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INTERMEDIATE INPUTS, EXTERNAL REBALANCING AND RELATIVE PRICE ADJUSTMENT

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THE COMPETITIVENESS RESEARCH NETWORK

CompNet The Competitiveness Research Network

This paper presents research conducted within the Competitiveness Research Network (CompNet). The network is composed of economists from the European System of Central Banks (ESCB) - i.e. the 28 national central banks of the European Union (EU) and the European Central Bank – a number of international organisations (World Bank, OECD, EU Commission) universities and think-tanks, as well as a number of non-European Central Banks (Argentina and Peru) and organisations (US International Trade Commission).

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Abstract

This paper proposes a methodology for tracing out the effect of intermediate inputs, including 'processing trade', on the link between external rebalancing and relative price adjustment. We find that neglect of inputs distorts parameterization of the traditional multi-sector macro model. Distortions affect the link between external rebalancing and relative price through several opposing channels. (1) Mismeasured imported inputs exaggerate economic openness and *under*state the price response to rebalancing. (2) Mismeasured domestic inputs increase cross-sectoral asymmetry in openness, leading to an *over*stated price response. (3) Mismeasured price elasticities tend to *over*state the price response. (4) Distortions in model parameters interact to generate a sizable further *under*statement of the price response. Quantitative results show that the identified channels can each be significant in economic terms.

JEL Classifications: F32; F41

Keywords: Real exchange rate; external sector adjustment; intermediate inputs; transfer problem

Non-technical summary

Building on a traditional multi-sector macro modeling framework, this paper proposes a methodology for tracing out the effect of intermediate inputs, including 'processing trade', on the link between external sector rebalancing and relative price adjustment. A widely held view is that by not taking imported inputs into account, the traditional approach to rebalancing overstates economic openness and, as a result, understates the price response to a given external sector rebalancing. We label this the 'imported inputs' effect.

This paper argues that overstated openness is only a part of a broader set of parameter distortions that stem from the neglect of inputs by traditional macro models. Accounting for domestic inputs in a multi-sector setting with manufactures and services can be equally important. Because services are used as inputs in manufacturing, they are more tradable than implied by the traditional approach – one that ignores inputs. To put it differently, value added of the service sector is traded more than the gross output of the service sector. A reverse effect is at work in the manufacturing sector. This finding – a reduced cross sectoral asymmetry in openness when inputs are correctly accounted for – redistributes the price adjustment away from the internal margin of the real exchange rate (i.e., the relative price of nontradables to tradables) and towards the external margin (i.e., the terms of trade), which reduces the size of the overall real exchange rate response. In contrast to the 'imported inputs' effect above, this 'domestic inputs' effect leads the traditional approach to overstate the price response to rebalancing. In traditional macro models both effects distort sectoral consumption preference parameters.

We also argue that the traditional approach mismeasures price elasticities. Because there is no sufficient data available on sectoral flows of value-added, empirical estimates of elasticities from sectoral gross flows are used instead. We estimate that this short-cut tends to result in an overstated price response in traditional multi-sector macro models. Last but not least, results show that the identified distortions interact to generate a sizable additional understatement of the price response. We conclude that parameterization of both sectoral preference weights and price elasticities needs to take inputs into account to correctly measure the link between external adjustment and relative prices.

1 Introduction

This paper revisits the link between external rebalancing and relative price adjustment. Conventional macro models dictate that external sector adjustment be accompanied by relative price changes – a depreciation of the real exchange rate (RER) in case of an increase in external balance and an appreciation in case of a decrease. One key determinant of the size of the adjustment is substitutability between goods. Another crucial factor is the degree of openness – in more open economies prices need to adjust by less.

This traditional approach to rebalancing has been criticized for its neglect of intermediate production inputs. Consider, for example, the case of the iPad. China's value added content in an iPad is estimated at only 2 percent.[1] When imported inputs are ignored, it is implicitly assumed that iPad is 100 percent made in China. In this case an appreciation in RMB increases the price of the iPad and decreases its exports. In contrast, when imported inputs are accounted for, RMB appreciation has no effect on the price and exports of the iPad, because it affects only 2 percent of iPad's value.

iPad example resonates in the macroeconomic policy debate. It is commonly argued that the effectiveness of exchange rate appreciation in China is hampered by China's role as a processing hub. Similarly, effectiveness of a devaluation in crisis-hit Latvia in 2008-09 was questioned on the grounds that it would increase input costs in the export sector, muting any effect on external sector rebalancing.[2] To recast this criticism in model terms, by ignoring imported inputs the traditional approach equates gross trade flows with trade in value added, overstating trade and openness. This leads one to *under*state the price adjustment that accompanies a given external rebalancing, and therefore requires a correction.

This paper extends the traditional approach to external rebalancing to account for intermediate inputs. Our multi-sector framework distinguishes between sectoral flows in 'gross' and 'value added' terms,[3] as well as between inputs of domestic and foreign origin. Both distinctions are crucial to account for inputs' role in external sector rebalancing.

To identify the role of inputs, we contrast results of a rebalancing exercise in the extended

[1] See Kraemer, Linden and Dedrick (2011).
[2] See Garcia-Herrero and Koivu (2010) and Purfield and Rosenberg (2010).
[3] The two types of flows are defined in the next section.

framework with inputs – our preferred benchmark – with the traditional approach in the literature. The exercise is set up as a classic 'transfer problem'. A key ingredient of the exercise is a global input-output (IO) table, which we construct following a methodology outlined in Bems, Johnson and Yi (2010) and Johnson and Noguera (2012). This global IO table provides detailed data on the use of sectoral gross outputs by countries and sectors and differentiates between intermediate and final uses. The table ensures a consistent parameterization of the benchmark and traditional models.

We find that neglect of inputs distorts parameterization of preference weights and price elasticities in the traditional model, which can under- or over-state the price adjustment that accompanies external rebalancing. This finding does *not* support the notion in the literature (summarized above) that neglecting inputs necessarily leads to an understated price response. To shed more light on our findings, we decompose deviations in the RER response between our benchmark and traditional models into several distinct components. First, accounting for imported inputs – i.e., processing trade – reduces economic openness and, consequently, increases the response of the RER to a given external adjustment. This 'imported inputs' effect implies that the traditional approach *under*states the price adjustment. Second, accounting for domestic inputs increases trade in services and reduces trade in manufactures, because services are embodied in manufactures and exported indirectly. The resulting reduced cross-sectoral asymmetry in openness dampens the RER response to rebalancing. Because of this 'domestic inputs' effect, the traditional approach *over*states the price response. We link both 'imported inputs' and 'domestic inputs' effects to distorted preference weights. Third, we estimate that by neglecting inputs the traditional approach overstates (understates) CES price elasticity within (across) sectors. Quantitatively, the direct effect of this distortion is to *over*state the RER response to a transfer shock. Last but not least, distortions in preference weights and elasticities interact to generate a further *under*statement in the price response. Quantitative results for 20 large economies show that the identified effects on the RER adjustment can each be significant in economic terms.

This study is related to an extensive literature on external rebalancing and RER adjustment. Recent contributions include Obstfeld and Rogoff (2004, 2005), whose framework of the classic 'transfer problem' we take as a starting point. Subsequent papers examine alternative model specifications to address roles of intensive versus extensive margins, monetary policy and factor market flexibility. These papers investigate how the relative price adjustment varies with the time horizon over which the transfer shock is implemented.[4]

Our approach is distinct in that we refine the link between objects in the traditional model and data rather than modify the model specification or the nature of shocks that drive the rebalancing. Parametrization of the traditional model in the literature neglects inputs.[5] The contribution of our paper it to show that this neglect leads to parameter distortions, which can significantly affect the adjustment in relative prices.

Our finding that price elasticities in models with and without intermediate inputs are distinct can be related to macro models with distribution services. Burstein, Neves and Rebelo (2004) argue that modeling distribution margin for tradables goods has similar effects to lowering the elasticity of substitution between tradables and non-tradables in a model without distribution. In Corsetti, Dedola and Leduc (2008) distribution sector drives a wedge between trade elasticity and elasticity of substitution between home and foreign tradables in consumption. In our model price elasticities for sectoral gross flows are distinct from elasticities for sectoral value added because of intermediate inputs.

Taken more broadly, this paper serves as an illustration of a more general issue with mapping into data multi-sector macro models that neglect production inputs. Parametrization of such models requires detailed data on supply of and demand for sectoral 'value added'. While on the supply side such data is available, sectoral demand data is reported exclusively in terms of gross flows. Faced with this problem, macroeconomists have reverted to simplifying assumptions, such as equating trade in value added with gross trade flows. This paper explores consequences of these assumptions for a particular application - external rebalancing. More general implications for macro models remains an open research question.

The rest of the paper is structured as follows. Section 2 introduces a global IO table and

[4] See, e.g., Faruqee, Laxton, Muir and Pesenti (2007), Ferrero, Gertler and Svensson (2010), Mejean, Rabanal and Sandri (2011) and Corsetti, Martin and Pesenti (2013).

[5] Dekle, Eaton and Kortum (2008) is a notable exception. The paper accounts for the use of inputs with a simplified input-output structure – services are inputs in production of manufactures, but production of services does not require inputs from the manufacturing sector. However, Dekle et al. (2008) do not study the role of inputs in external sector rebalancing.

examines the relationship between sectoral flows in 'value added' and 'gross' terms. Section 3 presents our benchmark model with inputs and links it to the traditional model in the literature. Section 4 parameterizes the two models and compares RER responses to a transfer shock. Resulting RER deviations are decomposed into contributing factors - distorted preference weights and price elasticities - in Section 5. Section 6 considers several extensions to the rebalancing exercise and Section 7 concludes.

2 'Value-Added' versus 'Gross' Flows

One can distinguish between two internally consistent approaches to specify a multi-sector macro model. The traditional approach is to model output in terms of value added of each sector and, correspondingly, specify demand in terms of expenditures on the sectoral value added. We label this the 'value added' approach or 'VA model' for short. An alternative is to explicitly model inputs in each production function, so that supply is expressed in terms of sectoral gross outputs and demand is specified in terms of expenditures on sectoral gross outputs. We label this the 'gross output' approach or 'GO model' for short. Because of the different nature of sectoral outputs, when the two models are mapped into data, model parameters need note have the same interpretation and values.

This section discusses data on sectoral flows that are consistent with the VA and GO models. We start with National Income Account (NIA) identities and discuss the additional information that a global IO table provides. Next, we describe how to disentangle sectoral gross flows of a global IO table into flows of value added. The two types of flows are defined and compared, highlighting implications for the parameterization of the GO and VA models. Finally, we present sectoral flow data that underlie the traditional parametrization practices for VA models and show that such flows are not consistent with either the VA or the GO models.

2.1 The Global Input-Output Table

Increased availability of national IO tables over the last two decades makes it possible to construct a global IO table. In recent years there has been a proliferation of work on this topic involving a range of participants from academic economists to international organizations.[6] The methodology of this paper draws on these developments.

A global IO table is in essence a unified presentation of the information in country-specific IO tables. Where a national IO table reports country's linkages with the rest of the world, the global IO table zooms in on bilateral linkages between countries. Construction of a global IO table is discussed in great detail in, e.g., Timmer (2012). Because of data limitations, global IO tables rely on a battery of assumptions, often invoking proportionality. For example, proportionality assumption is used to allocate imported intermediates by source country[7]. The key takeaway for our study is that, despite the limitations, global IO tables do capture the headline trends in the globalization of production.

Let us start by presenting a multi-sector IO table of the global economy. Without loss of generality we focus on a simple 2-country case, in which a country, a good and a sector have an identical meaning. Global make and use identities describing the flow of expenditures are summarized in Figure 1. The two row identities in the figure are resource constraints for each good. Gross output of country 1, go_1, is used either as intermediate input in the production of the home good, x_{11}, or in the production abroad, x_{12}. Alternatively, it can be absorbed by final demand in one of the two countries, f_{11} or f_{12}. A symmetric use identity holds in country 2. These resource flows are sectoral 'gross' flows, because they describe the use of sectoral gross output. The two column identities in Figure 1 show expenditures on production inputs. Gross output in country 1 is spent on factor inputs, va_1, own intermediate production input, x_{11}, or intermediate production inputs from country 2, x_{21}. A symmetric identity holds for country 2. Column and row identities add up to the same gross output.

Identities in Figure 1 contain all the information that economists routinely obtain from NIA. For example, final demand in country 1 is the sum of expenditures on domestic and foreign gross outputs, $f_{11} + f_{21}$. Gross exports for country 1 are the sum of exported intermediate production inputs and final goods, $x_{12} + f_{12}$. For imports the corresponding terms are $x_{21} + f_{21}$. Value added of country 1 equals gross output less intermediate inputs, $x_{11} + x_{12} + f_{11} + f_{12} - x_{11} - x_{21}$.

[6] See, e.g., Hummels, Ishii and Yi (2001), Johnson and Noguera (2012), OECD-WTO (2012) Timmer (2012) and Koopman, Wang and Wei (2014).

[7] BEC classification of trade flows into intermediate and final goods allows one to partially relax this proportionality assumption (see, e.g., Timmer, 2012, for details).

A more detailed table would contain such data for sectors in addition to the aggregate economy.

A multi-sector GO model can be parametrized directly from the data reported in Figure 1. However, such data is not sufficient to parametrize a multi-sector VA model, because gross and value-added flows differ. For example, parametrization of sectoral consumption weights in country 1 requires final demand expenditures on the value added of each sector, rather than final expenditures on sectoral gross outputs, f_{11} and f_{21}.

The advantage of the global IO table over NIA is that the former contains additional information about intermediate linkages needed to decompose gross flows into value-added flows and, hence, parametrize a VA model. Value-added flows describe the ultimate destination of value added from each sector. For example, sectoral value-added flows show how much of the U.S. manufacturing value added is ultimately absorbed at home, in Mexico or any other destination. Value-added flows are distinct from sectoral 'gross' flows, which in this example describe the country/sector destination of the gross output from the US manufacturing sector. Next section describes the decomposition procedure.

2.2 Value-Added Decomposition

We follow value added decomposition of Johnson and Noguera (2012) and apply it to our 2-country case.[8] Rewrite resource constraints for the two sectors in a matrix form as

$$\begin{bmatrix} go_1 \\ go_2 \end{bmatrix} = A \begin{bmatrix} go_1 \\ go_2 \end{bmatrix} + \begin{bmatrix} f_{11} + f_{12} \\ f_{21} + f_{22} \end{bmatrix},$$

where

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = \begin{bmatrix} \frac{x_{11}}{go_1} & \frac{x_{12}}{go_2} \\ \frac{x_{21}}{go_1} & \frac{x_{22}}{go_2} \end{bmatrix}$$

[8] For a general N-country and S-sector exposition of the decomposition the reader is referred to the original paper.

is the Leontief requirement matrix for inputs. Gross output can then be decomposed by its final destination as

$$\begin{aligned}
\begin{bmatrix} go_1 \\ go_2 \end{bmatrix} &= (I-A)^{-1}\begin{bmatrix} f_{11} \\ f_{21} \end{bmatrix} + (I-A)^{-1}\begin{bmatrix} f_{12} \\ f_{22} \end{bmatrix} \\
&= \begin{bmatrix} \frac{(1-a_{22})f_{11}+a_{12}f_{21}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}} & \frac{(1-a_{22})f_{12}+a_{12}f_{22}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}} \\ \frac{a_{21}f_{11}+(1-a_{11})f_{21}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}} & \frac{a_{21}f_{12}+(1-a_{11})f_{22}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}} \end{bmatrix} \\
&\equiv \begin{bmatrix} go_{11} & go_{12} \\ go_{21} & go_{22} \end{bmatrix},
\end{aligned} \tag{1}$$

where go_{ij} is gross output of country i absorbed in country j. Finally, to decompose value added, we use proportionality between gross output and value added

$$va_{ij} = (1 - a_{1j} - a_{2j})\, go_{ij}.$$

This decomposition transforms the global IO table into a table of destination-based value added flows, depicted in Figure 2. We label these flows 'IO-based' sectoral value added flows, because they are derived using the information provided by the global IO table. Intuitively, the decomposition traces out the flow of value added from a particular sector/country through the global IO table. Some of the value added is directly consumed in the country of origin. In this case the mapping into a final destination is straightforward. However, value added is also used as an input in the production of domestic or foreign goods. For example, value added of the U.S. manufacturing sector is an input in the production of manufacturing goods in Mexico. The output from Mexico can then be consumed in Mexico, sent back to the U.S., or sent to a third country. Under each scenario output can again be used as an input in production or it can flow to final consumption. Such considerations generate complex linkages between sectors within and across countries, captured in (1) by the term $(I-A)^{-1} = I + A + A^2 + \ldots$.

Of particular interest for our paper are value added exports and imports, which in Figure 2 are represented by the final demand for value added of country 2 in country 1, va_{21}, and final demand for value added of country 1 in country 2, va_{12}. One can show that the relationship between gross trade flows and trade in value added satisfies

$$\underbrace{(x_{21}+f_{21})}_{\text{gross trade}} - \underbrace{va_{21}}_{\text{trade in value added}} = (x_{12}+f_{12}) - va_{12} > 0.$$

In words, value added exports and imports are smaller than gross exports and imports. Also, the difference between the gross and value added trade flows is the same on the export and import sides, leaving net trade unaffected. This is the case because the derivation of trade in value added amounts to an identification of re-exported imports, which are subtracted from both gross exports and imports.

2.3 Traditional Value-Added Flows

To identify the contribution of this paper, we need to link the above discussed sectoral gross and value-added flows with the traditional parametrization practices for VA models. In the absence of sectoral value added flow data, the traditional approach has relied on sectoral gross flows. In case of our simple example, sectoral consumption weights of the traditional parametrization of the VA model are derived by equating value added imports and exports to corresponding gross flows. The domestic component of final demand is then backed out as a residual. With multiple sectors per country, sectoral value added components are derived from more detailed sectoral gross flows and final expenditure data, or by imposing assumptions such as no cross-border trade in services.[9]

Figure 3 summarizes this traditional approach. The matrix for intermediate consumption is 'zeroed out' by (i) transferring intermediate consumption of a cross-sectoral output to final consumption in the same destination, e.g., $f_{21}+x_{21}$, and (ii) subtracting the same amount from the final consumption of the destination sector's output, e.g., $f_{11}-x_{21}$. The latter adjustment is crucial because it ensures that row and column equalities are preserved.

One can verify that such a transformation of gross flows from Figure 1 into traditional value-added flows in Figure 3 does not distort aggregate variables, such as a country's value added, aggregate final demand or net trade. However, sectoral weights in final demand under this

[9] See, e.g., references in footnote 4.

transformation differ from the weights in the IO-based decomposition (see Figure 2). Intuitively, this traditional method accounts only for the first-order effect from the use of cross-sectoral value added as an intermediate input. E.g., if the U.S. manufacturing output is used as an input in Mexico, the traditional approach assumes that Mexico is the final destination for the value added. Whether this is a reasonable approximation depends on the specific research question as well as the structure of cross-sectoral inputs. In the rest of the paper we use terms 'traditional' value added flows and 'traditional' VA model to describe this traditional parameterization practice.

To sum up this section, we introduced a global IO table that can be used to parametrize a multi-sector GO model. Next, we showed how to derive sectoral value added flows on which a VA model can be parametrized. Finally, we cast the traditional parametrization practices for VA models from the perspective of a global IO framework: the traditional approach approximates value added flows with gross flows. The rest of the paper draws on these three constellations of parametrized models – (i) the GO model, (ii) IO-based VA model and (iii) traditional VA model – to study the role of intermediate inputs in external rebalancing.

3 The Modeling Framework

This section presents a modeling framework with intermediate inputs – a GO model – as well as a version of the model without inputs – a VA model. The model describes a steady state in a multi-sector, multi-country global economy.

3.1 Gross Output Model

Global economy consists of N countries, indexed by n and j, and output in each country is partitioned into S sectors, indexed by s and i, that supply differentiated goods, so that the total number of goods is SN. Sectoral value added in each country is provided in the form of an endowment and sectoral gross output is produced by combining value added and intermediate inputs with a CES aggregation function. Then supply in sector s of country n is

$$y_{sn} = \left(\delta_{sn}^{\frac{1}{\lambda^g}} \overline{va}_{sn}^{\frac{\lambda^g-1}{\lambda^g}} + (1-\delta_{sn})^{\frac{1}{\lambda^g}} \left(\sum_{i=1}^{S} \theta_{i,sn}^{\frac{1}{\alpha^g}} \left(\sum_{j=1}^{N} \theta_{ij,sn}^{\frac{1}{\beta^g}} m_{ij,sn}^{\frac{\beta^g-1}{\beta^g}} \right)^{\frac{\beta^g(\alpha^g-1)}{\alpha^g(\beta^g-1)}} \right)^{\frac{\alpha^g(\lambda^g-1)}{\lambda^g(\alpha^g-1)}} \right)^{\frac{\lambda^g}{\lambda^g-1}}$$

where $\overline{va}_{sn}$ is the endowment of value added in sector s of country n; δ_{sn} is the sector- and country-specific weight of value added in gross output ($0 \leq \delta_{sn} \leq 1$); $m_{ij,sn}$ represents intermediate inputs from sector i of country j into sector s of country n with the corresponding within-sector weight captured by $\theta_{ij,sn}$ ($0 \leq \theta_{ij,sn} \leq 1$, $\sum_{j=1}^{N} \theta_{ij,sn} = 1$) and sectoral weight captured by $\theta_{i,sn}$ ($0 \leq \theta_{i,sn} \leq 1$, $\sum_{i=1}^{N} \theta_{i,sn} = 1$); λ^g, α^g and β^g are elasticities of substitution between, correspondingly, value added and inputs, inputs across sectors and inputs within sectors, where we use superscript g to differentiate between elasticities in the GO (g) and VA (v) models.

Consumer utility is specified as CES Armington (1969) demand system for goods and products. Utility of the representative consumer in country n is

$$U_n = \left(\sum_{i=1}^{S} \mu_{i,n}^{\frac{1}{\gamma^g}} \left(\sum_{j=1}^{N} \mu_{ij,n}^{\frac{1}{\omega^g}} c_{ij,n}^{\frac{\omega^g-1}{\omega^g}} \right)^{\frac{\omega^g(\gamma^g-1)}{\gamma^g(\omega^g-1)}} \right)^{\frac{\gamma^g}{\gamma^g-1}}$$

subject to a budget constraint

$$\sum_{i=1}^{S} \sum_{j=1}^{N} p_{ij} c_{ij,n} = \sum_{i=1}^{S} q_{in} \overline{va}_{in} + T_n.$$

Here $c_{ij,n}$ stands for consumption of goods from sector i of country j in country n with the corresponding within-sector weight captured by $\mu_{ij,sn}$ ($0 \leq \mu_{ij,sn} \leq 1$, $\sum_{j=1}^{N} \mu_{ij,sn} = 1$) and sectoral weight captured by $\mu_{i,sn}$ ($0 \leq \mu_{i,sn} \leq 1$, $\sum_{i=1}^{N} \mu_{i,sn} = 1$); p_{ij} is the price of the differentiated good from sector i of country j; q_{in} is the price of value added from sector i in country n; T_n is a transfer term that allows the static model to capture a non-zero net trade for country n in data; γ^g and ω^g are elasticities of substitution, correspondingly, across and within sectors.

The model is closed with SN resource constraints

$$\sum_{j=1}^{N} c_{sn,j} + \sum_{i=1}^{S}\sum_{j=1}^{N} m_{sn,ij} = y_{sn}$$

and a global adding up constraint for transfers,

$$\sum_{n=1}^{N} T_n = 0.$$

The model solution is characterized by SN resource constraints, $N-1$ consumer budget constraints, SN^2 first order conditions with respect to consumption of the SN differentiated goods in N countries and $(SN)^2$ first order conditions with respect to the usage of SN differentiated inputs in the production of SN differentiated goods. For a given set of parameter values, transfers and endowments, we then solve the system of $(SN)^2 + SN^2 + SN + N - 1$ nonlinear equations for SN^2 consumption quantities, $(SN)^2$ input quantities and $SN + N - 1$ relative prices.

External sector adjustment in this model can be proxied with changes in the exogenous transfer term, T_n. In the presence of home bias in consumption, changes in the transfer redistribute income and demand for goods across countries and sectors and, in equilibrium, are accompanied by endogenous changes in relative prices. An aggregate relative price of primary interest for this paper is RER, defined as the relative price of the aggregate consumption basket at home and abroad. The model implies that the price of the aggregate consumption basket in country n is a weighted average of the prices of differentiated goods

$$P_n = \left(\sum_{i=1}^{S} \mu_{i,n}^{\frac{1}{1-\gamma^g}} \left(\sum_{j=1}^{N} \mu_{ij,n}^{\frac{1}{1-\omega^g}} p_{ij}^{\frac{\omega^g}{\omega^g-1}} \right)^{\frac{\gamma^g(\omega^g-1)}{\omega^g(\gamma^g-1)}} \right)^{\frac{\gamma^g-1}{\gamma^g}}. \tag{2}$$

Then for $N = 2$ RER is a ratio of home and foreign aggregate prices,

$$RER_n = P_n / P_{j \neq n}. \tag{3}$$

For $N > 2$, the price in the denominator is a weighted average of foreign aggregate prices.

This GO model with explicit account for intermediate inputs is our *benchmark* for studying external rebalancing. To study the role of inputs in external rebalancing, we next turn to a traditional VA model, which does not model inputs.

3.2 Value-Added Model

When $\delta_{sn} = 1$, the GO model collapses to a model with no inputs. In this case, on the supply side, consistent with Figures 2 and 3, sectoral value added endowments equal sectoral outputs, $y_{sn} = \overline{va}_{sn}$. On the demand side, consumer's utility remains unchanged

$$U_n = \left(\sum_{i=1}^{S} \phi_{i,n}^{\frac{1}{\gamma^v}} \left(\sum_{j=1}^{N} \phi_{ij,n}^{\frac{1}{\omega^v}} z_{ij,n}^{\frac{\omega^v - 1}{\omega^v}} \right)^{\frac{\omega^v(\gamma^v - 1)}{\gamma^v(\omega^v - 1)}} \right)^{\frac{\gamma^v}{\gamma^v - 1}}, \tag{4}$$

subject to a budget constraint

$$\sum_{i=1}^{S} \sum_{j=1}^{N} q_{ij} z_{ij,n} = \sum_{i=1}^{S} q_{in} \overline{va}_{in} + T_n. \tag{5}$$

The model is again closed with SN resource constraints $\sum_{n=1}^{N} z_{ij,n} = \overline{va}_{ij}$ and a global adding up constraint for transfers, $\sum_{n=1}^{N} T_n = 0$.

3.3 Discussion

Both models treat sectoral value added, $\overline{va}_{in}$, as exogenous, with the corresponding price denoted by q_{in}, and use the same subscript structure for the various parameters and variables. However, consumption quantities ($c_{ij,n}$ versus $z_{ij,n}$), weights ($\mu_{i,n}, \mu_{ij,n}$ versus $\phi_{i,n}, \phi_{ij,n}$) and elasticities (γ^g, ω^g versus γ^v, ω^v) are denoted differently in the two models. In the VA model sectoral output is value added of the sector in question, while in the GO model sectoral output is a composite of value added from domestic and foreign sectors. Given distinct outputs, the accompanying endogenous prices and quantities as well as exogenous weight and elasticity parameters should be allowed to differ.

Our benchmark GO and traditional VA models can be interpreted as two extremes in terms of accounting for production inputs. On the one end of the spectrum, the GO model can be parameterized to replicate allocations of a global IO table, including cross-sectoral input linkages and bilateral trade flows separately for inputs and final consumption goods. On the other end of the spectrum, the VA model ignores inputs entirely. Parametrizing it using data on sectoral gross flows will lead to distortions.

For the purpose of studying the transfer problem models with richer trade structure (e.g., Ricardian model in Dekle et al. 2008) can be interpreted as an intermediate case.[10] These models allow for production inputs, so that parameter distortions are likely to be smaller than in the traditional VA model. At the same time, these models fall short of replicating allocations of a global IO table. In Dekle et al. (2008) this is the case because intermediate inputs in the service sector are not modeled. More generally, models with richer trade structure, along the lines of Eaton and Kortum (2002), can pin down one matrix of bilateral trade shares, while in the global IO table there are two independent matrices: one for trade in inputs and one for trade in final consumption goods. As a result, from the perspective of our benchmark GO model, parameters in this intermediate case will be distorted, but likely less so than in the VA model.

The rest of the paper studies how accounting for inputs affects the link between external rebalancing and relative prices. We identify the role of inputs by comparing a benchmark parameterized GO model with a parameterized traditional VA model, which ignores inputs. Next section parameterizes the GO and traditional VA models and compares RER response to a transfer shock. Subsequent section links RER deviations between the two models to distorted preference weights and price elasticities in the traditional VA model.

[10]Dekle et al. (2008) show that the transfer problem in their Ricardian model can be represented with a simplified version of our GO model, where switching the extensive margin on/off amounts to increasing/decreasing the elasticity of substitution. The reason is that the transfer problem does not affect trade costs and production efficiency, so that only forces of the Armington model are operative.

4 External Sector Rebalancing Exercise

The external rebalancing exercise we consider is a version of the classic 'transfer problem'. A transfer shock redistributes wealth across borders. If there is home bias in consumption - a widely held and empirically justified assumption - the transfer of wealth, in equilibrium, is accompanied by an endogenous adjustment in relative prices. Country that becomes poorer sees its relative price fall, because demand for its output is reduced. Transfer problem thus provides a link between external balance and relative prices and serves well to study the role of inputs in external sector rebalancing.

Obstfeld and Rogoff (2004, 2005) argue that both terms of trade and relative price of tradables to nontradables (i.e., the internal RER) play an important role in the external adjustment process. To account for the two adjustment channels – the *inter* and *intra*national price adjustments – we focus on the case of 2 countries and 2 goods per country, i.e., $S = 2$ and $N = 2$, where the two sectors are broadly defined as tradable manufacturing and nontradable services.[11] $S = 2$ and $N = 2$ is also the minimum sectoral and country detail necessary for both domestic and imported inputs to be present. As we shall demonstrate, both types of inputs play important but distinct roles in external rebalancing.

The exercise is implemented for two familiar constellations of external sector imbalances: (i) U.S. versus the rest of the world and (ii) China versus the rest of the world. The two cases are chosen because both exhibit large and persistent imbalances. Also, the two countries differ in terms of openness and the prevalence of processing trade. We derive the model response to a 1 percent of GDP reduction in the external imbalance and then compare RER responses between the benchmark GO and traditional VA models. We also report summary results for the same rebalancing exercise for 20 large economies, in addition to the U.S. and China.

4.1 Parameterization

This section discusses parameterization of the GO and traditional VA models.

[11] Tradables are defined as all sectors of industry, including mining. Nontradables are defined as all other sectors, including domestic distribution services.

4.1.1 GO Model

The GO model is parameterized using a consistent sectoral gross flow data. First, a global IO table is constructed using the methodology of Johnson and Noguera (2012) and data from GTAP 7.1. Panel (a) in Figure 4 presents the resulting aggregated global IO table with the world economy partitioned into the U.S. and the rest of the world and two sectors per country. The structure of this table is identical to the one detail in Section 2, except for 2 sectors per country.

Second, weight parameters and income are set so that the GO model replicates allocations in the global IO table. In particular, sectoral incomes, $\overline{va}_{in}$, are set equal to the sectoral value added, defined as both capital and labor incomes, in panel (a) of Figure 4. Sectoral weight parameters, δ_{sn}, $\theta_{i,sn}$, $\theta_{ij,sn}$, $\mu_{i,n}$ and $\mu_{ij,n}$, are set to replicate sectoral expenditure shares in final and intermediate consumption in the same panel (a).[12] Transfer terms, T_n, are set to match the trade balance between the two countries.

Next, we need to specify elasticities of substitution. The benchmark GO model differentiates elasticities between goods within sectors (e.g., manufactures from the U.S. versus the rest of the world) and across sectors (e.g., services versus manufactures). It further allows elasticities to differ in production and consumption. IO tables do not help to pin down these elasticities, as they contain only expenditures, not prices. We use elasticity values from the literature instead. Available empirical estimates of elasticities do not discriminate between final consumption and intermediate use. Given this limitation, we equate elasticities in final and intermediate use and consider a range of values centered on $\alpha^g = \gamma^g = 0.5$ and $\beta^g = \omega^g = 1$. Both values are in line with empirical estimates and parameterization practices in the macro literature.[13] Importantly, these elasticity estimates are based on sectoral *gross* flow data, such as e.g., gross imports, and are, hence, consistent with elasticity parameters in the GO model. Finally, we also need to parametrize the elasticity between value added and intermediates, λ^g. We set the value of this elasticity to 1, so that, consistent with evidence from IO tables, the share of value added in gross

[12] All initial prices are normalized to unity, so that CES weight parameters, as specified in Section 3, equal expenditure shares.

[13] See, e.g., Stockman and Tesar (1995), Heathcote and Perri (2002), Obstfeld and Rogoff (2004), Feenstra, Obstfeld and Russ (2012) and references therein.

output remains stable over time.

4.1.2 Traditional VA Model

Parameterization of the traditional VA model follows well-established practices in the macro literature.[14] Sectoral value added in the model is set to replicate sectoral value added in data. Transfer terms, T_n, are set to match the trade balance. Weight parameters in consumption, $\phi_{i,n}$ and $\phi_{ij,n}$, are set so that the model replicates economic openness, as measured by ratios of gross imports and exports to GDP. These parameterization practices were discussed in Section 2.3. For the case of global economy partitioned into the U.S. and the rest of the world the relevant data targets are summarized in panel (b) of Figure 4, which the traditional VA model is parametrized to replicate.

For the purpose of the rebalancing exercise, note that trade balances and sectoral value added are identical in panels (a) and (b) of Figure 4 – US runs a 4.3% of GDP deficit. Consequently, a 1% of GDP shock to the external transfer is comparable between the benchmark GO and traditional VA models. However, sectoral consumption values in panel (b), and hence the weight parameters in the traditional VA model, are distorted, because sectoral flows do not account for value added flows correctly. We postpone a more detailed comparison of sectoral gross and value-added flows, as reported in panels (a)-(c) of Figure 4, until the next section.

The traditional VA model differentiates between final consumption elasticities within, ω^v, and across, γ^v, sectors. Again, IO tables do not help to pin down these parameters. Furthermore, there is no empirical literature that estimates elasticities of substitution for sectoral *value-added* flows, because construction of such data is challenging. Instead, we revert to the standard parameterization short-cut for traditional VA models and assume that elasticities for value-added flows are identical to those for gross flows , i.e., $\gamma^v = \gamma^g = 0.5$ and $\omega^v = \omega^g = 1$. Implications of this distortion will be explored in detail in Section 5.2.

[14] See, e.g., Backus, Kehoe and Kydland (1994) and Obstfeld and Rogoff (2004).

4.2 Results

RER responses, defined in equations (2)-(3), for both models to a 1% of GDP reduction in the cross-border transfer, T_n, are summarized in panels (a)-(b) of Figure 5. Y-axis shows the change in the RER induced by the reduction in the transfer and x-axis shows how the price response varies with the elasticity of substitution. To limit the presentation to two-dimensional figures, panel (a) fixes the intrasectoral elasticity, $\omega^g = 1$, while panel (b) fixes the intersectoral elasticity, $\gamma^g = 0.5$. Panels (c)-(d) present corresponding results for the world economy partitioned into China and the rest of the world. These plots show RER response to a 1% of GDP reduction in China's trade surplus.

The economic intuition behind the price adjustment is a straightforward one. The parametrized model exhibits home bias in consumption, as measured by the global IO table. In the presence of a home bias, a reduction in the transfer that the US receives from the rest of the world decreases income and demand in the US. Because final demand falls disproportionately on domestic goods, in equilibrium the relative price of domestic goods falls. Through an off-setting increase in income, a reinforcing price effect is at work in the rest of the world. In this case, the increase in income falls disproportionately on the non-US goods. The more substitutable the goods are, the less the relative prices need to adjust. An identical mechanism with the opposite sign is at work in case of China.[15]

In level terms, the RER adjustment in Figure 5 varies in the -0.25 to 0 range for the US and 0.1 to 0.4 range for China. Thus, depending on the assumed elasticities, the RER adjustment can be interpreted as large or small in economic terms. This finding is consistent with conclusions of the extensive literature on the topic, to which our paper provides no new insights.

The focus of our paper is instead on understanding deviations in RER responses between the two models. We find that differences in the RER response can be large. For example, in case of China in Figure 5 the traditional VA model can understate the RER adjustment by as much as 40%. Furthermore, in contrast to the conventional view in the literature, differences

[15] On the supply side the model assumes that aggregate value added of each sector is fixed in real terms. Factor flexibility and substitution of intermediate inputs is present, but limited to a reallocation by 'use' within a sector. E.g., in response to a shock employees that generate value added in the US manufacturing sector can be reallocated from producing goods for the U.S. consumer to producing goods destined for consumers in the rest of the world.

the RER response do not exhibit a systematic sign. The conventional view is that by ignoring inputs the traditional VA model overstates the degree of openness and, hence, understates the required price adjustment. We, instead, find that the traditional VA model can under/overstate the RER adjustment depending on the assumed elasticities.

We conclude this section by extending above results to 20 large economies. In each case we aggregate the underlying global IO table to the 2-sector country in question and the rest of the world and compute the RER adjustment in the benchmark GO and traditional VA models. For tractability elasticity values are restricted to $\omega^g = 1$ and $\gamma^g = 0.5$. For each country we compute the RER adjustment that accompanies a 1% of GDP increase in trade balance.

Results, reported in Table 1, are broadly consistent with the findings for the US and China. Differences in the RER response between the two models can be large. E.g., in case of Mexico and Korea the traditional VA model understates the RER response by 20%. For the median sample country the traditional VA model understates the RER response, but there are notable exceptions, including the US, where the sign is the opposite. It is worth stressing that quantitative results in Table 1 are sensitive to the assumed elasticity values, as can be inferred from the detailed discussion of results for the U.S. and China. Also, since the underlying model is nonlinear, the size of the RER adjustment is not linear with respect to the change in the trade balance.

Overall, the findings of this section are *not* consistent with the notion, laid out in the introduction, that ignoring inputs necessarily leads to an underestimate of the RER response to a transfer shock. The main contribution of this paper, presented in the next section, is to offer a methodology that decomposes the RER deviations into contributing factors, including but not limited to distorted economic openness.

5 Sources of RER Deviations

This section examines sources of RER deviations between the traditional VA and GO models. We first quantify separately effects from eliminating distortions in preference weights and price elasticities. Then we put the pieces together and decompose deviations in RER responses into contributions from each of the two distortions, their interaction and a residual that captures differences in model specification.

5.1 Distorted Preference Weights

To obtain weight parameters that are consistent with the VA model we set weights in the VA model so as to replicate allocations in panel (c) of Figure 4 rather than panel (b), which was the data target for the traditional VA model. Intuitively, to obtain the correct preference weights, we need to modify the parameterization of the traditional VA model to target sectoral flows in value added rather than sectoral gross exports and imports. Panel (c) of Figure 4 implements such a modification.[16]

Comparison of flow data in panels (b) and (c) reveals two key distortions. First, panel (b) overstates aggregate openness, as measured by trade flows relative to GDP. In panel (b) aggregate trade flows equal gross flows in panel (a) and exceed trade in value added in panel (c).[17] As discussed in Section 2.2, the use of imports as inputs implies that a fraction of imports is re-exported and hence gross trade flows exceed trade in value added. This distortion results from the fact that the parameterization of the traditional VA model does not correctly account for *imported inputs*.

Second, panel (b) mis-measures sectoral trade flows. Compare, for example, trade flows in the service sector between panels (b) and (c). In line with the discussion in Section 2.3, service trade flows in panel (b) equal the corresponding sectoral gross flows in panel (a).[18] In panel (c), by contrast, both service exports and service imports significantly exceed levels reported in panel (a). In value added terms services constitute 50% of the U.S. exports, while in gross terms services account for 28% of exports. For trade in value added of the manufacturing sector, relative to trade in the gross output of the sector, there is an off-setting large reduction.

[16] This approach is eqvivalent to (i) generating data with the parametrized GO model, (ii) decomposing the resulting model-based sectoral gross flows into flows of value added and (iii) parameterizing sectoral weights in a VA model to be consistent with the model-based flows of value added. This is the case because the GO model parametrization replicates allocations of the global IO table and the decomposition of sectoral gross flows into flows of value added is model-free.

[17] E.g., U.S. imports in panel (b), $0.24 + 1.28$, equal imports in panel (a), $0.14 + 0.03 + 0.07 + 0.20 + 0.50 + 0.59$, both of which exceed imports in panel (c), $0.81 + 0.54$.

[18] The U.S. exports of services are 0.12+0.06+0.12 in panel (a) and 0.29 in panel (b). The U.S. imports of services are 0.14+0.03+0.07 in panel (a) and 0.24 in panel (b).

What explains such large differences in sectoral trade flows? While for the aggregate economy value added trade by definition is smaller than gross trade, the same does not hold at the sectoral level. Value added of the service sector is traded more than gross output of the sector, because services are used as intermediate inputs in manufacturing and hence exported indirectly.[19] This second distortion stems from the fact that the parameterization of the traditional VA model does not correctly account for *domestic* inputs.

To gauge the quantitative importance of these distortions in imported and domestic inputs, we next turn to the external sector rebalancing exercise. The U.S. and the rest of the world are again subjected to the same 1% of GDP decrease in the U.S. trade deficit, with results summarized in Figure 6. Panels (a) and (b) mimic Figure 5, except the benchmark is the VA model with corrected preference weights, not the GO model. Deviations in RER responses show the impact of eliminating distortions in preference weights from the traditional VA model parameterization.

Panels (c) and (d) further decompose deviations in the RER response into contributions from distortions in domestic and imported inputs. Squared dots reproduce the gap between the two RER responses reported in panels (a) and (b) and denoted by Δrer for (log change in) the traditional VA model and Δrer^{IO} for the (log change in) model with corrected preference weights. E.g., in panel (c) a value of $\ln(\Delta rer/\Delta rer^{IO}) = 0.3$ when $\gamma^g = 0.3$ and $\omega^g = 1$ means that the traditional VA model overstates the RER response by 30%. If the elasticity across sectors is increased to $\gamma^g = 1$, the traditional VA model understates the RER response by 18%. The two sets of bars report results of a decomposition, based on

$$\ln \frac{\Delta rer}{\Delta rer^{IO}} \approx \underbrace{\ln \frac{\Delta rer^{dom}}{\Delta rer^{IO}}}_{\text{Domestic inputs}} + \underbrace{\ln \frac{\Delta rer^{imp}}{\Delta rer^{IO}}}_{\text{Imported inputs}}, \tag{6}$$

where the first decomposition term, Δrer^{dom}, is derived from a parameterization of the VA model

[19] Indeed, panel (a) in Figure 4 reveals that domestic cross-sectoral inputs in production are considerably larger than imported inputs. In case of the U.S., inputs from the domestic service sector account for 21% (1.23/5.82) of the manufacturing gross output. Business services (37%), retail and wholesale trade (25%) and transport (15%) sectors together account for 77% of the domestic service inputs. In comparison, imported inputs account for 9% of manufacturing gross output.

that preserves distortions in sectoral trade flows, but does not distort aggregate openness.[20] Thus, for this modified parametrization any deviations in RER are due to the neglect of domestic inputs only. The remaining term of the decomposition, Δrer^{imp}, is a residual and captures RER deviations due to the neglect of imported inputs.

We find that RER deviations in Figure 6 closely resemble those in Figure 5, indicating that distorted preference weights is an important driver of the deviations. When elasticities across and within sectors are similar in size, the traditional VA model understates the RER response. However, as we move towards a relatively lower substitutability across sectors, i.e., $\gamma^g << \omega^g$, the understated RER response of the traditional VA model turns into an overstated one.

The decomposition of RER deviations reveals two distinct contributing factors at work:

'Imported inputs' effect Exaggerated economic openness, stemming from equating gross trade with trade in value added by the traditional VA model, results in an *under*stated RER response to a given transfer shock. This effect is captured by the negative white bars in panels (c) and (d) of Figure 6. If all cross-sectoral inputs were imported, i.e., $S = 1$, this effect would be the sole driver of RER deviations. In this case the traditional model would uniformly understate the RER response, as suggested by the literature.

'Domestic inputs' effect When $S > 1$, the traditional VA model exhibits excessive cross-sectoral asymmetry in openness. There is too little trade in the value added of the service sector and too much trade in the value added of the manufacturing sector. Implications of this distortion on the RER are captured by the positive grey bars in panels (c) and (d) of Figure 6. We find that this distortion leads the traditional VA model to *over*state the RER response when $\gamma^g < \omega^g$. Intuitively, a rise in cross-sectoral asymmetry in openness increases the weight of the internal RER, as opposed to the terms-of-trade, in the overall RER adjustment. Because adjustment in internal RER is less sensitive to price changes than adjustment in the terms-of-trade, this distortion increases the overall adjustment in RER. Further details on this 'domestic inputs' effect are presented in Appendix B.

Are there findings unique to the U.S. economy? Comparable results for China are presented

[20] For details on the construction of the flow matrix for such an economy see Appendix A.

in Figure 7 and convey a similar picture. For both constellations of the global economy – the U.S.-ROW and China-ROW – there are economically significant and opposing RER deviations that can be linked to distortions in imported and domestic inputs in the traditional VA model. The relative size of the two contributing factors depends on the assumed elasticity parameters.

5.2 Distorted Price Elasticities

In the absence of sectoral value added flow data, consistent elasticities for the VA model are estimated from data generated by the benchmark GO model. We start by computing the model response to a 1% of GDP transfer shock in the GO model parameterized in section 4.1.1. Next, we decompose the resulting changes in sectoral gross flows into changes for flows of value added, as well as derive changes in prices of value added, as implied by the transfer shock. Price elasticity for value added between services and manufactures, γ^v, as well as between domestic and foreign components within each sector, ω^v, is then estimated from the familiar Armington demand equation that links changes in expenditure shares with changes in relative prices in the VA model:

$$\widehat{\omega}^v_{sn} = 1 - \frac{\Delta \ln \left(s_{sj,n}/s_{sn,n}\right)}{\Delta \ln \left(q_{sj}/q_{sn}\right)} \text{ and } \widehat{\gamma}^v_n = 1 - \frac{\Delta \ln s_{i,n}}{\Delta \ln \left(Q_{in}/Q_n\right)},$$

where $\Delta \ln \left(s_{sj,n}/s_{sn,n}\right)$ and $\Delta \ln s_{i,n}$ capture changes in expenditure shares on sectoral value added within and across sectors; $\Delta \ln \left(q_{sj}/q_{sn}\right)$ and $\Delta \ln \left(Q_{in}/Q_n\right)$ are changes in relative prices of value added with Q_{in} and Q_n denoting, correspondingly, sectoral price index and aggregate price index, as implied by the VA model. Because Q_{in} and Q_n depend on ω^v, value added elasticities are estimated sequentially: first within sectors and then across sectors.

We repeat this procedure for each of the 21 countries listed in Table 1, which gives us 42, i.e., SN, estimates of value added elasticities within sectors and 21, i.e., N, estimates of value added elasticities across sectors. Finally, common elasticities within and across sectors for all sample countries, $\widehat{\omega}^v$ and $\widehat{\gamma}^v$, are computed as the mean value from the sets of within and across elasticity estimates.

Results of the estimation are summarized in Table 2. For each pairing of elasticities in the GO model, $\{\gamma^g, \omega^g\}$, above procedure derives estimates of $\{\widehat{\gamma}^v, \widehat{\omega}^v\}$. Estimates are reported for the range of elasticities examined in previous sections. Results confirm that elasticities in the GO and VA models are distinct. The only exception is the case when all elasticities of substitution in the GO model are unitary. One can show that in this case the GO model can be recast as the VA model with identical unitary price elasticities.[21] Beyond this special case, we find that, quantitatively, price elasticity of value added across sectors exceeds that in the GO model. At the same time, price elasticity of value added within sectors tends to be lower than that in the GO model, although the reverse holds for some elasticity pairings. For benchmark values of $\{\gamma^g, \omega^g\} = \{0.50, 1.00\}$ we estimate that $\{\widehat{\gamma}^v, \widehat{\omega}^v\} = \{0.62, 0.93\}$. Because distortions across and within sectors have the opposite signs, the overall impact on RER requires a quantitative assessment.

To gauge the effect of the identified distortions in price elasticities on the RER, we next compare the price response in the traditional VA model with a VA model where our estimated VA elasticities are used instead. Panels (a)-(b) in Figure 8 present results for the US and panels (c)-(d) for China. RER responses for the traditional VA model are replicated from Figure 5. Responses for the VA model with estimated value added elasticities are plotted by, first, estimating $\{\widehat{\gamma}^v, \widehat{\omega}^v\}$ for each $\{\gamma^g, \omega^g\}$ pairing on the x-axis and then computing RER response to a transfer shock in the VA model parametrized to $\{\widehat{\gamma}^v, \widehat{\omega}^v\}$. Note that for both models considered in Figure 8 we keep the distorted preference weights of the traditional VA model. Hence, the figure singles out the effect of distorted elasticities on the RER response.

Results for both the US and China show that distortions in elasticity values lead to *over*stated RER responses. This finding implies that, quantitatively, the distortion in the cross-sectoral elasticity, i.e., $\gamma^g < \widehat{\gamma}^v$, dominates the effective elasticity between aggregate consumption baskets.

5.3 Decomposition of RER Deviations

Parameter distortions can also have an interactive effect on the RER response. To examine this interaction, this section implements a complete decomposition of deviations in the RER responses between the GO and traditional VA models for 20 large economies into four components: (i) distorted preference weights, (ii) distorted price elasticities, (iii) interaction between the two

[21] This case also requires imposition of balanced trade.

distortions and (iv) a residual, which captures differences in model specifications. In addition to examining the interactive effect, this decomposition extends results for distorted preference weights and distorted elasticities beyond the US and China.

Decomposition results are summarized in Table 3, where for tractability we again restrict elasticities to $\gamma^g = 0.5$ and $\omega^g = 1$. Starting point of the decomposition – the percentage point gap in the RER response to a 1% of GDP negative transfer shock between the GO and traditional VA models – is reported in column 1. It replicates the last column of Table 1. Decomposition results are presented in terms of RER implications from eliminating distortions one at a time or jointly. E.g., a value of -0.5 for Korea in column 1 implies that distortions in the traditional VA model lead to a price response that is understated by 0.5 p.p. relative to the benchmark GO model.

Columns 2-4 report the direct effect from distorted preference weights broken down into the opposing 'imported inputs' and 'domestic inputs' effects. Results for China and USA were already analyzed in detail in Section 5.1. For the extended set of countries we find that the 'domestic inputs' effect tends to dominate. For the median country distorted preference weights lead to an overstated RER response of 0.1 p.p. This finding is in sharp contrast to the notion in the literature that the distortion is limited to overstated openness, i.e., the 'imported inputs' effect, and leads to an understated RER response.

Column 5 reports the direct effect from distorted price elasticities. In line with findings for the U.S. and China, distorted elasticities alone overstate the RER response. The understated price elasticity of the internal RER (i.e., elasticity across sectors) in the traditional VA model, as implied by $\gamma^g < \widehat{\gamma}^v$, dominates the RER response to a transfer shock, because services and manufacturing are sufficiently asymmetric in terms of economic openness. Greece is the only country where the RER response is understated. Not surprisingly, Greece is also the country with the smallest asymmetry in openness across the two sectors, as most of its exports are tourism services. In this case, a sufficiently large weight is put on the adjustment in the terms of trade for the distortion in the within-sector elasticity, i.e., $\omega^g > \widehat{\omega}^v$, to dominate the overall distortion in the RER response.

Next, in column 6 we turn to the interaction between the two distortions. Let η denote elasticities in the VA model, which can be distorted, η^d. Similarly, let w denote preference weights, which can be distorted, w^d. Contribution of the interaction between parameter distortions to RER deviations can be conceptualized as follows:

$$\widehat{rer}\left(\eta^d w^d - \eta w\right) = \widehat{rer}\left(\eta^d \Delta w\right) + \widehat{rer}\left(w^d \Delta \eta\right) - \widehat{rer}\left(\Delta w \Delta \eta\right), \tag{7}$$

where $\widehat{rer}(.)$ maps model differences in parameter values into RER deviations and $\Delta x \equiv x^d - x$. In words, deviations in RER responses between the VA model parametrized with and without distortions, $\widehat{rer}(\eta^d w^d - \eta w)$, can be decomposed into a direct contribution from distorted preference weights, $\widehat{rer}(\eta^d \Delta w)$, a direct contribution from distorted elasticities, $\widehat{rer}(w^d \Delta \eta)$ and an interactive term, $\widehat{rer}(\Delta w \Delta \eta)$. Note that when direct contributions are formulated in terms of eliminating a distortion, the interactive term has a negative sign.[22] RER deviations in column 6 of Table 3 are derived as the difference between the left-hand side and the first two terms of the right-hand side of (7).

Results suggest that distortions interact to generate a large additional understatement of the RER response in the traditional VA model. This effect is driven by interaction of the 'domestic inputs' effect and distorted price elasticities. Intuitively, distortions simultaneously (i) increase the cross-sectoral asymmetry in openness and (ii) significantly magnify the difference between elasticities across and within sectors. Each of these effects leads to an overstated RER response (see columns 4 and 5). Interaction of the two effects generates an further magnification effect, which enters the decomposition in Table 3 with a negative sign, as shown in (7). This interaction effect is quantitatively large. For the median sample country it understates the RER response by 0.4 p.p.

To complete the decomposition exercise, column 7 reports deviations in the RER response between the correctly parameterized VA model and the GO model. This column captures differences in model specification between the VA and GO models rather than parameter distortions.

[22] Alternatively, one can formulate the decomposition in terms of introducing distortions, so that:

$$\widehat{rer}\left(\eta^d w^d - \eta w\right) = \widehat{rer}\left(\eta \Delta w\right) + \widehat{rer}\left(w \Delta \eta\right) + \widehat{rer}\left(\Delta w \Delta \eta\right).$$

In this case, the interactive term has a positive sign. We present results in terms of eliminating distortions, because such results are more applicable to macro models.

In essence, this residual captures deviations in the RER response that stem from specifying consumer utility as CES in sectoral gross flows (GO model) versus CES in sectoral flows of value added (VA model). We find that this residual for the median sample country is close to zero.

Overall, the key takeaway from the decomposition exercise in Table 3 is that a correction of distortions in both preference weights and price elasticities is desirable. Correcting only one of the distortions not only leaves out the other distortion, but also fails to account for potentially significant interaction effects.

6 Extensions

This section extends the external sector rebalancing exercise in two dimensions. First, we investigate the impact of inputs on transfer-induced changes in consumption quantities, in addition to prices. Second, we study the effect inputs have on the distribution of the multilateral RER adjustment among bilateral partners.

6.1 Adjustment in Consumption Quantities

Studies of external sector rebalancing focus primarily on the behavior of relative prices, but adjustment in terms of quantities is also of interest. To examine the response for quantities, we broaden the investigation from prices to expenditure shares and decompose the response of the expenditure share into contributions from prices and consumption quantities.

Results for China are summarized in Figure 9, where we consider the same 1% of GDP fall in China's trade surplus. The reduced surplus increases China's share in global expenditures. Panels (a)-(b) show percentage point contribution of prices to the increase in the global expenditure share for the GO and traditional VA models. As expected, price contributions mimic responses reported in Figure 5.

Panels (c)-(d) report comparable results for consumption quantities. Deviations in the quantity response between the two models are in magnitude comparable to deviations in prices. For the particular case of China and the range of elasticity values, the traditional VA model understates the adjustment in quantities. We also examine the larger set of 20 economies, listed in

Table 1, and find that the neglect of intermediates by the traditional VA model can under- or over-state the adjustment in consumption quantities, relative to the GO model. For the median country 2/3 of the deviations in the response of the global expenditure share between the two models are attributed to consumption quantities and 1/3 to prices.

6.2 Increasing the Number of Countries

The 2-country rebalancing exercise, studied in sections 4 and 5, is silent about the distribution of the multilateral price adjustment among bilateral trade partners. Such distribution could reveal further distortions stemming from the neglect of intermediate inputs by the traditional VA model. Here we address this issue by extending the framework to 9 countries/regions, i.e. S=2 and N=9, and implementing a global rebalancing exercise, whereby trade in all regions is simultaneously balanced.

Results are reported in Table 4. The first column reports the initial trade balance in each region, as implied by the GTAP 7.1 data for year 2004. As expected, in response to the shock of rebalancing, defined as $NX/GDP = 0$ in all countries, the relative price falls in countries with large trade deficits and increases in countries with surpluses. Columns 2 and 3 report REER responses in the GO and traditional VA models.

Our main interest is column 4, which reports absolute deviations in REER responses between the two models. A positive deviation implies that the traditional VA model overstates the price response. We find sizable differences in REER gaps across regions: e.g., for South East Asia neglecting intermediates leads to a significantly understated price adjustment, while for Japan the price response is overstated. Observed RER deviations can be linked to 'imported and domestic inputs' effects, discussed in Section 5.1. In regions that are more integrated in global production chains (South East Asia, China, Emerging Europe) the 'imported inputs' effect dominates and, hence, the traditional VA model understates the price adjustment. At the same time, South America, Japan and 'the rest of the world' regions are among the least integrated in production chains. In this case, the 'domestic inputs' effect dominates and column 4 reports an overstated price response.

7 Conclusions

Building on a traditional macro modeling framework, this paper proposes a methodology for tracing out the effect of intermediate inputs, including processing trade, on the link between external sector rebalancing and relative price adjustment. A widely held view is that by not taking processing trade into account, the traditional approach to rebalancing overstates economic openness and, as a result, understates the price response to a given external sector rebalancing. We label this the 'imported inputs' effect.

This paper shows that in a multi-sector setting with manufactures and services accounting for domestic inputs can be equally important. Because services are used as inputs in manufacturing, they are more tradable than implied by the traditional approach – one that ignores inputs. To put it differently, value added of the service sector is traded more than the gross output of the service sector. A reverse effect is at work in the manufacturing sector. This finding – a reduced cross sectoral asymmetry in openness when inputs are correctly accounted for – redistributes the price adjustment away from the internal margin towards the external margin, which reduces the size of the RER response. In contrast to the 'imported inputs' effect above, this 'domestic inputs' effect leads the traditional approach to overstate the price response to rebalancing.

We also argue that the traditional approach mismeasures price elasticities. Because there is no readily available data on sectoral value-added, empirical estimates of elasticities from data on gross flows are used instead. We estimate that this short-cut tends to result in an overstated price response in the traditional VA model. Last but not least, results show that distortions in elasticities and preference weights interact to generate a sizable additional understatement of the price response. We conclude that both distortions in preference weights and price elasticities need to be eliminated for the traditional model to correctly measure the link between external rebalancing and relative prices.

We have derived our results in a workhorse CES-Armington macro model. An interesting avenue for future research would be to pursue similar type of analysis in richer frameworks that do not model intermediate inputs (see, e.g., trade models of multinational production in Tintelnot (2012), Arkolakis, Ramondo, Rodriguez-Clare and Yeaple (2013)). Distortions in the size of cross-country trade linkages and elasticities that our paper identifies could be relevant for these richer frameworks. This is because these models face the same basic issue when taken to data: supply and demand in the model is specified over value added from geographic locations (optimally chosen by firms), but data used to parametrize these models are on sales of firms' gross output in different locations and, thus, potentially contain value added from multiple locations. Our methodology can also be extended to models that allow for intermediate production inputs, but fall short of replicating allocations of a global IO table. In this case distortions in parameter values are likely to be smaller than in the traditional VA model.

Finally, this paper is an attempt to map multi-sector macro models into consistent sectoral data, with an application to a classic 'transfer problem'. We show that the mapping is easier for models that are formulated in terms of gross flows. These are models where *each* sectoral production function, consistently with input-output tables, includes inputs. Models that abstract from this empirical fact are considerably harder to map into data and for some parameters, such as elasticities, there are no readily available estimates. As a result, short-cuts need to be used, which can bias model findings. The overarching lesson we draw from his study is that multi-sector models should be formulated in terms of sectoral gross flows.

References

[1] Arkolakis, C., N. Ramondo, A. Rodriguez-Clare and S. Yeaple, 2013, "Innovation and Production in the Global Economy," NBER Working Paper No. 18792.

[2] Armington, P., 1969, "A Theory of Demand for Products Distinguished by Place of Production," *IMF Staff Papers*, Vol.16, No.1, pp. 159-178.

[3] Backus, D., P. Kehoe and F. Kydland, 1994, "Dynamics of the Trade Balance and the Terms of Trade: The J-Curve?" *American Economic Review*, Vol. 84, No. 1, pp. 84-103.

[4] Bems, R., R. Johnson, and K.-M. Yi, 2010, "Demand Spillovers and the Collapse of Trade in the Global Recession," *IMF Economic Review*, Vol. 58, No. 2, pp. 295-326.

[5] Burstein, A., J. Neves and S. Rebelo, 2004, "Distribution Costs and Real Exchange Rate Dynamics During Exchange-Rate-Based-Stabilizations," *Journal of Monetary Economics*, Vol. 50, No. 6, pp. 1189-1214.

[6] Corsetti, G., L. Dedola and S. Leduc, 2008, "International Risk Sharing and the Transmission of Productivity Shocks," *Review of Economic Studies,* Vol. 75, No. 2, pp. 443–473.

[7] Corsetti, G., P. Martin and P. Pesenti, 2013, "Varieties and the Transfer Problem," *Journal of International Economics*, Vol. 89, No. 1, pp. 1-13.

[8] Dekle, R., J. Eaton and S. Kortum, 2008, "Global rebalancing with Gravity: Measuring the Burden of Adjustment," *IMF Staff Papers*, Vol. 55, No.3, pp. 511-540.

[9] Eaton, J., and S. Kortum, 2002, "Technology, Geography and Trade," *Econometrica*, Vol. 70, No.5, pp. 1741-1779.

[10] Faruqee, H., D. Laxton, D. Muir and P. Pesenti, 2007, "Smooth Landing or Crash? Model-Based Scenarios of Global Current Account Rebalancing," in R. Clarida (ed.), G7 Current Account Imbalances: Sustainability and Adjustment, Chicago, IL: University of Chicago Press, pp. 377-456.

[11] Feenstra R., M. Obstfeld, and K. Russ, 2012, "In Search of the Armington Elasticity," mimeo, UC Davis.

[12] Ferrero, A., M. Gertler, and L. Svensson, 2010, "Current Account Dynamics and Monetary Policy," in Jordi Gali and Mark J. Gertler (ed.), International Dimensions of Monetary Policy, University of Chicago Press, pp. 199 - 244.

[13] García-Herrero, A., and T. Koivu, 2010, "Impact of China's exchange-rate policy on trade in Asia," in S. Evenett (ed.), The US-Sino Currency Dispute: New Insights from Economics, Politics and Law, A Vox EU.org Publication, CEPR, April.

[14] Heathcote, J., and F. Perri, 2002, "Financial Autarky and International Business Cycles," *Journal of Monetary Economics*, Vol. 49, No. 3, pp. 601-627.

[15] Hummels, D., J. Ishii and K.-M. Yi, 2001, "The nature and growth of vertical specialization in world trade," *Journal of International Economics*, Vol. 54, No. 1, pp. 75-96.

[16] Johnson, R. and G. Noguera, 2012, "Accounting for Intermediates: Production Sharing and Trade in Value Added," *Journal of International Economics*, Vol. 86, No. 2, pp. 224-236.

[17] Koopman, R., Z. Wang, and S.-J. Wei, 2014, "Tracing Value-Added and Double Counting in Gross Exports," *American Economic Review*, Vol. 104, No. 2, pp. 459-494.

[18] Kraemer K., G. Linden, and J. Dedrick, 2011, "Capturing Value in Global Networks: Apple's iPad and iPhone," Personal Computing Industry Center Research Paper, July.

[19] Mejean, I., P. Rabanal and D. Sandri, 2011, "Current Account Rebalancing and Real Exchange Rate Adjustment between the U.S. and Emerging Asia," IMF Working Paper 11/46, March.

[20] Obstfeld, M. and K. Rogoff, 2004, "The Unsustainable US Current Account Position Revisited," NBER Working Paper 10869.

[21] Obstfeld, M. and K. Rogoff, 2005, "Global Current Account Imbalances and Exchange Rate Adjustments," *Brookings Papers on Economic Activity*, Vol.25, No.1, pp.67-123.

[22] OECD-WTO, 2012, "Trade in Value-Added: Concepts, Methodologies and Challenges," www.oecd.org/sti/ind/49894138.pdf

[23] Purfield, C., and C. Rosenberg, 2010,"Adjustment under a Currency Peg: Estonia, Latvia and Lithuania during the Global Financial Crisis 2008-09," IMF Working Paper 10/213, September.

[24] Stockman A., and L. Tesar, 1995, "Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements," *American Economic Review*, Vol. 85, No. 1, pp. 168-185.

[25] Timmer, M., ed., 2012, "The World Input-Output Database (WIOD): Contents, Sources and Methods," WIOD Working Paper #10, http://www.wiod.org/publications/papers/wiod10.pdf.

[26] Tintelnot F., 2012, "Global Production with Export Platforms," mimeo, Penn State.

Table 1: RER response to a 1% of GDP negative transfer shock

	RER response, in %		Gap in RER response, in p.p.
	Benchmark GO model	Traditional VA model	
Country	(1)	(2)	(3)
AUS	-5.3	-5.4	0.1
CHN	-2.2	-1.9	-0.4
JPN	-7.2	-7.2	-0.1
KOR	-2.6	-2.1	-0.5
IND	-5.9	-5.9	-0.1
CAN	-3.0	-2.6	-0.4
USA	-10.5	-11.1	0.7
MEX	-2.4	-1.9	-0.5
ARG	-3.3	-3.0	-0.2
BRA	-4.7	-4.4	-0.3
FRA	-4.1	-4.0	-0.2
DEU	-2.6	-2.5	-0.1
GRC	-3.0	-2.7	-0.3
ITA	-3.8	-3.6	-0.2
POL	-2.6	-2.6	0.0
PRT	-3.2	-2.9	-0.3
ESP	-3.9	-3.7	-0.2
GBR	-4.1	-4.0	-0.2
RUS	-2.4	-2.5	0.0
TUR	-3.5	-3.3	-0.2
ZAF	-2.9	-3.1	0.2
Median	-3.3	-3.1	-0.2

Notes: The rebalancing exercise for each country is set up as $N = 2$: country-ROW; $S = 2$: manufactures - services; $\gamma^g = 0.5$; $\omega^g = 1$.

Table 2: Estimates of value added elasticities within and across sectors

(a) Varying elasticity within sectors, ω^g

$\{\gamma^g;\omega^g\}$	$\{0.50;0.50\}$	$\{0.50;0.66\}$	$\{0.50;1.00\}$	$\{0.50;1.50\}$	$\{0.50;2.00\}$
$\{\widehat{\gamma}^v;\widehat{\omega}^v\}$ (St. dev.)	$\{\underset{(0.04)}{0.59};\underset{(0.04)}{0.57}\}$	$\{\underset{(0.04)}{0.60};\underset{(0.02)}{0.68}\}$	$\{\underset{(0.04)}{0.62};\underset{(0.02)}{0.93}\}$	$\{\underset{(0.04)}{0.63};\underset{(0.09)}{1.35}\}$	$\{\underset{(0.05)}{0.64};\underset{(0.24)}{1.90}\}$

(b) Varying elasticity across sectors, γ^g

$\{\gamma^g;\omega^g\}$	$\{0.25;1.00\}$	$\{0.33;1.00\}$	$\{0.50;1.00\}$	$\{0.75;1.00\}$	$\{1.00;1.00\}$
$\{\widehat{\gamma}^v;\widehat{\omega}^v\}$ (St. dev.)	$\{\underset{(0.05)}{0.44};\underset{(0.04)}{0.89}\}$	$\{\underset{(0.05)}{0.49};\underset{(0.03)}{0.90}\}$	$\{\underset{(0.04)}{0.62};\underset{(0.02)}{0.93}\}$	$\{\underset{(0.02)}{0.80};\underset{(0.01)}{0.97}\}$	$\{\underset{(0.00)}{1.00};\underset{(0.00)}{1.00}\}$

Notes: Each $\widehat{\gamma}^v$ based on 21 observation, each $\widehat{\omega}^v$ based on 42 observation.

Table 3: Decomposition of deviations in RER response between the GO and traditional VA models to a 1% of GDP negative transfer shock

	Gap in RER response, in p.p.	Decomposition: (1) = (2) + (5) + (6) + (7)					
		Distorted preference weights, (3) + (4)	'Imported inputs' effect	'Domestic inputs' effect	Distorted price elasticities	Interaction between (2) & (5)	Residual
Country	(1)	(2)	(3)	(4)	(5)	(6)	(7)
AUS	0.1	0.3	-1.0	1.3	0.1	-0.5	0.1
CHN	-0.4	-0.2	-0.8	0.6	0.1	-0.3	0.0
JPN	-0.1	0.4	-1.0	1.3	0.2	-0.7	0.1
KOR	-0.5	-0.3	-1.2	0.9	0.1	-0.3	-0.1
IND	-0.1	0.2	-1.3	1.6	0.0	-0.7	0.4
CAN	-0.4	0.0	-1.1	1.0	0.2	-0.3	-0.2
USA	0.7	1.2	-2.2	3.3	0.5	-1.3	0.4
MEX	-0.5	-0.2	-1.1	0.9	0.1	-0.3	0.0
ARG	-0.2	0.0	-0.6	0.6	0.0	-0.3	0.0
BRA	-0.3	0.0	-0.6	0.6	0.0	-0.3	0.1
FRA	-0.2	0.2	-1.4	1.5	0.3	-0.5	-0.1
DEU	-0.1	0.2	-0.9	1.0	0.1	-0.3	-0.1
GRC	-0.3	-0.3	-1.0	0.7	-0.1	-0.2	0.3
ITA	-0.2	0.1	-1.1	1.2	0.1	-0.4	0.1
POL	0.0	0.0	-1.3	1.3	0.2	-0.4	0.1
PRT	-0.3	-0.1	-1.8	1.7	0.2	-0.5	0.1
ESP	-0.2	0.0	-1.3	1.4	0.2	-0.5	0.0
GBR	-0.2	0.1	-1.1	1.2	0.1	-0.4	0.1
RUS	0.0	0.2	-0.4	0.6	0.0	-0.2	0.0
TUR	-0.2	0.2	-1.3	1.5	0.3	-0.5	0.2
ZAF	0.2	0.4	-0.8	1.2	0.2	-0.4	0.0
Median	-0.2	0.1	-1.1	1.2	0.1	-0.4	0.0

Notes: $\gamma^g = 0.5$; $\omega^g = 1$.

Table 4: REER responses to global rebalancing in the benchmark GO and traditional VA models

Country-Region	Initial net trade, NX/GDP in % (1)	Change in trade-weighted REER, in %: Benchmark GO model (2)	Change in trade-weighted REER, in %: Traditional VA model (3)	Gap in absolute REER response, in p.p. (4)
CHN	6.7	24.1	21.7	-2.4
JPN	2.3	26.8	30.9	4.1
USA	-4.3	-30.7	-30.4	-0.3
South America	7.4	58.8	60.8	2.0
South East Asia, excl. JPN, CHN	10.5	25.5	19.1	-6.4
Emerging Europe	-4.8	-9.0	-7.5	-1.5
EMU	-0.7	-1.2	-0.6	-0.6
NAFTA, excl. USA	-0.8	3.4	3.6	0.2
Rest of the world	2.7	11.0	11.7	0.7

Notes: N=9; S=2; REER computed using trade-based weights; REER gap computed as p.p. deviations in absolute terms, i.e., (4) = |(3)|-|(2)|; NX/GDP based on GTAP 7.1 data for 2004; Rebalancing shock defined as NX/GDP=0 in all countries/regions.

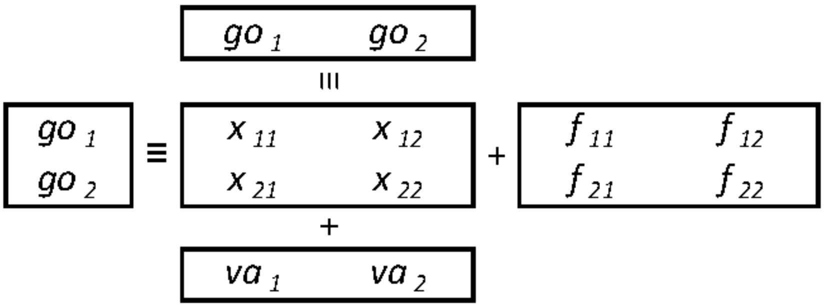

Figure 1: Global make and use identities (2 countries)

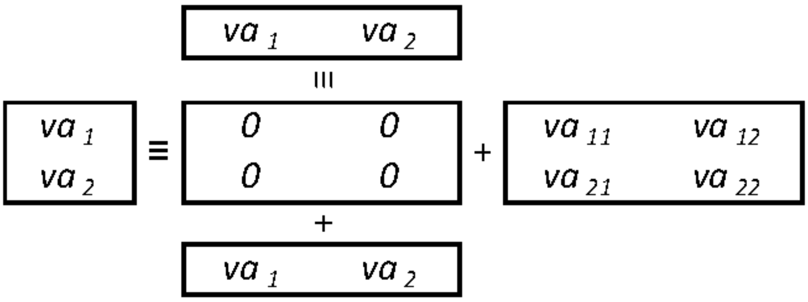

Figure 2: IO-based decomposition of value added by destination (2 countries)

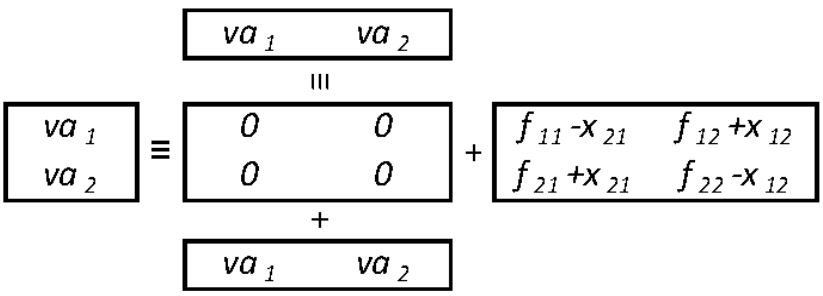

Figure 3: Traditinal decomposition of sectoral value added by destination (2 countries)

(a) Gross flows

	S_{usa}	M_{usa}	S_{row}	M_{row}	c_{usa}	c_{row}	Y
S_{usa}	3.66	1.23	0.12	0.06	9.09	0.12	14.27
M_{usa}	1.33	1.85	0.12	0.36	1.88	0.28	5.82
S_{row}	0.14	0.03	9.20	4.26	0.07	19.36	33.06
M_{row}	0.20	0.50	4.41	10.09	0.59	6.82	22.60
rk+wl	8.94	2.22	19.22	7.83			
Y	14.27	5.82	33.06	22.60			

(b) Traditional value added flows

	S_{usa}	M_{usa}	S_{row}	M_{row}	c_{usa}	c_{row}	Y
S_{usa}	0	0	0	0	8.65	0.29	8.94
M_{usa}	0	0	0	0	1.46	0.76	2.22
S_{row}	0	0	0	0	0.24	18.98	19.22
M_{row}	0	0	0	0	1.28	6.55	7.83
rk+wl	8.94	2.22	19.22	7.83			
Y	8.94	2.22	19.22	7.83			

(c) IO-based value added flows

	S_{usa}	M_{usa}	S_{row}	M_{row}	c_{usa}	c_{row}	Y
S_{usa}	0	0	0	0	8.50	0.44	8.94
M_{usa}	0	0	0	0	1.78	0.44	2.22
S_{row}	0	0	0	0	0.54	18.68	19.22
M_{row}	0	0	0	0	0.81	7.02	7.83
rk+wl	8.94	2.22	19.22	7.83			
Y	8.94	2.22	19.22	7.83			

Figure 4: Global input-output table presented in terms of (a) gross flows, (b) traditional flows of value added and (c) 'IO-based' flows of value added (N=2: USA - ROW; S=2: manufactures - serives; 2004; trillion USD)

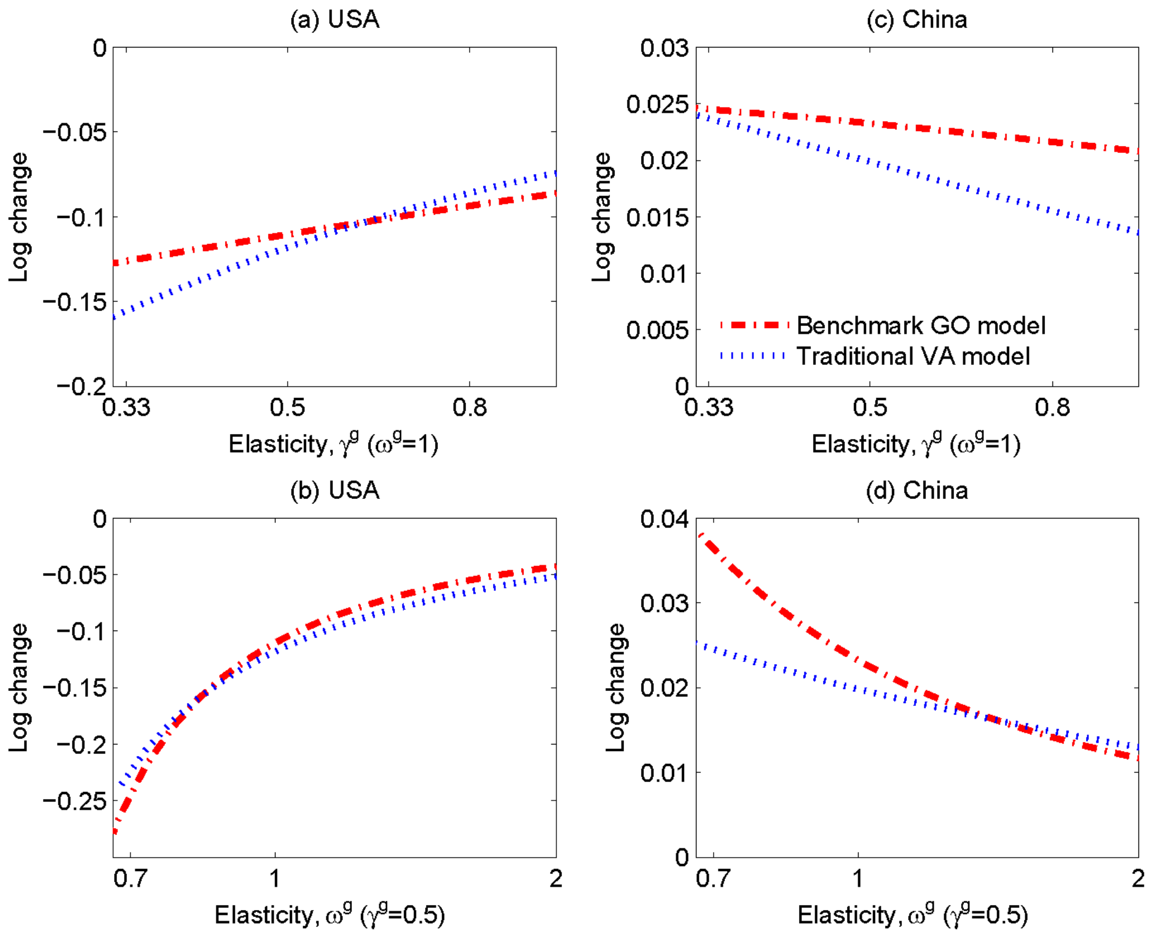

Figure 5: RER response to a 1 % of GDP reduction in trade imbalance (traditional VA model and benchmark GO model)

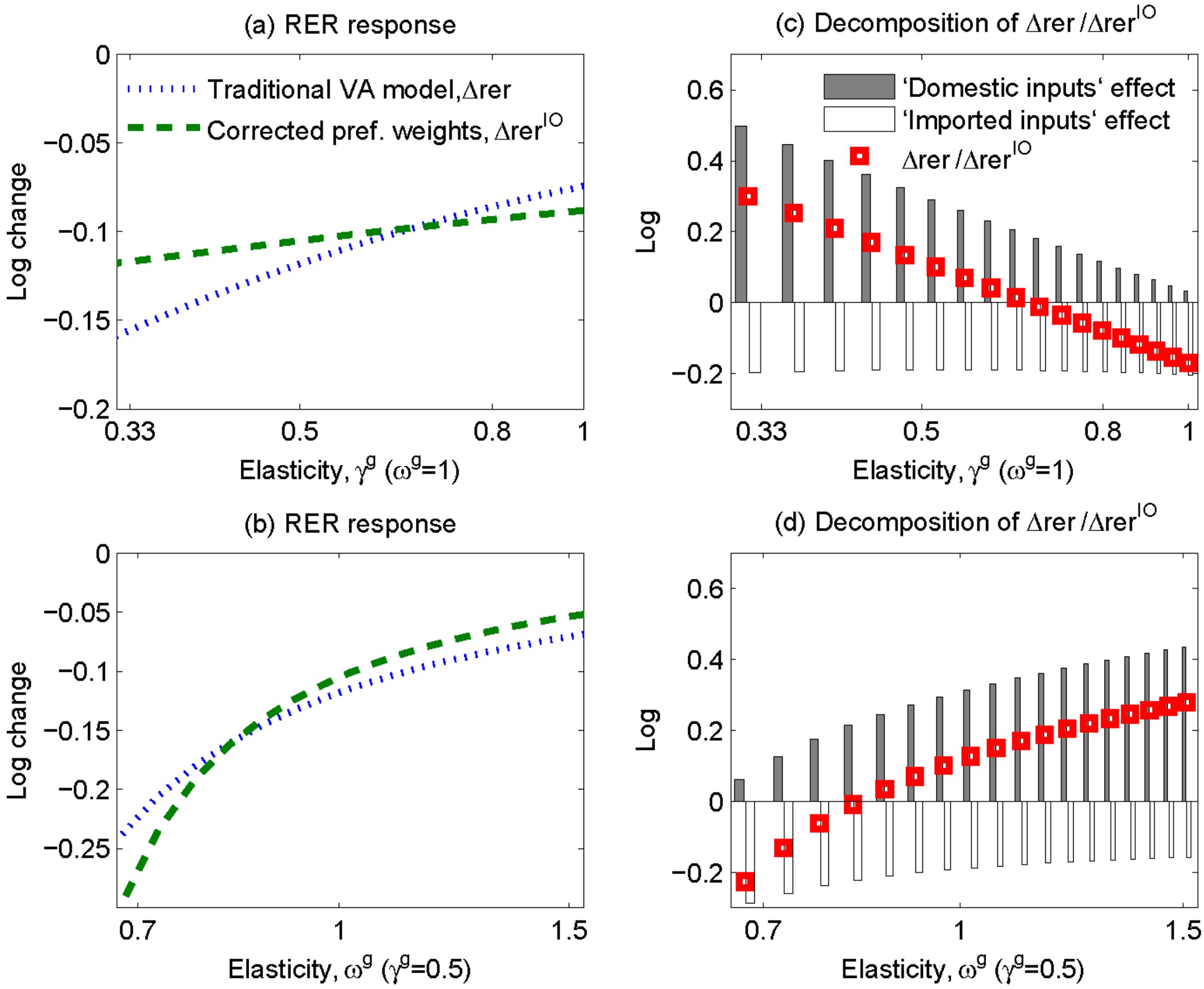

Figure 6: RER response to a 1% of GDP reduction in the U.S. trade deficit and decomposition of response deviations into contributions from 'imported inputs' and 'domestic inputs' effects (traditional VA model and VA model with corrected preference weights)

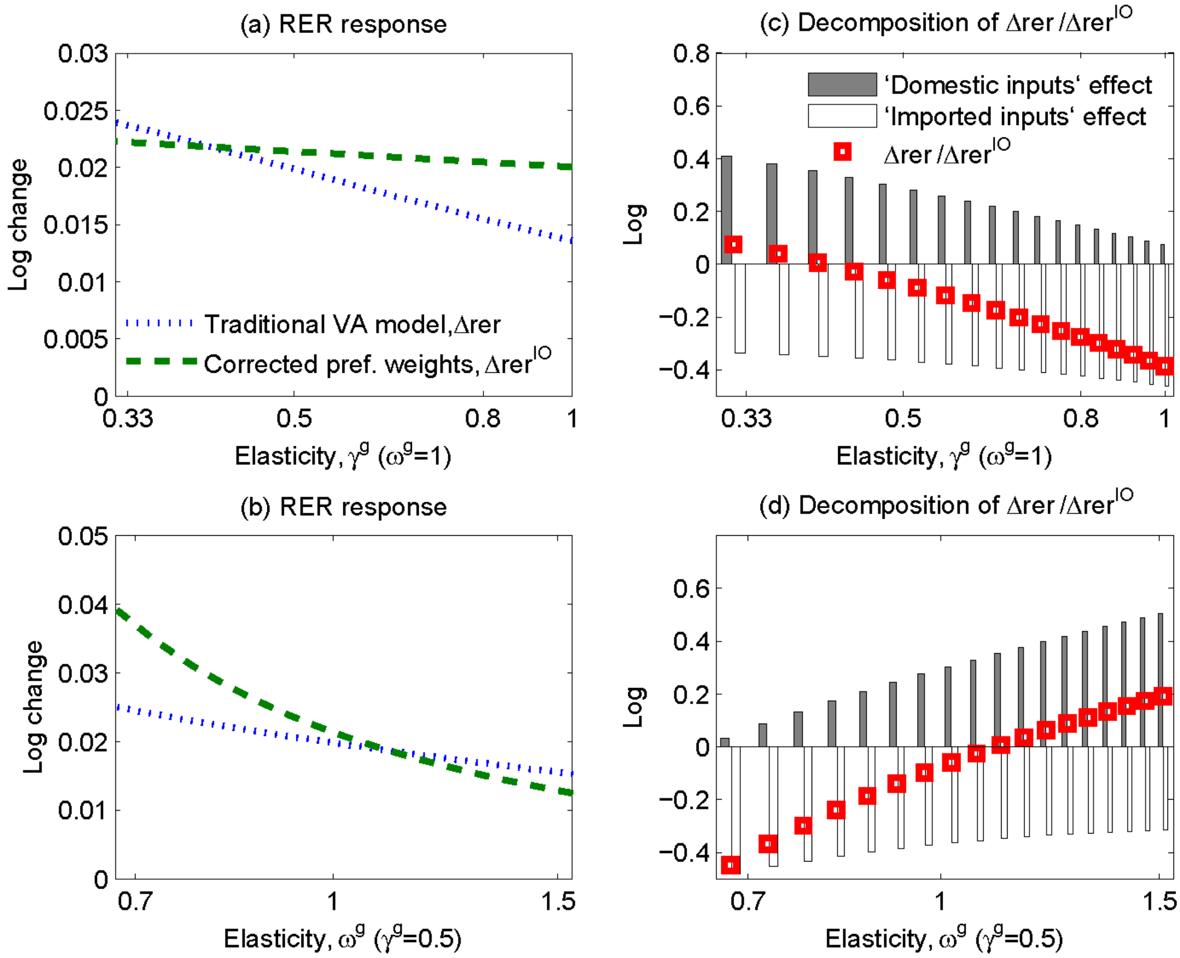

Figure 7: RER response to a 1% of GDP reduction in China's trade surplus and decomposition of response deviations into contributions from 'imported inputs' and 'domestic inputs' effects (traditional VA model and VA model with corrected preference weights)

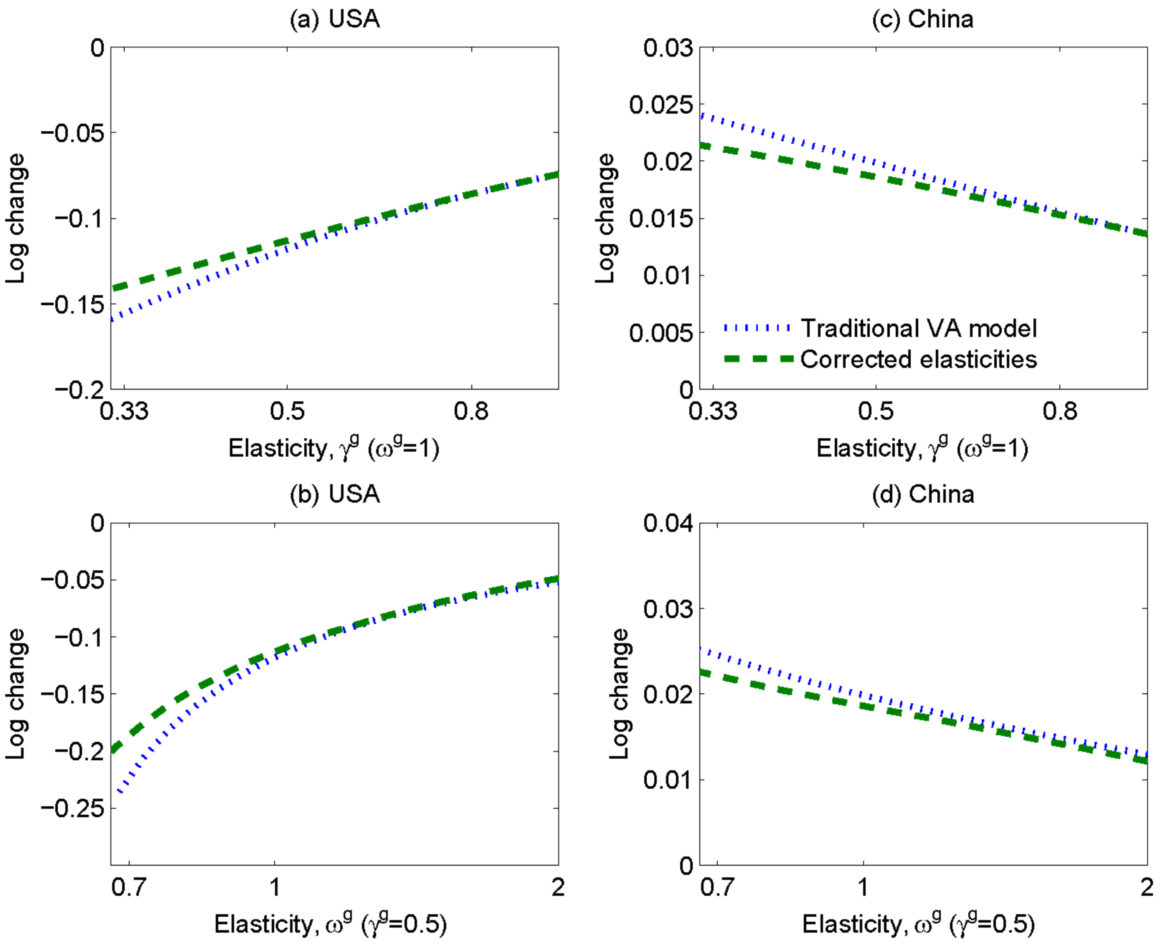

Figure 8: RER response to a 1% of GDP reduction in trade imbalance (traditional VA model and VA model with corrected elasticities)

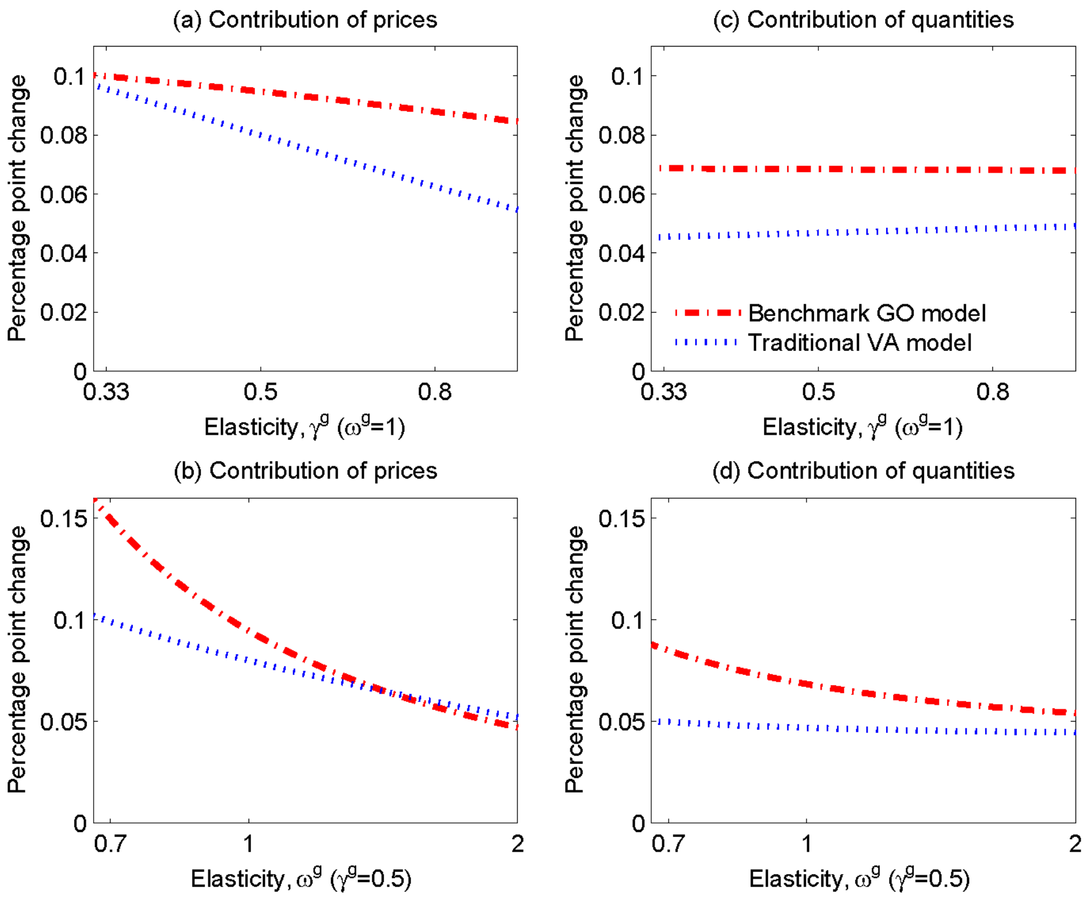

Figure 9: Response of China's global expenditure share, decomposed into price and quantity effects, to a 1% of GDP reduction in trade surplus (traditional VA model and benchmark GO model)

A Construction of Value Added Flows with Distorted Domestic Inputs

Final demand vectors of the traditional VA flows in panel (b) of Figure 4 are modified as follows

$$\begin{bmatrix} h_{11}+\alpha_2 & h_{12}-\alpha_2 \\ h_{21}+\beta_2 & h_{22}-\beta_2 \\ h_{31}-\alpha_1 & h_{32}+\alpha_1 \\ h_{41}-\beta_1 & h_{42}+\beta_1 \end{bmatrix},$$

where

$$\begin{aligned} \alpha_1 &= h_{31}(1-(h_{31}+h_{41})/(va_{31}+va_{41}));\ \alpha_2 = h_{12}(1-(h_{12}+h_{22})/(va_{12}+va_{22})), \\ \beta_1 &= h_{41}(1-(h_{31}+h_{41})/(va_{31}+va_{41}));\ \beta_2 = h_{22}(1-(h_{12}+h_{22})/(va_{12}+va_{22})). \end{aligned}$$

h_{ij} are sectoral final demand components from the traditional value-added flows, defined in Section 2.3 and va_{ij} are sectoral final demand components from the IO-based value-added flows, defined in Section 2.2.

This modification eliminates distortions in aggregate openness for the traditional value-added flows, but preserves distortions in sectoral trade flows. Aggregate demand or value added in any of the four sectors are not affected.

B Underpinnings of the 'Domestic Inputs' Effect

Using definition in (3), we can write

$$\begin{aligned} RER_n &= P_n^x/P_j^m * \left(P_j^m/P_n^x * P_n/P_j\right), \\ \Delta rer_n &= \Delta tot_n + \Delta int_n, \end{aligned}$$

where $\Delta x \equiv \ln x_{t+1}/x_t$; superscripts x and m denote prices of exports and imports so that Δtot denotes change in the terms of trade; Δint is the residual capturing changes in the internal

RER, i.e., the relative price adjustment between the domestic consumption bundle and exports in both countries.

One can then further decompose the contribution to RER deviations from distorted domestic inputs in (6) and Figure 6 into contributions from terms of trade and an internal RER as

$$\Delta rer^{dom} - \Delta rer^{IO} = \underbrace{\Delta tot^{dom} - \Delta tot^{IO}}_{\text{Terms of trade}} + \underbrace{\Delta int^{dom} - \Delta int^{IO}}_{\text{Internal RER}}.$$

We use this decomposition to gain further insight into the workings of the 'domestic inputs' effect. The solid line in Figure 10 reproduces the $\Delta rer^{dom}/\Delta rer^{IO}$ term from panel (c) of Figure 6. Note that Figure 10 reports the deviations in terms of percentage point differences and includes a wider range of values for cross-sectoral elasticity, γ^g. The latter is done to illustrate the workings of this component for both cases: $\gamma^g < \omega^g$ and $\gamma^g > \omega^g$, even though $\gamma^g > \omega^g$ is of limited empirical relevance.

Figure 10 illustrates two important points. First, an exaggerated cross-sectoral asymmetry in openness, as implied by the distorted parametrization of the traditional VA model, redistributes the burden of the RER adjustment from the terms of trade to the internal RER. In Figure 10 response differences in the internal RER (i.e., gray bars) are positive, indicating that the traditional VA model overstates the contribution of this component to the RER deviations. At the same time, response differences in the terms of trade (i.e., white bars) are negative, indicating that the traditional VA model understates the contribution of this component.

The second point contrasts the absolute size of two components of the decomposition in Figure 10. In the empirically relevant case of $\gamma^g < \omega^g$ the internal RER component dominates the terms of trade component, $\left|\Delta int^{dom} - \Delta int^{IO}\right| > \left|\Delta tot^{dom} - \Delta tot^{IO}\right|$, because it is less price sensitive, i.e., generates a larger price response for a given transfer shock.

Put together these findings imply a 'domestic input' effect that leads the traditional VA model to overstate the RER response to a transfer shock. This effect counteracts the effect stemming form the neglect of imported inputs, i.e., 'imported inputs' effect.

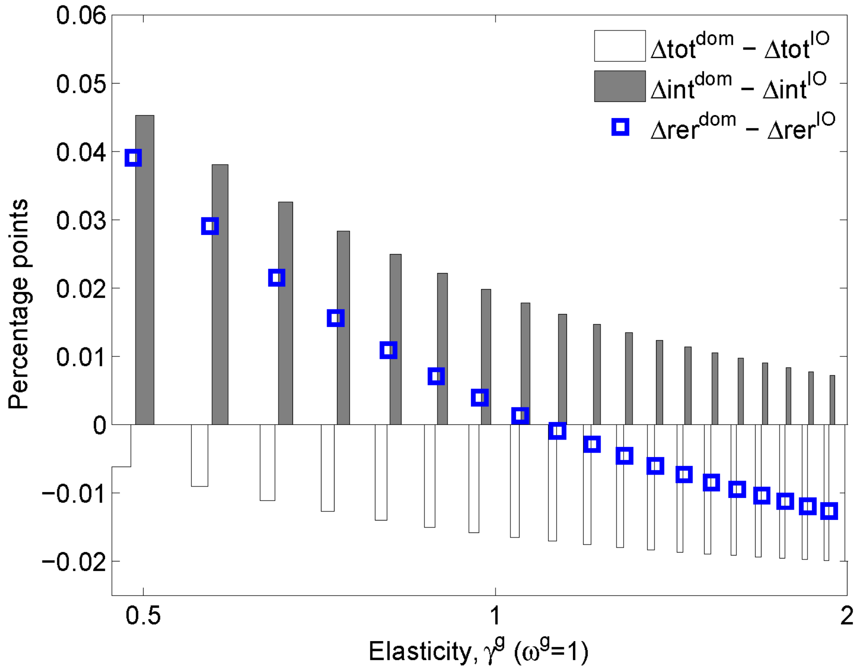

Figure 10: Decomposition of the 'domestic inputs' effect into contributions from the terms of trade and internal RER.