relationships. Focusing development of better model specification and database development may result in more realistic and accurate experiment results that could improve advice provided to policy makers. Our comparison would expand to include TiVA datasets from the WIOD project and OECD/WTO.

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Table 1 Regions and sectors in the GVC CGE model

Regions	Sectors
1 China	1 Crops
2 China - export processing zones	2 Livestock
3 Hong Kong	3 Forestry
4 Taiwan	4 Fishing
5 Japan	5 Coal
6 Korea	6 Oil and gas
7 Indonesia	7 Minerals nec
8 Philippines	8 Meat and dairy products
9 Malaysia	9 Other foods
10 Singapore	10 Beverages and tobacco products
11 Thailand	11 Textiles
12 Vietnam	12 Wearing apparel
13 India	13 Leather products
14 Australia, New Zealand	14 Wood products
15 Canada	15 Paper products, publishing
16 United States	16 Petroleum, coal products
17 Mexico	17 Chemical, rubber, plastic products
18 Mexico - export processing zones	18 Mineral products nec
19 Brazil	19 Ferrous metals
20 European Union - 12	20 Metals nec
21 European Union - 15	21 Metal products
22 Russia Federation	22 Motor vehicles and parts
23 South Africa	23 Transport equipment nec
24 Rest of high income countries	24 Electronic equipment
25 Rest of South America	25 Machinery and equipment nec
26 Rest of Asia	26 Manufactures nec
27 Rest of East Asia	27 Electricity
28 Rest of the world	28 Gas manufacture, distribution
	29 Water
	30 Construction
	31 Trade
	32 Transport nec
	33 Water transport
	34 Air transport
	35 Communication
	36 Financial services nec
	37 Insurance
	38 Business services nec
	39 Recreational and other services
	40 Public Admin., Defense, Educ., Health
	41 Dwellings

Figure 1 Linkages between processing trade (PT) in China, the rest of China, and Japan in the GVC CGE Model

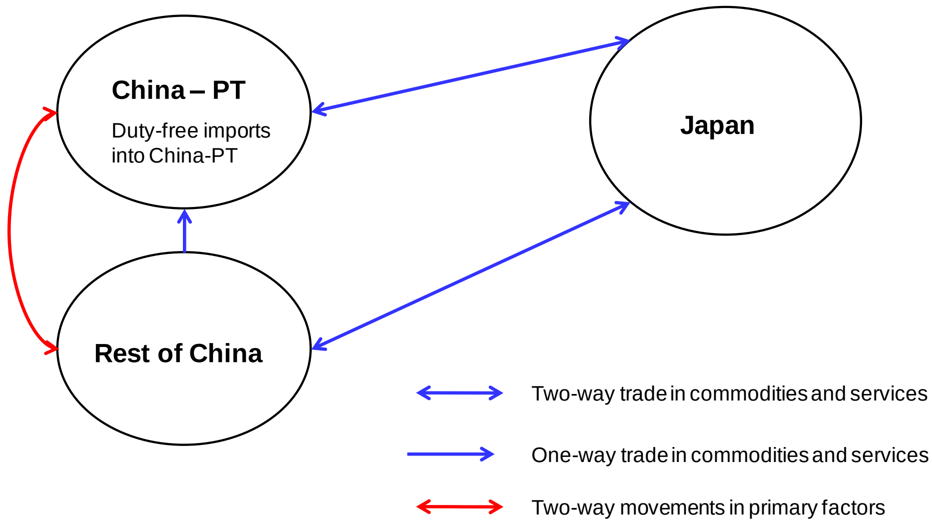
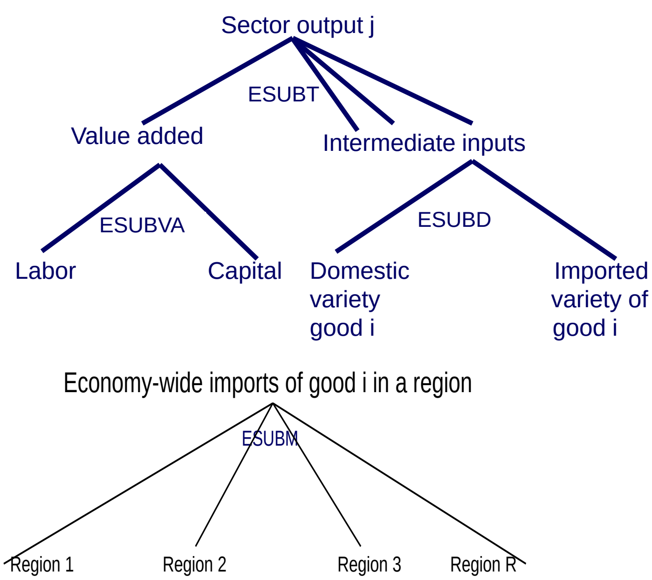
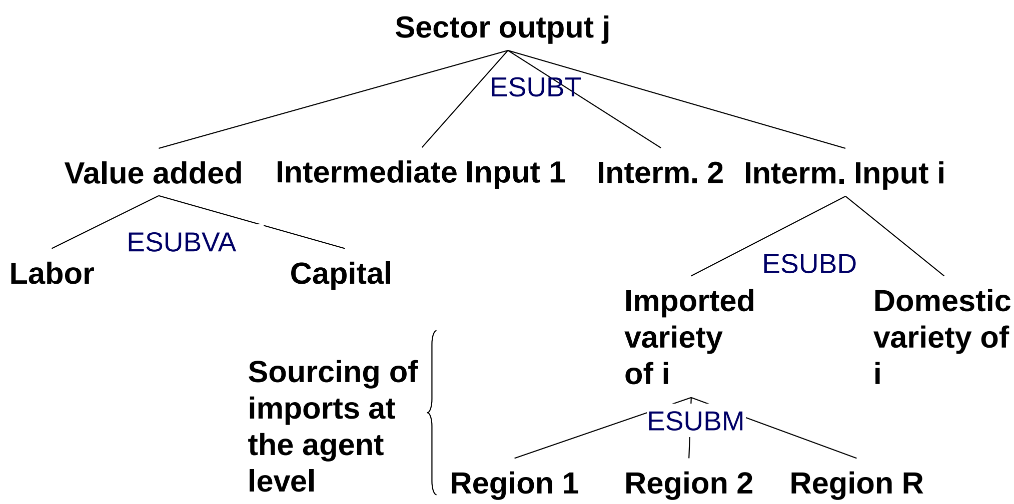


Figure 2 Sourcing of imported goods in the GTAP model



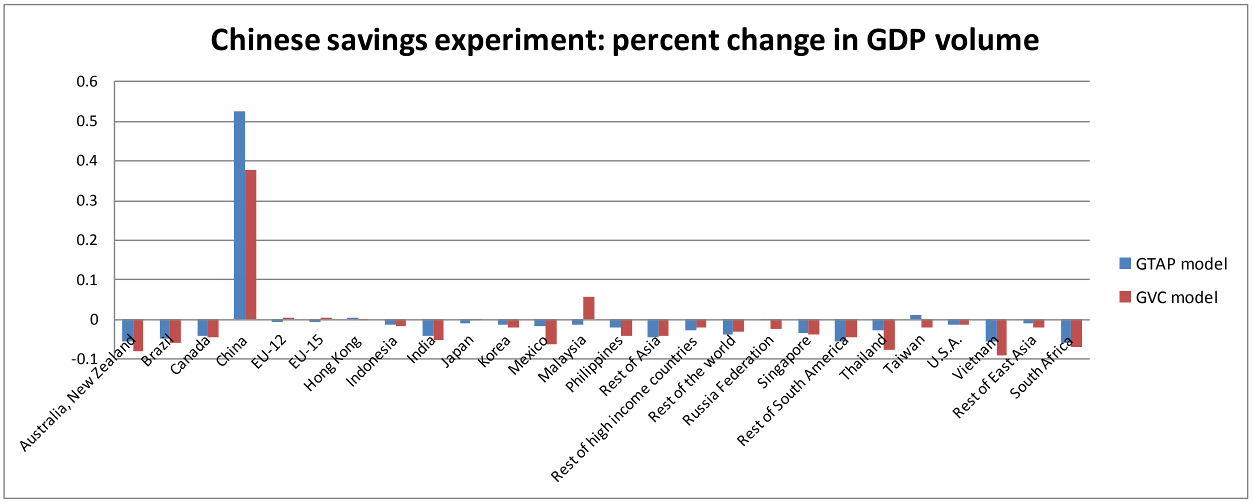
Source: Hertel, 1997.

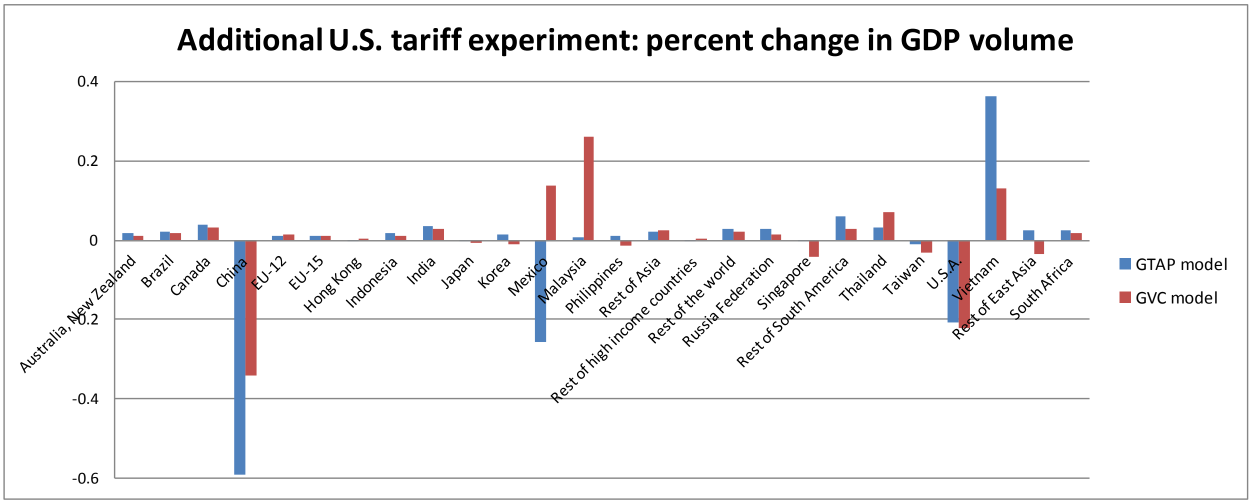
Figure 3 Sourcing of imported good in the GVC CGE model



Source: Authors.

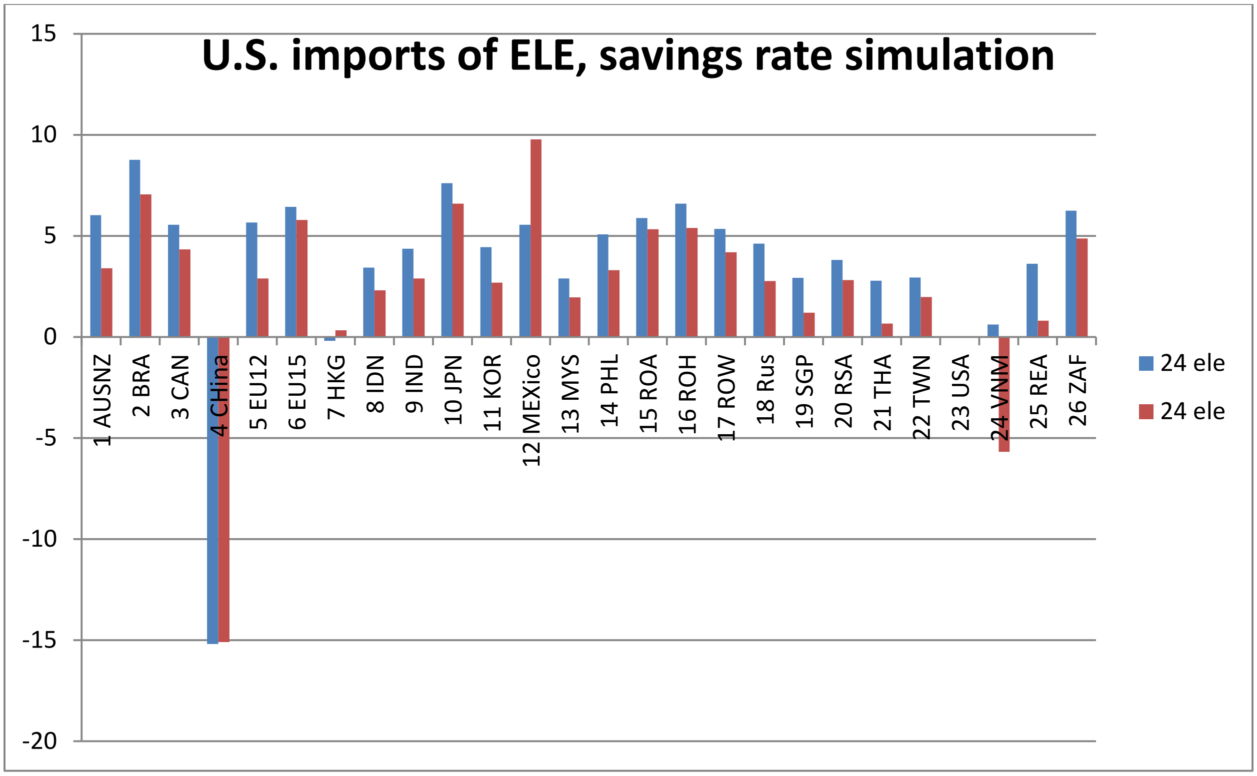
Figure 4 Percent change in GDP volume





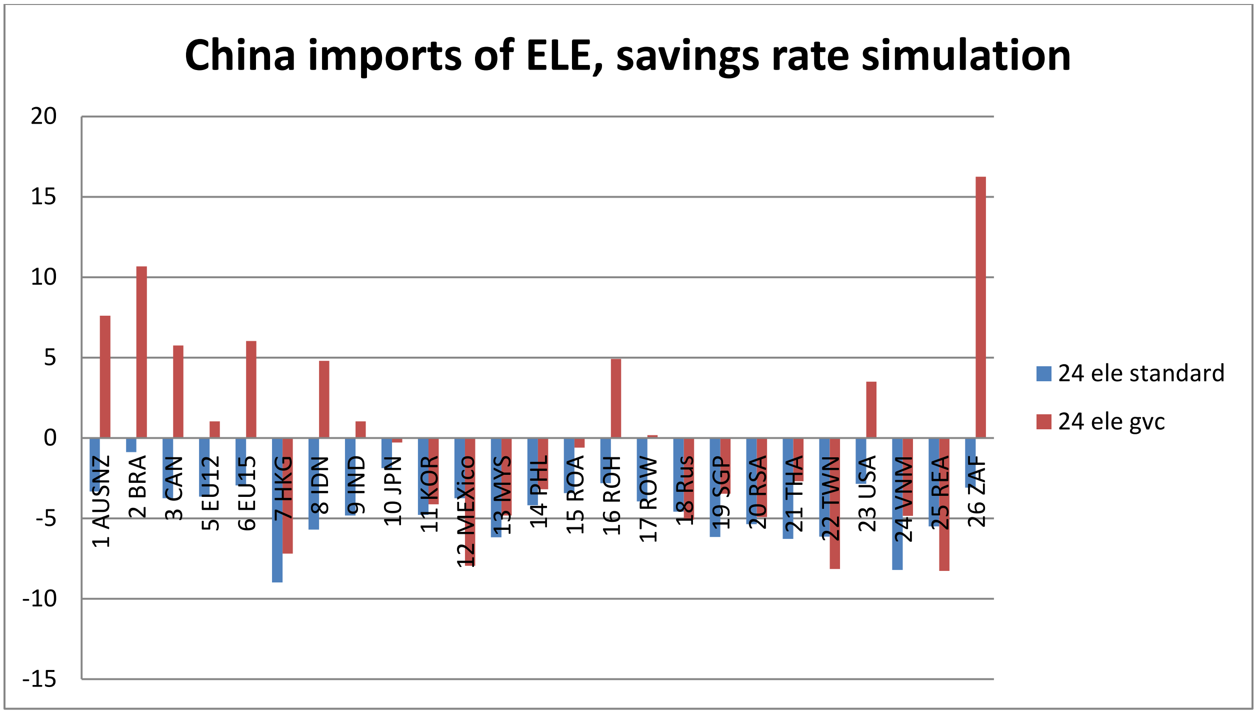
Source: Authors' calculations.

Figure 5 U.S. imports of electronics



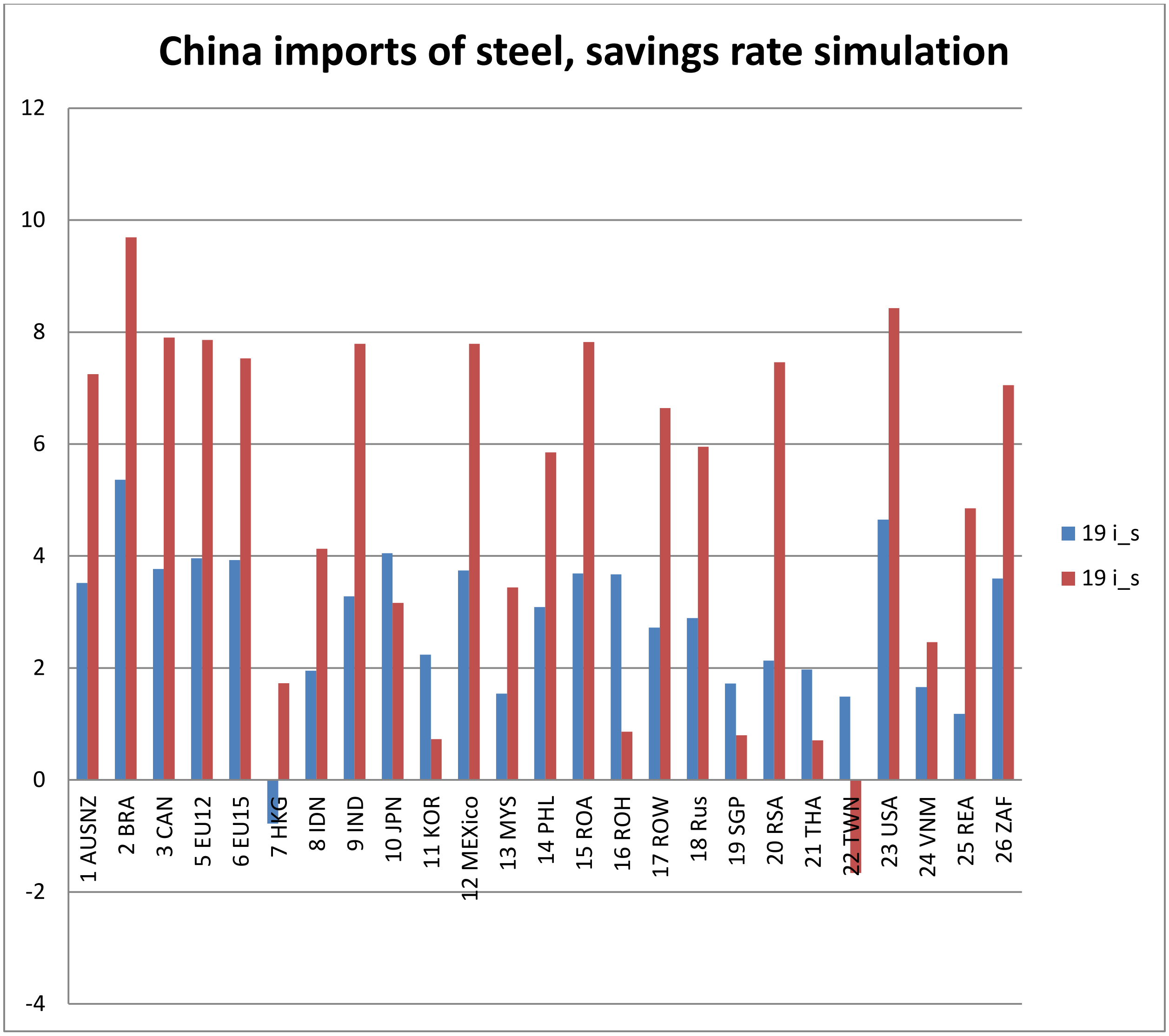
Source: Authors' calculations.

Figure 6 Chinese imports of electronics



Source: Authors' calculations.

Figure 7 Chinese imports of steel



Source: Authors' calculations.