World Prices and Business Cycles of a Small Open Input-Output Economy

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Abstract

The role of terms-of-trade shocks in driving economic fluctuations is revisited through a multisector small open economy (SOE) model, where the various types of goods can all be consumed and employed as inputs. Under this assumption, we show that contrary to conventional wisdom, terms-of-trade shocks may not necessarily trigger an economic boom for the exporting country, if its export goods are intensively employed or consumed domestically. We calibrate and estimate the proposed model using data from 15 emerging countries and find that it performs better than the standard model to explain the different impacts of terms-of-trade shocks across countries documented by Schmitt-Grohe and Uribe (2018).

Keywords: Terms of trade, business cycles, microfounded dynamic Leontief input-output model, DSGE model

JEL Codes: E32, F41, F44

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1 Introduction

Developping economies are known to exhibit high macroeconomic volatility. Seminal papers such as Mendoza, 1991 and Kose, 2002 have led to conventional wisdom suggesting that terms-of-trade shocks explain a large fraction of economic fluctuations in emerging countries. In a recent paper, Schmitt-Grohé and Uribe, 2018 challenge this prediction. They estimate a country-specific structural vector autoregression (SVAR) model based on 38 countries and show that the share of variance of macroeconomic indicators explained by terms-of-trade shocks represents approximately 10% on average, and not 30% as is commonly thought. They also perform a rigorous comparative analysis with a theoretical business cycle model, and find that once variables are measured in the same units as in the data, theoretical and empirical predictions converge on average. However, at the country-by-country level, theoretical results tend to over-estimate impulse responses of macroeconomic aggregates. They conclude therefore that it is necessary to understand origins of this disconnect problem, and discuss some potential avenues.

This disconnect could be partly driven by the fact that a single world price (terms of trade) may fail to capture the transmission mechanism of world shocks as advocated by Fernández, Schmitt-Grohé, and Uribe, 2017. The authors show that multiple world prices (of commodities) constitute a channel through which world shocks propagate better. Their results indicate that commodity price shocks explain a large fraction of business cycle fluctuations. In this case, an improvement of the empirical model pushes the empirical results closer to the theoretical predictions. Schmitt-Grohé and Uribe, 2018 argue that another way to resolve this disconnect could involve modifying the theoretical SOE model to allow for government policy to isolate fluctuations in terms of trade, which would attenuate their role.

I suggest in this paper a further proposition that consists of generalizing the theoretical SOE model used by Schmitt-Grohé and Uribe, 2018, in a way to incorporate explicitely the input-ouput structure of an economy so as to calibrate it accurately for each country. The structure of the standard SOE model they use and its calibration are indeed such that the input-output structure implicitely induced is the same for each country, with a domestic absorption of the export good representing only 5% of total output versus a median of 29% indicated by real data. In consequence, following a price increase of the export good on world markets (a terms-of-trade shock of 10 % for example), it is normal that the standard model tends to over-estimate the economic expansion generated for the exporting country (2% of growth on impact for each country), given it under-evaluates the negative effects related to its domestic use in terms of consumption and production. Improving the standard model as proposed allows to calibrate accurately the structure of the global demand for each country, and hence, to better account for the dampening effects of the increase in production and consumption prices following a terms-of-trade shock. Indeed, unless the degree of substitution between goods is relatively high in the domestic economy, a price increase of the export good on world markets discourages also production efforts through higher costs and lower real payoffs.

The alternative structure proposed to extend the standard SOE model is close those of existing input-output models, like for example Jones, 2011 or Johnson, 2014. The incoporation of an explicit input-output structure to the SOE model is in fact technically easier when assuming production functions that include intermediate goods in addition to capital and labor. This makes the structure different from the (round about) production system of the standard version of the model where capital and labor produce intermediate goods first, and where final goods are obtained in a second step by transforming different types of intermediate goods. Such a structure implies indeed a complicated calibration and constrained endogenous prices. In the proposed framework, any good can be used as an intermediate or capital good to reproduce itself, and can eventually be consumed. The structure of the model replicates exactly the one of input-output national accounts data, and it is the calibration which indicates whether a sector good can be viewed as essentially an intermediate or fixed capital input, or a final consumption good. The price of the import, export and non-tradable good are left exogenous and estimated using real data, for instance terms of trade, output, consumption, investment and the trade balance.

Before evaluating the contribution of the proposed theoretical model, I start with a discussion of empirical facts regarding the domestic use of export goods, and an SVAR analysis of the role of terms-of-trade shocks based on 15 emerging countries. I then follow the same comparision methodology as Schmitt-Grohé and Uribe, 2018 and find that the theoretical results of the proposed model (we will refer to as the SOE-IO model) confirm on average the moderate effect of terms-of-trade shocks of approximately 10% obtain with the SVAR model. That is, external shocks on export prices do not explain a large fraction of output volatility. In some cases, the dampening effects related to the global demand can also totally offset the positive effects of the supply side, so that the overall impact on output can even be nil, if not negative.

Using the estimated SOE-IO model, I also propose to analyse quantitatively the effects of different kinds of input-output structures within a domestic economy and to make a comparative analysis across countries. I conclude from this exercise that it is important to account for the right country-specific economic structure to understand the propagation of shocks on world prices to the domestic country and their impact on the dynamics of macroeconomic aggregates.

The remainder of this paper is organized as follows. Section 2 presents empirical facts regarding country-specific input-output structures and recalls the results of the SVAR model of Schmitt-Grohé and Uribe, 2018 about the role of terms-of-trade shocks in economic fluctuations. Section 3 develops a theoretical three-sector SOE model based on the structure of input-output data tables. Section 4 describes the calibration and estimation strategy. Section 5 analyzes the results in comparison with the empirical SVAR model. Section 6 investigates the role of the input-output structure regarding responses of macroeconomic aggregates to terms-of-trade shocks. Section 7 presents a sensitivity analysis of results with respect to different degrees of elasticity of substitution between goods., and section 8 concludes.

2 Empirical facts

2.1 Domestic use of export goods

The input-output structure of an economy matters for the impacts of terms-of-trade shocks. For example, a commodity exporter should produce more if the international price of that commodity rises. However, if the exported good is intensively employed in the domestic country with limited scope for substitution by other products, the price increase of that good translates into a higher general production and consumption price index (PPI and CPI, respectively), which may consequently dampen or eventually offset the growth cycle. Hence, in studying the role of terms-of-trade shocks, it is useful to first highlight, through empirical data, the heterogeneity across countries in terms of input-output structure, and precisely in terms of domestic use of export goods. It is also interesting to examine the effects of variations of export prices on production and consumption price indexes.

In this paper, I consider 15 countries of the 38 studied in Schmitt-Grohé and Uribe, 2018 for which the appropriate input-output data required to calibrate the theoretical model in section 3.4 are available; data come from from the World Input Output Database (Winput-outputD) and the OECD Input-Output Tables. Those countries are Argentina, Brazil, Colombia, Costa Rica, India, Indonesia, Malaysia, Mexico, Morocco, Peru, Philippines, South Africa, South Korea, Thailand, and Turkey. The first task is to define how to classify all sectors of each country within one of our three categories: the import, export and nontradable sectors. To do so, I set up a simple rule based on the degree of openness formalized by $\rho_j = \frac{M_j+X_j}{P_jQ_j}$, where M_j refers to imports and X_j to exports. Below a certain low degree $\rho*$, a sector is classified into the nontradable good sector, and above this limit, the sign of net exports is what determines whether the good is importable or exportable. Using input-output data from 2000, I determine the degree $\rho*$ that allows us to obtain the same size of the nontradable good sector as Schmitt-Grohé and Uribe, 2018 for each country, that is 50% of GDP. Nonetheless, I suggest an upper limit for this degree $\rho*_{max} = 20\%$, above which it becomes relatively implausible to define a sector as a nontradable one.

Table 1: Domestic Use of Export goods (%) and Price Index correlations

	Sectors						Prices Correlations	
Country	M	X	N	I	C	Global	$\rho(\Delta P^Y, \Delta P_x)$	$\rho(\Delta P^C, \Delta P_x)$
Argentina	33	55	25	10	25	29	0.082	-0.013
Brazil	20	45	21	18	19	22	0.017	0.071
Colombia	33	57	18	11	32	32	0.38	0.36
Costa Rica	10	39	32	68	24	29	NA	0.49
India	28	42	28	19	34	32	0.25	0.402
Indonesia	29	41	30	4	28	21	0.46	0.24
South Korea	22	62	27	30	19	32	0.65	0.76
Malaysia	22	66	40	23	35	40	0.012	0.55
Mexico	28	49	25	28	21	21	-0.12	0.33
Morocco	10	42	20	2	30	24	-0.19	0.37
Peru	12	43	19	1	20	20	-0.011	0.28
Philippines	4	43	10	14	3	11	0.31	0.59
South Africa	39	54	30	21	31	36	0.19	0.5
Thailand	31	50	39	26	33	36	0.73	0.75
Turkey	26	55	22	9	31	27	0.10	0.63
Median	26	49	25	18	28	29	0.14	0.40

Note: The table displays the shares of export goods in total intermediate goods used by each sector (M,X,N), the shares of export goods in total investment and consumption and a global share calculated with respect to total output. Data on shares of export goods are obtained by aggregating Winput-outputD and OECD Input-Output Data from 2000 by sector. Data on export good prices, PPI and CPI are obtained from Penn World Tables and Trading Economics.

Table 1 presents the proportions of export goods used by each country as total intermediate consumption, total investment and total consumption. The use of export goods as intermediate consumption is detailed by sectors M, X, and N, referring to the import, export and nontradable good sectors, respectively. The total share is computed as the ratio of export goods absorbed domestically versus total output. We notice that for 8 countries out of 15, the use and consumption of export goods represents more than 29% of their total production. The highest shares are 40% for Malaysia and 36% for Thailand. In both countries, a large portion of export goods consists of products of mass consumption, for instance food, fuel, hotels and restaurants, nonmetallic materials and plastics, textiles and wood. The lowest share appears to be 11% for the Philippines. The country hardly consumes any export goods, which primarily consist of textile products, leather and footwear, wood products, computer and electronic equipment, manufacturing machinery, R&D and business activities.

In the last two columns, I represent the correlation of coefficients of growth rates of export good prices and growth rates of PPI and CPI of each country. In almost all countries (for which data are available), I notice a significant positive correlation between variations in export good prices and variations in the PPI and CPI (medians are 14.4% and 40.2%, respectively). Additionally, as expected, countries that use intensively export goods as production factors tend to exhibit strong correlations between production price index and export good prices (for example, Thailand, Colombia, South Korea and India), and countries that employ small fractions of export goods tend to exhibit low or even negative correlation coefficients (Turkey, Peru, Morocco, Argentina, and Brazil). On the final demand side, almost all countries consume a significant share of export goods (the median value is 28%), which is in accordance with high correlations of export good and consumption price index variations.

2.2 Empirical analysis of terms of trade shocks

This paper is an attempt to resolve the problem of the disconnect between theoretical and empirical predictions of Schmitt-Grohé and Uribe, 2018 concerning the effects of terms-of-trade shocks across countries. Given that my contribution consists in improving the theoretical model, I recall the results of their empirical SVAR model to make the same comparisons. The terms-of-trade effect is estimated country by country based on annual data (from 1980 to 2011) provided by the WDI database. We recall for instance the specification they present in section 3 of their paper, which includes the U.S. interest spread, the terms-of-trade variable, the U.S. dollar real exchange rate, gross domestic product (GDP), the gross fixed capital formation (investment), consumption, and the trade balance to output ratio. We concentrate on the 15 countries specified previously for which detailed input-output data is available (out of 38 in the benchmark study of Schmitt-Grohé and Uribe, 2018).

The terms-of-trade variable is defined as the ratio of the export to the import price index, denoted respectively P_{xt} and P_{mt}:

$$tot_t = \frac{P_{xt}}{P_{mt}}.$$

The real exchange rate included in the SVAR model is defined as:

$$RER_t = \epsilon_t \frac{P_t^{US}}{P_t},$$

where ϵ_t denotes the dollar price in domestic currency, P_t^{US} represents the U.S. consumption price index, and P_t is the domestic consumption price index.

All variables are expressed in log deviations from a quadratic trend (the results are shown by SGU to be robust to HP filtering and first differencing). We note that the trade balance is divided by this estimated quadratic trend. The SVAR model is given by:

$$A_0 x_t = A_1 x_{t-1} + \mu_t, \tag{1}$$

where x_t denotes the vector of variables:

$$x_t \equiv \begin{bmatrix} \widehat{tot}_t \\ \widehat{s}_t \\ \widehat{tb}_t \\ \widehat{y}_t \\ \widehat{c}_t \\ \widehat{i}_t \\ \widehat{RER}_t \end{bmatrix}.$$

We let $\widehat{tot}_t$, $\widehat{s}_t$, $\widehat{tb}_t$, $\widehat{y}_t$, $\widehat{c}_t$, $\widehat{i}_t$, and $\widehat{RER}_t$ respectively denote log deviations of the terms of trade, the interest spread, the trade balance ratio, real output per capita, real private consumption per capita, real gross investment per capita, and the real exchange rate from their respective quadratic trends. The objects A_0 and A_1 are 7-by-7 matrices, and A_0 is assumed to be lower triangular, which implies that all variables do not affect the terms of trade contemporaneously. In line with the theoretical specification argued by Schmitt-Grohé and Uribe, 2018, I impose the restriction that all elements of the first two rows of A_1 be zero, except the first and second. The variable μ_t is a 7-by-1 vector of random variables with mean zero and variance-covariance matrix Σ. The reduced form of the model is obtained by premultiplying the system by A_0^{-1}:

$$x_t = Ax_{t-1} + \Pi\epsilon_t, \tag{2}$$

where $A \equiv A_0^{-1}A_1$, $\Pi \equiv A_0^{-1}\Sigma^{1/2}$, and $\epsilon_t \equiv \Sigma^{-1/2}\mu_t$. By construction, ϵ_t is a random vector with mean zero and identity variance-covariance matrix. The resulting system is supposed to be such that the first two equations take the form:

$$\begin{bmatrix} \widehat{tot}_t \\ \widehat{s}_t \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} \widehat{tot}_{t-1} \\ \widehat{s}_{t-1} \end{bmatrix} + \begin{bmatrix} \pi_{11} & 0 \\ \pi_{21} & \pi_{22} \end{bmatrix} \begin{bmatrix} \epsilon_t^{tot} \\ \epsilon_t^{s} \end{bmatrix} \tag{3}$$

The innovations to the terms-of-trade and interest spread equations ϵ_t^{tot} and ϵ_t^{s} relate to the interpretation of the terms-of-trade shock and the interest spread shock, respectively. The system assumes that the terms-of-trade shock affects the interest spread contemporaneously, whereas spread shocks impact the terms of trade with one time delay.[1] The reduced form of the model is then estimated country by country by OLS (detailed results are presented in the Appendix). We find that the cross-country median of the estimated autocorrelation coefficient a_{11} is close to that of the entire sample of countries in Schmitt-Grohé and Uribe, 2018, with a value of 0.56 (versus 0.52), which confirms that terms-of-trade shocks vanish relatively quickly. The median standard deviation of 0.078 is also comparable (versus 0.08).

Figure 1 presents the median impulse response functions of the macroeconomic variables included in the SVAR model following a terms-of-trade shock of 10% (a value close to the median standard deviation of 0.08). As in the case of the entire sample of 38 countries, the trade balance increases by 0.5% GDP on impact. In other words, the results of our sample confirm the Harberger-Laursen-Metzler (HLM) effect obtained not only by Schmitt-Grohé and Uribe, 2018 but also by Otto, 2003, who used a sample of 40 developing countries between 1960 and 1996.

[1]In their paper, Schmitt-Grohé and Uribe, 2018 also consider the possible alternative assumption that interest spread shocks affect terms of trade contemporaneously. They show that the results and conclusions are robust to the choice of specification.

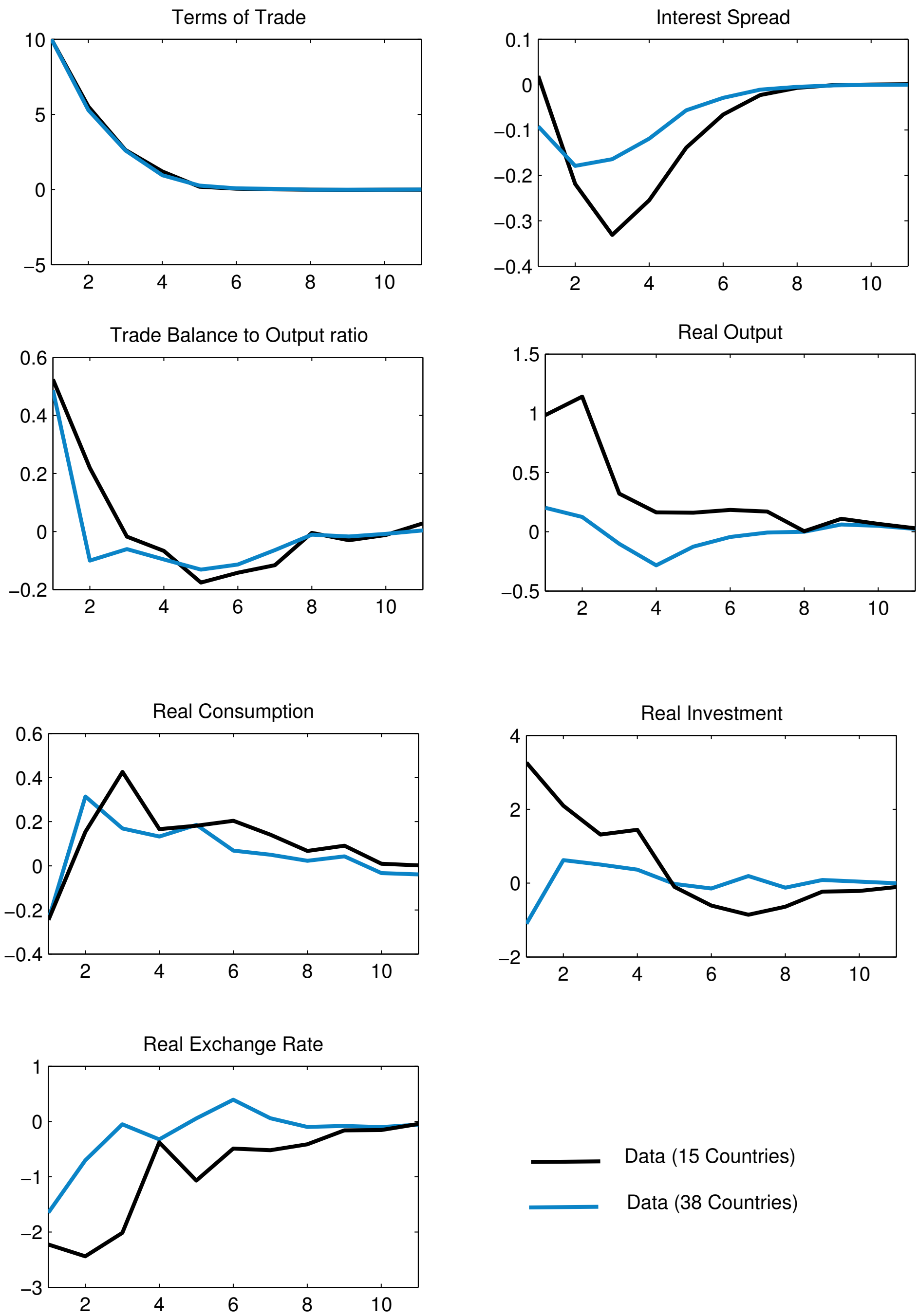

Figure 1: SVAR Impulse response functions following a 10% terms-of-trade shock

Note: Impulse responses are represented as point-by-point medians across countries. The country-specific impulse responses are presented in appendix with 66% confidence intervals.

The increase in terms-of-trade causes a response of real GDP growth on impact of 1%, which is higher than that obtained for the 38 countries in Schmitt-Grohé and Uribe, 2018, for instance, 0.36%. This median response remains sufficiently low to reject the idea that terms-of-trade shocks play important roles in the business fluctuations of emerging countries. Concerning other responses, our sample confirms that private consumption contracts on impact before expanding above its equilibrium path. It also confirms that investment reacts positively, or even contemporaneously in this case. The real exchange rate appreciates above 2% on impact (versus 1.6% when considering the 38 countries) and appears to be slightly more persistent.

Table 2: Share of variances explained by terms-of-trade shocks

Country	tot	s	tb	y	c	i	RER
Argentina	97	5	27	13	12	9	29
Brazil	90	20	51	16	5	31	48
Colombia	98	1	8	19	5	16	14
Costa Rica	88	14	17	2	2	2	1
India	85	3	4	5	19	1	1
Indonesia	97	8	6	11	10	15	7
Korea	74	13	5	3	3	12	11
Malaysia	95	2	8	7	4	7	2
Mexico	85	3	9	10	9	7	26
Morocco	97	11	2	1	0	2	5
Peru	99	22	17	24	16	26	19
Philippines	99	10	23	20	22	7	36
South Africa	78	7	9	3	3	2	10
Thailand	73	19	26	24	25	23	32
Turkey	94	5	3	15	17	31	7
Median	94	8	9	11	9	9	11
Med Abs Dev.	5	5	6	8	6	7	9

As noted by Schmitt-Grohé and Uribe, 2018, responses differ substantially at the country level. For instance, the observed expansions in output and in the trade balance are not significant for 7 and 9 countries out of 15, respectively, in view of the 66% confidence interval including zero (please refer to the Appendix). This remark applies also to the other variables included in the SVAR model. As a conclusion, there is no evidence, through the lens of an empirical SVAR model, that terms-of-trade shocks constitute a major source of business cycles of emerging and resource-limited countries, as suggested by conventional wisdom. Another way to observe the moderate effect of terms-of-trade shocks is to examine the Table 2, which presents the share of variance of macroeconomic variables they explain. We indeed notice that terms-of-trade shocks explain approximately 10% of the volatility of macro variables on average. An interesting question is now to determine whether extending the theoretical model of Schmitt-Grohé and Uribe, 2018 to account for the country-specific input-output structure can help improve understanding of the different roles of terms-of-trade shocks across countries.

3 The theoretical model

3.1 The supply side

We consider three sectors indexed by $j = m, x, n$, with for instance m referring to an import good sector, x to an export good sector, and n to a nontradable good sector. Each sector is composed of a large number of identical firms which employ labour and the goods produced as fixed and intermediate capital goods. This multi-sector model replicates the empirical structure of input-output tables. The technology in each sector exhibits constant returns to scale (CRS) and is defined as:

$$Q_{jt} = B_{jt}[K_j(X_t)^{\alpha}(A_t L_{jt})^{1-\alpha}]^{1-\theta} V_j(X_t)^{\theta} \tag{4}$$

where Q_{jt}, $V_j(X_t)$, $K_j(X_t)$, and L_{jt} denote respectively gross production, aggregate intermediate consumption, aggregate fixed capital, and labor employed by sector j at time t. The level of aggregate capital and intermediate consumption in each sector is expressed as a function of quantities of goods produced in the economy $X_t = (X_{mt}, X_{xt}, X_{nt})$. Producers chose $V_j(X_t)$, $K_j(X_t)$, and L_{jt} so as to maximize:

$$\Pi_{jt} = p_{jt} Q_{jt} - u_{jt} K_j(X_t) - w_{jt} L_{jt} - P_t^{V_j} V_j(X_t)$$

where u_{jt} denotes the capital remuneration rate paid by sector j, $P_t^{V_j}$ is the price index of the intermediate good basket used by sector j, w_{jt} is the wage rate paid, and p_{jt} denotes the price of good j at time t. The first-order conditions are given by:

$$p_{jt}Q_{jK}[K_j(X_t), L_{jt}, V_j(X_t)] = u_{jt} \tag{5}$$

$$p_{jt}Q_{jL}[K_j(X_t), L_{jt}, V_j(X_t)] = w_{jt} \tag{6}$$

$$p_{jt}Q_{jV}[K_j(X_t), L_{jt}, V_j(X_t)] = P_t^{V_j} \tag{7}$$

3.2 Households

We recall the period utility function assumed by Schmitt-Grohé and Uribe, 2018. Households are supposed to maximize:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{[C(X_t) - G(L_{mt}, L_{xt}, L_{nt})]^{(1-\gamma)} - 1}{1-\gamma} \tag{8}$$

where $C(X_t)$ denotes aggregate consumption and where:

$$G(L_{mt}, L_{xt}, L_{nt}) = \frac{L_{mt}^{\tau_m}}{\tau_m} + \frac{L_{xt}^{\tau_x}}{\tau_x} + \frac{L_{nt}^{\tau_n}}{\tau_n}$$

with γ, τ_m, τ_x, and $\tau_n > 0$. This specification implies limited scope for labor mobility across sectors in case of different wages (as soon as τ_j is significantly greater than 1.) To simplify notations, let $C_t = C(X_t)$, $K_{jt} = K_j(X_t)$, and $V_{jt} = V_j(X_t)$. Let also real investment of sector j be defined as $I_{jt} = I_j(X_t)$. The sequential budget constraint faced by the household when maximizing this objective function is defined as:

$$P_t^C C_t + \sum_j \left(P_t^{I_j} I_{jt} + \frac{\phi_j}{2} \left(K_{jt+1} - K_{jt}\right)^2 \right) = \frac{\xi_t D_{t+1}}{1+r_t} - \xi_t D_t + \sum_j \left(u_{jt} K_{jt} + w_{jt} L_{jt}\right),$$

where P_t^C denotes the consumption price index, $P_t^{I_j}$ is the investment price index associated to the aggregate investment in fixed capital I_{jt} in sector j (expressed in real terms). The parameters ϕ_j refer to a capital adjustment cost in each sector. It is assumed indeed that final goods invested are not equally transformed into productive capital. The quantity $\xi_t D_t$ represents the amount of foreign debt due at time t in domestic currency, ξ_t represents the outstanding nominal exchange rate, and r_t denotes the debt interest rate from period t to t+1. I assume that the nominal exchange rate of the small open economy is affected by terms-of-trade shocks and follows an AR(1) process given by:

$$log(\xi_t) = \rho_\xi log(\xi_{t-1}) + \pi^\xi \epsilon_t^{tot} \quad (9)$$

where ϵ_t^{tot} refers to the terms-of-trade innovation and π^ξ, to the standard deviation of its impact. The laws of motion of capital are defined as[2]:

$$K_{jt+1} = (1-\delta)K_{jt} + I_{jt} \quad (10)$$

The resolution of the household's program consists in choosing C_t, L_{jt}, D_{t+1}, and K_{jt+1}, (j=m,x,n), so as to maximize the objective function (8) subject to the sequential budget constraint. The first-order conditions are (the detailed resolution is described in the Appendix):

$$\frac{U_C(C_t, L_{mt}, L_{xt}, L_{nt})}{P_t^C} = \lambda_t \quad (11)$$

$$-U_{L_j}(C_t, L_{mt}, L_{xt}, L_{nt}) = \lambda_t w_{jt} \quad (12)$$

$$\lambda_t \xi_t = \beta(1+r_t)E_t \lambda_{t+1}\xi_{t+1} \quad (13)$$

$$\lambda_t[P_t^{I_j} + \phi_j(K_{jt+1} - K_{jt})] = \beta E_t \lambda_{t+1}[u_{jt+1} + (1-\delta)P_{t+1}^{I_j} + \phi_j(K_{jt+2} - K_{jt+1})] \quad (14)$$

3.3 Equilibrium of markets

Equilibrium of commodity markets implies :

$$\omega_{it}^C P_t^C C_t + \sum_j \omega_{it}^{I_j} P_t^{I_j} I_{jt} + \sum_j \omega_{it}^{V_j} P_t^{V_j} V_{jt} + NX_{it} = p_{it} Q_{it} \quad (15)$$

for $i, j = m, x, n$. The amount NX_{it} denotes net exports of good i at time t, and ω_{it}^C, $\omega_{it}^{I_j}$, and $\omega_{it}^{V_j}$ denote respecively optimal budget shares of final consumption,

[2]We suppose same functions for the aggregate measure of capital and investment. The assumption of an aggregate investment good can also be found in Fernández, González, and Rodriguez, 2018.

investment, and interemdiate consumption spent on good i. Letting $C(X_t)$, $I(X_t)$, and $V(X_t)$ be given by a CES Argminton aggregator, Armington, 1969), it is well known that price indexes and optimal shares maximizing $C(X_t)$, $I(X_t)$, and $V(X_t)$ have the following forms:

$$P_t^C = \left(\sum_i \zeta_i^{\sigma_C} p_{it}^{1-\sigma_C}\right)^{1/(1-\sigma_C)} \quad \omega_{it}^C = \zeta_i^{\sigma_C}\left(\frac{P_t^C}{p_{it}}\right)^{\sigma_C}, \tag{16}$$

$$P_t^{I_j} = \left(\sum_i \kappa_{ij}^{\sigma_{I_j}} p_{it}^{1-\sigma_{I_j}}\right)^{1/(1-\sigma_{I_j})} \quad \omega_{it}^{I_j} = \kappa_i^{\sigma_{I_j}}\left(\frac{P_t^{I_j}}{p_{it}}\right)^{\sigma_{I_j}}, \tag{17}$$

and

$$P_t^{V_j} = \left(\sum_i \nu_{ij}^{\sigma_{V_j}} p_{it}^{1-\sigma_{V_j}}\right)^{1/(1-\sigma_{V_j})} \quad \omega_{it}^{V_j} = \nu_{ij}^{\sigma_{V_j}}\left(\frac{P_t^{V_j}}{p_{it}}\right)^{\sigma_{V_j}}, \tag{18}$$

where ζ_i, κ_{ij}, and ν_{ij} define positive parameters of the corresponding CES aggregators, and where σ_C, σ_{I_j}, and σ_{V_j} correspond to degrees of elasticity of substitution between goods. Having defined equilibrium price indexes and budget shares, the resolution for the steady-state general equilibrium implies to determine the set of amounts NX_m^*, NX_x^*, and NX_n^* that satisfy equation (38) $\forall i, j = m, x, n$.. For the sake of simplicity, I let $\kappa_{ij} = \kappa_i$, $\omega_{it}^{I_j} = \omega_{it}^I$, and $P_t^{I_j} = P_t^I$, $\forall j = m, x, n$ (note indeed that information regarding gross fixed capital formation by sector is generally missing in input-output data.) As well, I propose $\sigma = \sigma_C = \sigma_{I_j} = \sigma_{V_j}$, $\forall j = m, x, n$ (to reduce the number of variables estimated next).

Summing equation 38 over each good i and combining the result with the budget constraint leads to:

$$\frac{\xi_t D_{t+1}}{1+r_t} - \xi_t D_t = \sum_j \phi_j (K_{jt+1} - K_{jt}) - \sum_i NX_{it} \tag{19}$$

which means that indebtment finances net imports and capital adjustment costs. The trade balance is given by:

$$TB_t = -\left(\frac{\xi_t D_{t+1}}{1+r_t} - \xi_t D_t\right) \tag{20}$$

The real exchange rate is expressed as:

$$RER_t = \frac{\xi_t P_t^{C*}}{P_t^C}, \tag{21}$$

where P_t^{C*} corresponds to the foreign consumption price index (for instance the U.S. consumption price index in the empirical counterpart) . The SVAR specification considers that terms-of-trade shocks influence the real-exchange rate, but not the reverse. Hence, assuming that changes in export good prices of the domestic country exert no real impacts on this foreign consumption price index, allows simplification of the measure of the theoretical real exchange rate dynamics (for instance, $RER_t = \frac{\xi_t}{P_t^C}$.)

Definition

Assuming an economy of J sectors that are indexed by j and that each produce a specific good $i \in J$, a competitive equilibrium is a set of $J \times 16 + 9$ processes K_{jt+1}, V_{jt}, L_{jt}, λ_t, Q_{jt}, I_{jt}, C_{it}, ω_{it}^C, ω_{it}^I, $\omega_{it}^{V_j}$, u_{jt}, w_{jt}, P_{xt}, P_{nt}, P_t^C, $P_t^{I_j}$, $P_t^{V_j}$, D_{t+1}, r_t, s_t, TB_t, RER_t and NX_{jt}, satisfying equations (4) to (21), given the initial conditions K_{j0}, V_{j0}, and D_{-1}.

We finally define theoretical counterparts of real output, real consumption and real investment as, respectively, $\hat{Y}_t = 1/P_t \sum_j p_{jt} Y_{jt}$, $\hat{I}_t = 1/P_t \sum_j P_t^I I_{jt}$, and $\hat{C}_t = 1/P_t \sum_j P_t^C C_t$, where $P_t = \sum_j p_{jt} Y_{jt} / \sum_j p_j^* Y_{jt}$ defines the theoretical counterpart of a Paasch production price index (i.e., the price deflator used in the data).

3.4 Price and Interest Premium shocks

The context of a small open economy means that the country has no possibility to influence world prices or the world interest rate. The economy is supposed to take export and import prices as given and to adjust to shocks that occur within world markets. To analyze the macroeconomic dynamics following a terms-of-trade shock, I propose to recall the estimated system of equation (3), and to implement it within the theroetical model. Letting $P_{mt} = P_{x*} = 1 \; \forall t$, where P_{x*} denotes the steady-state price of the export good, I can express the theoretical terms of trade as $tot_t = P_{xt}$ and let log deviations from steady-state $log(P_{xt})$ correspond to $\widehat{tot_t}$.

I also make the plaussible assumption that the price of non-tradable good is affected by terms-of-trade shocks, through the following rule :

$$log(P_{nt}) = \rho_n log(P_{nt-1}) + \pi^n \epsilon_t^{tot} + \pi_{lag}^n \epsilon_{t-1}^{tot}, \tag{22}$$

assuming the steady-state price P_{n*} is equal to 1. Note that I let the possibility for terms-of-trade shocks to affect the price of the non-tradable good with one time delay. Parameters π^n and π_{lag}^n refer to standard deviations of the terms-of-trade innovation at time t and $t-1$.
The domestic interest rate is given by:

$$r_t = r^* + s_t + \psi(e^{\tilde{D}_t - D^*} - 1) \tag{23}$$

where r^* denotes the world interest rate, ψ, a debt premium sensitivity parameter, s_t, the theoretical counterpart of the interest spread included in the SVAR model, and $\tilde{D}_t$ represents the aggregate level of external debt per capita that households assume as exogenous.

4 Calibration Strategy and Estimation

4.1 Standard parameters

The model admitting a more general technological structure than the standard SGU model is greater in size, with 57 endogenous variables and 46 parameters. Nonetheless, because its structure is directly in line with inpu-output data, the characterization of the steady state is greatly simplified. All parameters of the model that appear in equilibrium conditions evaluated at the steady state (36 parameters) are calibrated, and the remaining (10) parameters, which are σ, ψ, ϕ_j (j=m,x,n), ρ_n, π^n, π_{lag}^n, ρ_ξ and π^ξ, are estimated by matching impulse response functions of macroeconomic variables obtained with the SVAR model. Tables 6 and 4 summarize the calibration and estimation of all parameters.

The 36 calibrated parameters are α_j, B_j, θ_j, β, δ, γ, P_x^*, P_m^*, P_n^*, τ_j, κ_i^K, ν_{ij}^V, ζ_i^C, $(r^* + s^*)$, and D^*, $\forall i, j \in J$. For some of them, I simply recall the values from Schmitt-Grohé and Uribe, 2018. We let for instance $\gamma = 2$. As well, I let $\alpha_x = \alpha_m = 0.35$, $\alpha_n = 0.25$, $r^* = 0.07$, $\beta = \frac{1}{1+r^*+s^*} = 0.9$ (with $s^* = 0.04$), and $\delta = 0.1$. I also deduce the value of D^* to obtain a trade balance-to-output ratio of 1%. I let θ_j be the share of intermediate consumption among total output given by sector data (presented in section 2.1). Because I assume perfectly divisible goods, I define the units of output in each sector such that $P_{x*} = P_{m*} = P_{n*} = 1$. We let the relative values of B_j determine the sizes of sectors and note that absolute levels of B_j are calibrated to approximate the consumption-output ratio. The values of τ_j are set to 1.455 $\forall j = m, x, n$ to ensure a Frisch elasticity of laborsupply of 2.2. Input-output parameters κ_i, ν_{ij}, and ζ_i are calibrated to match, respectively, the observed investment budget shares ω_{it}^I (supposed as equal for all sectors), the observed intermediate consumption shares of goods used by each sector $\omega_{it}^{V_j}$, and the observed final consumption shares of goods defined previously as ω_{it}^C. In each case, values of the parameters are calibrated under the assumption of steady-state price indexes normalized to 1. The calibration is indeed simplified with $\zeta_i = \left(\omega_{it}^C\right)^{1/\sigma}$, $\kappa_i = \left(\omega_{it}^I\right)^{1/\sigma}$, and $\nu_{ij} = \left(\omega_{it}^{V_j}\right)^{1/\sigma}$.

4.2 Estimation

We propose to estimate the set of parameters

$$\Phi = [\sigma \ \phi_m \ \phi_x \ \phi_n \ \psi \ \rho_n \ \pi^n \ \pi_{lag}^n \ \rho_\xi \ \pi^\xi]$$

through the same partial information method as in Schmitt-Grohé and Uribe, 2018. The method consists of matching the theoretical impulse responses implied by terms-of-trade shocks, of output, consumptio, investment, and the real-exchange rate to the empirical responses of the SVAR model. We use the first five years of each of the impulse response functions weighted by the inverse of the width of the 66% confidence interval (denoted below by Δ_{tj}). We set Φ as the solution that minimizes:

$$Min \sum_{t=0}^{4} \sum_{j=\hat{Y},\hat{C},\hat{I},RER} \frac{1}{\Delta_{tj}} \left| IRF_{tj}^{SOE-IO}(\Phi) - IRF_{tj} \right|$$

where $IRF_{tj}^{SOE-IO}(\Phi)$ and IRF_{tj} respectively denote the impulse response at time t of the variable j following the terms-of-trade shock, obtained through the theoretical

Table 3: Calibrated parameters

Parameters	Description	Source	Value
γ	CRRA	SGU (2018)	2
δ	Depreciation rate	SGU (2018)	0.1
$r^* + s^*$	Risk-free interest rate + spread	SGU (2018)	0.11
β	Time Discounting rate	SGU (2018)	0.9009
α_x, α_m	Capital shares (X and M sector)	SGU (2018)	0.35
α_n	Capital share (N sector)	SGU (2018)	0.25
P_j^*	Final good prices	set	1
D^*	External debt	calibrated to target TBY = 1%	Table9
θ_j	Intermediate consumption share	SGU (2018)	0.5
B_j	Total Productivity parameters	calibrated to target sector shares	Table9
τ_j	Utility parameters	SGU (2018)	1.455
ζ_i	Preference parameter	equal to $\left(\hat{\omega}_{it}^{C}\right)^{1/\sigma}$	Table10
κ_i	Technological parameter	equal to $\left(\hat{\omega}_{it}^{I}\right)^{1/\sigma}$	Table11
ν_{ij}	Technological parameter	equal to $\left(\hat{\omega}_{it}^{V_j}\right)^{1/\sigma}$	Table 12

We let $\hat{\omega}$ refer to the observed budget shares given by input-output data. Values are displayed in Tables 9 to 12 in the Appendix

SOE-IO and the empirical SVAR model. The weighting factor is defined by the inverse of Δ_{tj}, which represents the width of the 66% confidence intervals of the variable j at time t.

5 Results

Results of the estimation are summarized in table 5 (details are reported in table 13 in the Appendix). The median of capital adjustment costs are close to standard values in the literature (4 to 8). The debt elasticity parameter is 5.13 and the overall degree of elasticity of substitution between goods is estimated at 0.75 (the literature indicates an interval between 0.5 and 1.) Terms-of-trade shocks transmit to the price of the non tradable good, but effects are not persistent (the AR parameter ρ_n is estimated at 0.3). Results by countries are displayed in the Appendix. Figure 2 below reports the median of the impulse responses to a 10 percent terms-of-trade

Table 4: Estimated parameters

Parameters	Description	Source	Value
σ	CES parameter	estimated	Table13
ψ	Debt elasticity parameter	estimated	Table13
ϕ_j	Capital adjustment costs	estimated	Table13
ρ_n	AR(1) parameter Non-tradable Price	estimated	Table13
π_n	Stderr of shock on Non-Tradable Price	estimated	Table13
π^n_{lag}	Stderr of lagged shock on Non-Tradable Price	estimated	Table13
ρ_ξ	AR(1) parameter Nom. Exch. rate	estimated	Table13
π^ξ	Stderr of lagged shock on Nom.Exch.rate	estimated	Table13
a_{11}	VAR coefficient	SGU (2018)	Table 7
a_{12}	VAR coefficient	SGU (2018)	Table 7
a_{21}	VAR coefficient	SGU (2018)	Table 7
a_{22}	VAR coefficient	SGU (2018)	Table 7
π_{11}	VAR coefficient	SGU (2018)	Table 7
π_{21}	VAR coefficient	SGU (2018)	Table 7
π_{22}	VAR coefficient	SGU (2018)	Table 7

shock of the 15 countries in consideration. The proposed SOE-IO model fits relatively better the empirical SVAR predictions compared to the standard SOE model. It predicts lower median responses of real output, real consumption and investment and reproduces the shape of the dynamics of most aggregate variables remarkably well.

Table 5: Results of Estimation

	ϕ_m	ϕ_x	ϕ_n	ψ	σ	ρ_n	π^n	π^n_{lag}	ρ_ξ	π^ξ
Median	8.02	4	4.1	5.13	0.75	0.3	0.03	0.02	0.88	-0.01

Note: The minimization program is solved starting from restricted guess values (and through a CMAES algorithm).

Figure 3 helps understanding the propagation of terms-of-trade shocks in the domestic economy by presenting impulse responses of marcoeconomic variables disagregated over sectors and goods. It gives for instance details about theoretical impulse responses displayed in Figure 2. An increase of the relative price of exportables generates an expansion of production in the export good sector by attracting more resources through higher real remunerations. In parallel, production falls in the import good sector and remains relatively constant in the non-tradable one (second row of the Figure 3). Overall, the response of real aggregate output is slightly positive. In order to match this response, the price of the non-tradable good is predicted to increase so as to obtain producers in that sector maintain same quantities of output. The mechanism described is qualitatively similar to the one of Schmitt-Grohé and Uribe, 2018, however, variations appear amplified in the presented model. The higher response of the export good sector (left panel of second row of Figure 3) is caused by a more important inflow of labor from the import good sector, that results essentially from the effect of the consumption price index. The real wage is indeed more impacted in the presented model where export goods constitute a significant fraction of domestic consumption.

Both theoretical models predict correctly the increase of real investment following a terms of trade shock that is expected to be persistent (right panel of the third row in Figure 2). In each case, the export good sector is predicted to attract more capital resources to the detriment of the import good sector (third row of Figure 3). As regards real consumption, the presented model does slightly better in reproducing the shape of the empirical response (left panel of the third row in Figure 2). At the disagregated level, real consumption of import goods decreases contrary to real consumption of export and non-tradable goods (fourth row of Figure 3). Such a result has to do with the degree of elasticity of substitution which is relatively low. Indeed, as discussed in the last section, the median impulse response of the model is very close to the perfect complement case; the degree of elasticity of substitution needs to increase significantly to obtain a real consumption of export and non-tradable goods decrease to the benefit of relatively cheaper import goods.

This analysis of the quality of fit of the theoretical models to the data, should be completed by a country-by-country comparison of shares of variances of macroeconomic indicators explained by terms-of-trade shocks. Theoretical shares of variances are defined as ratios of theoretical variances conditionnal on terms of trade shocks

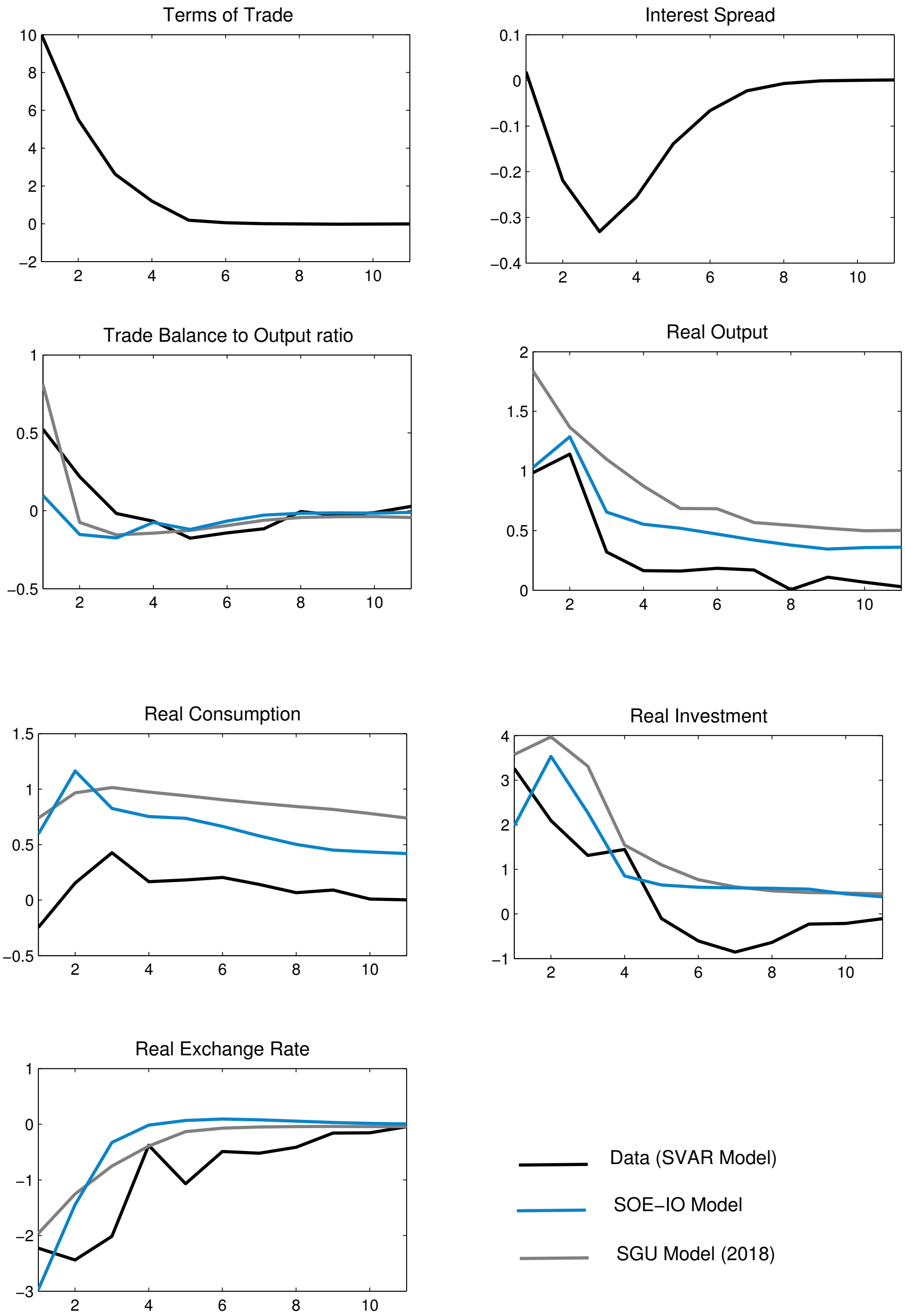

Figure 2: Impulse responses following a 10% terms-of-trade shock

Note: Impulse responses are represented as point-by-point medians across countries. The country-specific impulse responses are presented in appendix with 66% confidence intervals.

to unconditionnal variances obtained with the SVAR model. Figure 4 displays the empirical shares of variance of real output against the theoretical ones obtained with the standard SOE model and the alternative SOE-IO version proposed. Simi-

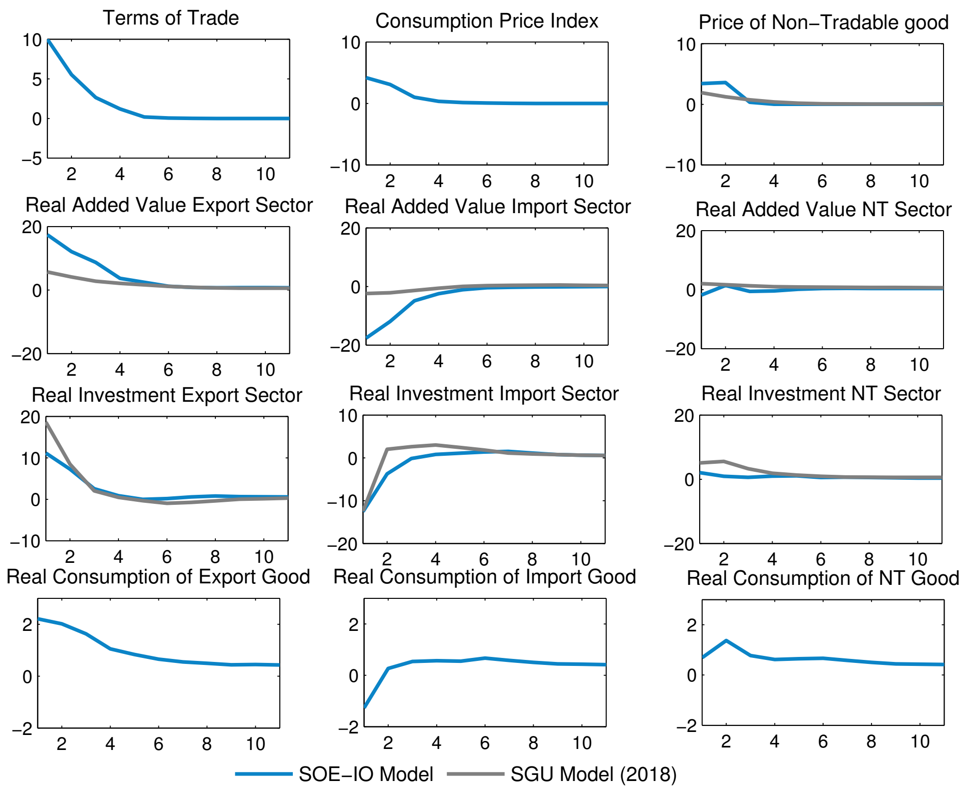

Figure 3: Theoretical impulse responses following a 10% terms-of-trade shock for additionnal variables

Note: Impulse responses are represented as point-by-point medians across countries.

lar figures for real consumption, real investment, the trade balance-to-output ratio and the real exchange rate are presented in Figure 5. If the points lie on the 45 degree line, theoretical predictions confirm empirical ones for each country. As can be seen, the presented SOE-IO model tends to confirm most of the different impacts of terms of trade shocs on real GDP predicted by the SVAR model by ordering each point around the 45 degree line. It also predicts better the country responses of real consumption and real investment than the standard model, in view of a more apparent positive realtionship (first and second row of Figure 5). Concerning the real exchange rate, results are obtained by matching impulse responses of an AR(1) process with the data. Some refinements remain however necessary to bring the model closer to the observed dynamics of the trade-balance-to-output ratio.

Should we conclude that accounting for the country-specific input-output structure is the main reason of the imrpovement of the quality of fit ? The answer is

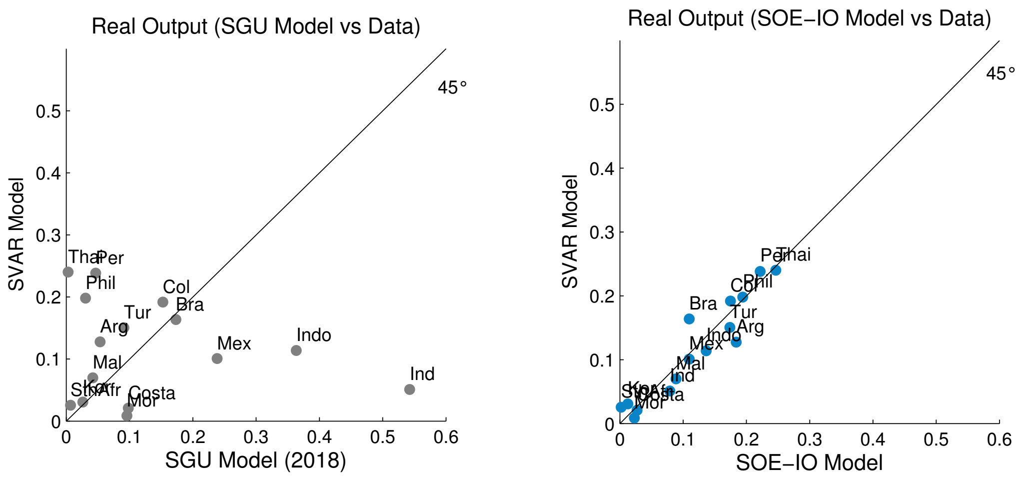

Figure 4: Comparison of Variances of Real GDP

actually no at this step given the models differ in several respects. To clarify the contribution of the input-output structure, we propose therefore to perform some simulation exercises.

6 The role of the input-output structure

6.1 Analysis within a domestic economy

The goal of this section is to quantify the role of the input-output structure. In a first subsection, the idea is to analyse within a domestic economy how the structure of the global demand for intermediate, investment and consumption goods affects the dynamics in response to terms-of-trade shocks. The second subsection addresses a global comparative analysis over the different countries of the sample.

In the literature using the standard SOE model, the greater the size of the export good sector, the greater the favorable impact on the domestic country following a relative price increase of the export good. The role of the input-output structure of the economy is precisely to amplify or dampens this positive impact (and in a general manner, the impact of a sector size). Assuming two countries which differ only across their input-output structure, the one which employs more intensively the goods getting more expensive after a given shock, with limited possibilities to substitute,

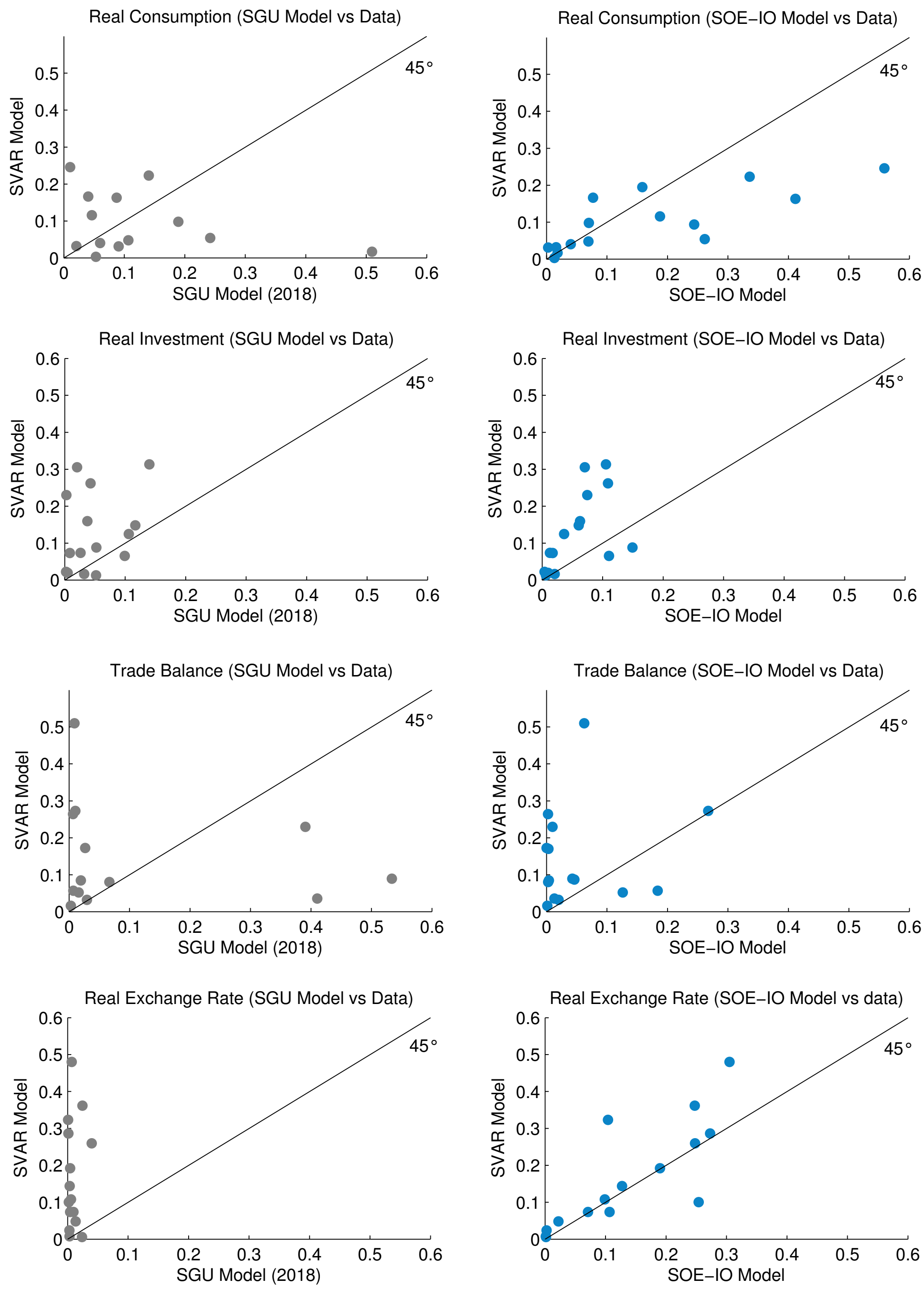

Figure 5: Comparison of Variances of Real Macro Variables

should obviously experience the lowest economic expansion. Production is indeed discouraged through both input prices and through the higher consumption price index which causes to reduce real remunerations. This first subsection quantifies the effects related to higher prices of capital goods, intermediate goods, and consumption goods.

Starting from calibrated and estimated models, we consider 3 alternative input-output structures for each country. The first one (scenario 1) assumes that each country uses no export goods as intermediates; i.e., $\nu_{xj} = 0$, $\forall j = m, x, n$. The second one (scenario 2) considers no use of export goods in terms of intermediate and capital goods; i.e., $\nu_{xj} = 0$ and $\kappa_x = 0$, $\forall j = m, x, n$. The last one (scenario 3) considers no use of export goods at all; i.e., $\nu_{xj} = 0$, $\kappa_x = 0$, and $\zeta_x = 0$, $\forall j = m, x, n$. In each scenario, it is assumed that the use of non-tradable and import goods remains proportionnal.

The median impulse responses corresponding to the fitted SOE-IO model and to each scenario are presented in Figure 6. As expected, the less the export good is employed within the domestic economy, the larger the resulting expansion from the relative increase of the export good price (conversely, from scenario 3 to scenario 1, one obtains the dampening effects of a more intensive use). Excluding the use of exports as intermediate goods produces a significant positive effect on real output, which can be understood through equations derived from the producers program. Indeed, when sectors use export goods as intermediates, the increase of production costs resuling from the terms-of-trade shock causes an incentive to reduce the quantities of intermediate goods, which in turn makes labor less productive. Firms decrease therefore their use of labor, so that output declines immediately in each sector. As regards the marginal effect of excluding export goods from capital inputs (scenario 2), its size appears almost neglible for all macro indicators. This is however not the case for what concerns the marginal effect of eliminating exports from the consumption basket (scenario 3). It can indeed be noticed that the consumption price index increases less, since in that case, it is affected by the non-tradable price only. Note that the increase of the price of the non tradable good should not necessarily be viewed as a consequence of higher production costs, but also as the result of the markets equilibrium dynamics.

6.2 A cross-country analysis

In this section, I evaluate whether the heterogeneity in terms of input-output structure across countries plays an important role in theoretical predictions presented

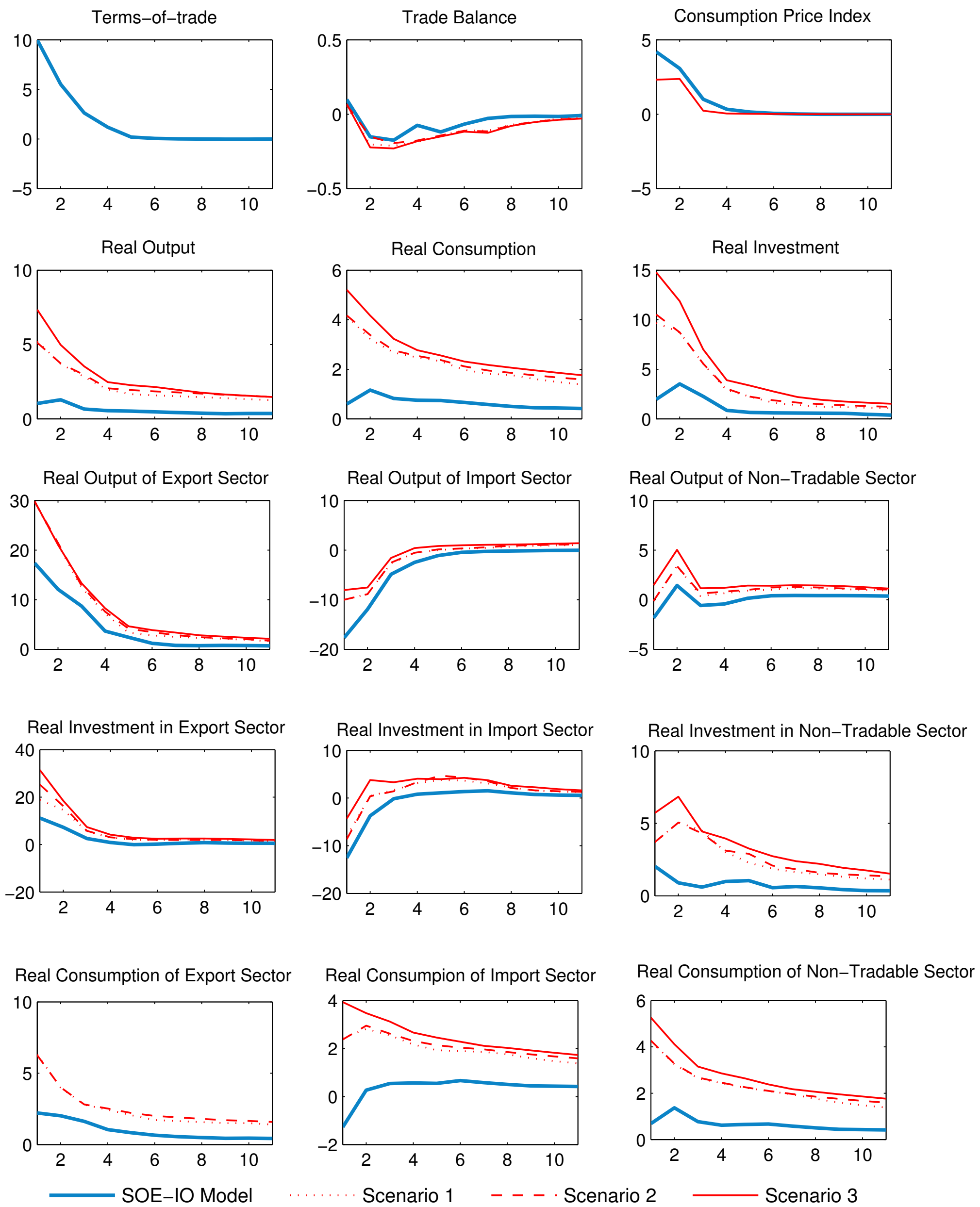

Figure 6: Theoretical impulse responses for different levels of use of exports

Note: Impulse responses are represented as point-by-point medians across countries for each scenario; scenario 1 being the one where exports are not employed as intermediates, scenario 2 being the one where exports are neither used as intermediate nore as capital goods, and scenario 3 being the one where export goods are not employed at all.

so far. Expressed differently, do the heterogenous reponses across countries discussed in the previous section depend significantly on the input-output structure of their economy ? One way to address this question is to consider once again the calibrated and estimated models for the 15 countries, and to analyze the effects of inter-changing their respective input-output structure. Table 6 recalls the median proportions of export goods used domestically (from Table 1) and presents two alternative scenarios in terms of input-output structure for each country: the first involves increasing proportions of export goods employed in the production system and consumed by households up to the same levels as Malaysia (sample maximum), and the second involves decreasing the proportions down to those of the Philippines (sample minimum).

Table 6: Domestic Use of Export goods (%)

	Sectors				
Country	M	X	N	Invest.	Cons.
Median	26	49	25	18	28
Scenario 1 (Malysia)	22	66	40	23	35
Scenario 2 (Philippines)	4	43	10	14	3

Figure 7 displays median impulse responses of the fitted SOE-IO model and the two scenarios of the simulation exercise for the enitre sample of countries. If all countries had an input-output structure comparable to the one of Malaysia, the growth cycle would be offset by the increase of domestic prices (on impact of a terms-of-trade shock of 10%, real output drops of -1.6%). The consumption price index for example increases above 2% (instead of 0.9%). On the opposite, if all countries had an input-output structure comparable to the one of Philippines, the predicted mediane growth rate of the sample would be this time around 5% in real terms. Hence, differences across countries in terms of production and global demand structures influence considerably the impact of terms-of-trade shocks. The comparision of theoretical and empirical shares of variance realized by Schmitt-Grohé and Uribe, 2018 should thus necessarily account for the country specific input-output structures. Figure 8 confirms this necessity. It shows that shares of variances can be drastically altered when assuming unconform economic structures.

The important role of the input-output structure can also be confirmed in a

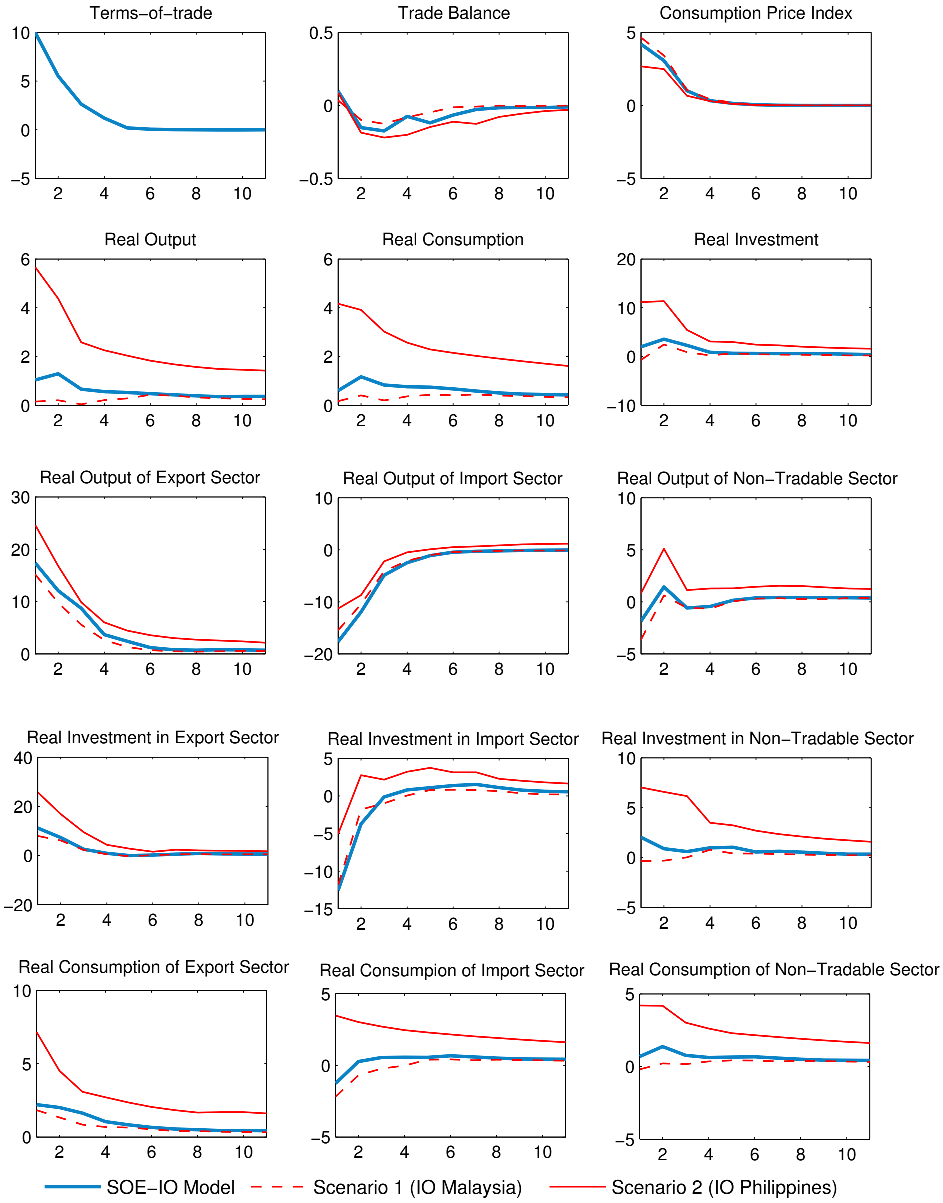

Figure 7: Theoretical impulse responses for different levels of use of exports

Note: Impulse responses are represented as point-by-point medians across countries for each scenario; scenario 1 assumes the input-output structure of Malaysia in each country, and scenario 2, the input-output structure of Philippines in each country.

simple way. The median response of output calculated over countries with a rate of domestic use of exports below the sample median of 29% (see Table 1) reaches a level of 1.6% on impact of a 10% terms-of-trade shock, whereas the median calculated for countries above 29% reaches only 0.7% on impact.

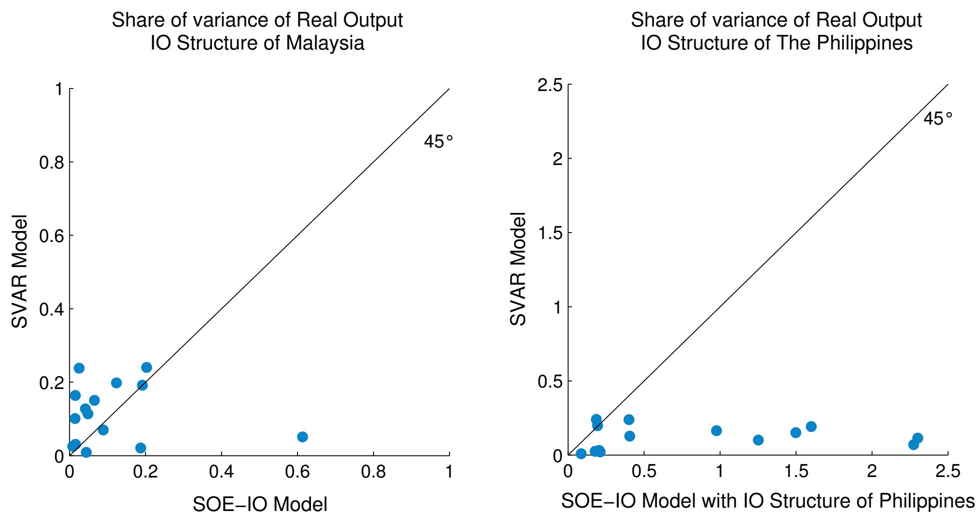

Figure 8: Comparison of Variances of Real GDP under input-output structures of Malaysia and Philippines

7 The role of the elasticity of substitution

This section presents a sensitivity analysis of results with respect to different degrees of elasticity of substitution between goods. Indeed, if the role of terms-of-trade shocks in explaining business cycles of an emerging country directly related to the global supply and demand structure of its economy, then it necessarily depends also upon the nature of the goods produced, employed as inputs and consumed. Specifically, the more goods are substitutes, the more a country can benefit from a price increase on world markets. A value of the degree of elasticity of substitution approaching zero for example, corresponds to the perfect complement case where the dampening effect of the input-output channel is maximal. On the opposite, an extremely high value corresponds to the perfect substitute case where the input-output structure does not influence the role of terms-of-trade shocks anymore.

The sample median of the degrees of elasticity of substitution has been reported previously to be 0.75. Departing from the calibrated and estimated models as in the previous section, I propose to simulate impulse responses for different values of the degree of elaticity of substitution, everything equal.

Results are displayed in Figure 9. The case of perfect of substitute goods consti-

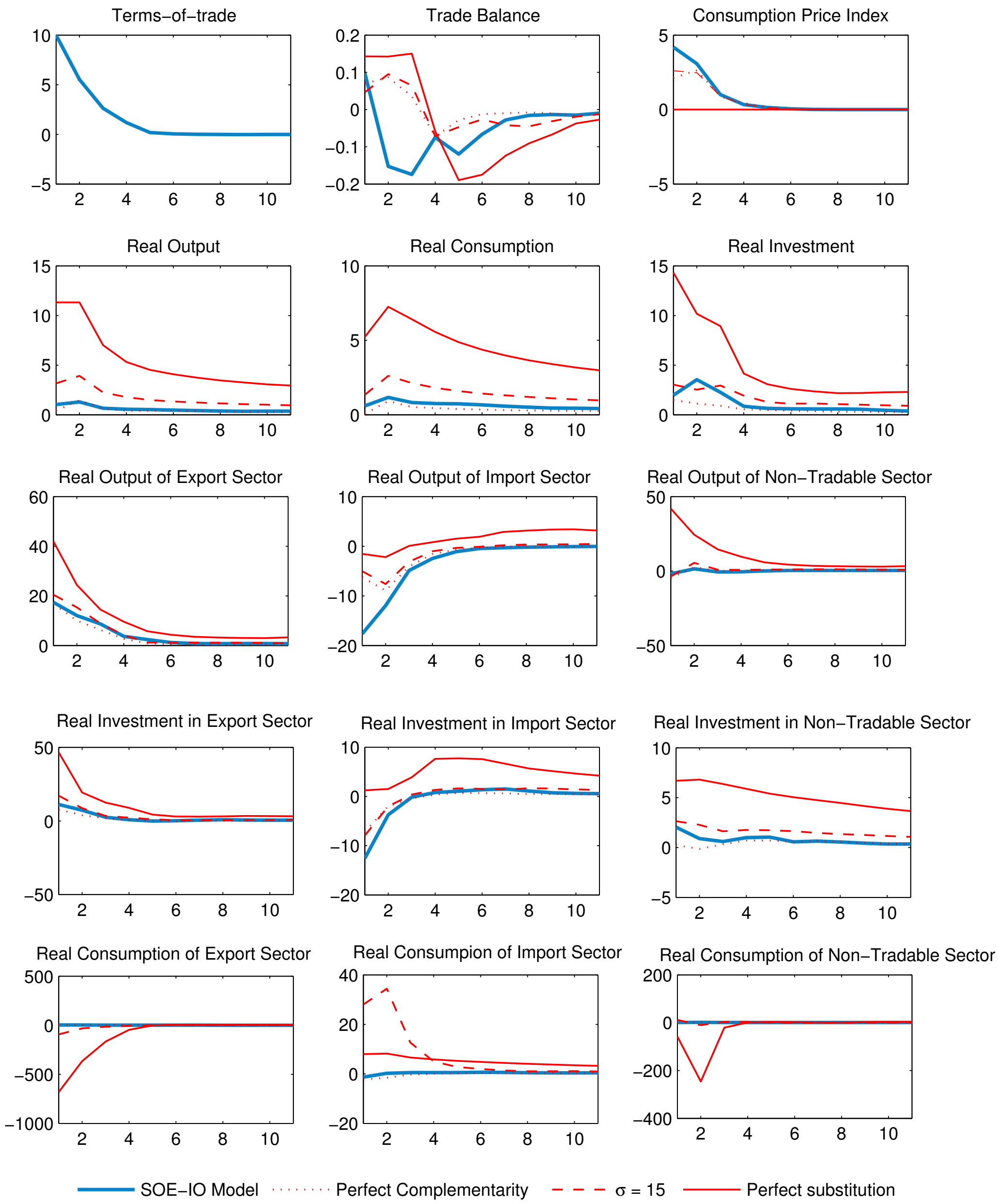

Figure 9: Theoretical impulse responses for different levels of use of exports

Note: Impulse responses are represented as point-by-point medians across countries for each scenario; the figure presents results of the model and results of simulations when changing the elasticity of substitution between goods.

tutes, as expected, the upper-bound limit of the economic expansion generated by a 10% terms-of-trade shock. Real output increases on impact by approximately 11%, which appears almost two times more than in the case studied previously under the assumption of no domestic absorption of export goods (scenario 3 in section 6.1).

Indeed, perfect substitution implies stable price indexes, whereas in the previous case of no absorption of export goods, the increase of the non-tradable price affects production and consumption costs. As regards the case of perfect complementarity, results appear close to median impulse responses of estimated models. The response of real output reaches 3.2% on impact when the degree of elasticity of substitution between goods is supposed equal to 15, hence, almost three times the growth impact obtained through the median response of countries.

8 Conclusion

This article extends the study of Schmitt-Grohé and Uribe, 2018 concerning the impacts of terms-of-trade shocks on business fluctuations of emerging and resource-limited countries. Indeed, it appears that theoretical and empirical predictions do not converge at the country-by-country level. This disconnect problem might be resolved either by dampening the theoretical effects of terms-of-trade shocks or by increasing the empirical effects related to shocks on world prices as proposed by Fernández, Schmitt-Grohé, and Uribe, 2017. In this paper, I focus on how to mitigate the theoretical overprediction of macroeconomic fluctuations in emerging and resource-limited countries following a price increase of their export goods on world markets. I study this question through an alternative multisector SOE model which can be calibrated on real input-output data with precision. This allows to better account for the structure of the domestic global demand, and to set the right level of domesic absorption of export goods (29% on average versus a calibration of only 5% in Schmitt-Grohé and Uribe, 2018). Depending indeed on how much a country uses its own export goods as intermediate, capital or consumption goods (under the hypothesis of imperfectly substitute goods), the growth effects of a terms-of-trade shock can either be dampened or amplified through the channel of production costs.

The proposed model appears to resolve the disconnect problem with theoretical impulse responses and shares of variances closer to the empirical results. It is then used to evaluate the role of the input-output structure regarding the hetergenous responses to terms-of-trade shocks across countries. The analysis confirms in several ways that accounting for the right specific input-output structure of an economy is fundamental to understand and measure the domestic impacts of shocks on export and import prices.

The proposed SOE model confirms the minor impacts of terms-of-trade shocks on macroeconomic fluctuations of emerging countries predicted by an SVAR model. It would be interesting to analyze what this SOE model teaches about the conclusions of Fernández, Schmitt-Grohé, and Uribe, 2017 concerning the greater impacts of shocks on commodity prices.

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9 Appendix

A1.Description of Data Sources

The paper uses the same data as Schmitt-Grohe and Uribe (2018) for the SVAR model, for instance World Bank's World Development Indicators (WDI) database. The raw data from this source consists of the following annual time series.

- Net barter terms of trade index (2000 = 100), TT.PRI,MRCH.XD.WD
- GDP per capita in constant local currency units, NY.GDP.PCAP.KN
- Gross capital formation (% of GDP), NE.GDI.TOTL.ZS
- Imports of goods and service (% of GDP), NE.IMP.GNFS.ZS
- Exports of goods and service (% of GDP), NE.EXP.GNFS.ZS
- Households consumption expenditure (% of GDP), NE.CON.PETC.ZS
- Consumer price index (2010 = 100), FP.CPI.TOTL.
- Official exchange rate (LCU per US dollars, period average), PA.NUS.FCRF
- Real effective exchange rate index (2005 = 100), PX.REX.REER.

The paper uses also input-output data of year 2000 to calibrate the SOE-IO model:

- OECD Input-Output Database is used for Argentina, Colombia, Costa-Rica, Peru, Malaysia, Morocco, The Philippines, Thailand, and South Africa.
- WIOD data for Brazil, India, Indonesia,South Korea, Mexico, and Turkey.

The study of correlations of prices indexes in section 2 uses data from:

- Penn World Tables for the export and consumption price index.
- WDI for the Wholesle price and Trading Economics for the Production price index

10 Appendix

A2.The empirical SVAR model: Estimated parameters

Table 7: The joint law of motion of the terms of trade and interest spread: Parameter estimates of SGU (2018)

Country	a_{11}	a_{12}	a_{21}	a_{22}	π_{11}	π_{21}	π_{22}
Argentina	0.3932	0.7545	-0.0204	0.5429	0.0783	0.0033	0.0127
Brazil	0.6094	1.5689	-0.0457	0.4277	0.0802	-0.0014	0.0124
Columbia	0.2898	0.6119	0.0002	0.5269	0.0818	-0.0016	0.0132
Costa Rica	0.5664	1.3821	-0.0457	0.4918	0.0695	-0.0007	0.0126
India	0.6051	1.6957	-0.0170	0.5401	0.0858	0.0004	0.0131
Indonesia	0.5654	-1.0671	0.0220	0.4588	0.1066	0.0002	0.0127
Korea	0.6595	1.2577	-0.0717	0.5465	0.0414	0.0013	0.0126
Malaysia	0.4990	0.6063	-0.0236	0.5327	0.0533	0.0019	0.0130
Mexico	0.7450	-1.6568	0.0106	0.5461	0.0876	-0.0018	0.0131
Morocco	0.4358	-0.5860	-0.0034	0.5293	0.0609	0.0045	0.0125
Peru	0.5444	0.4493	-0.0395	0.4433	0.0842	-0.0030	0.0124
Philippines	0.5452	0.5154	-0.0346	0.4725	0.0832	0.0009	0.0127
South Africa	0.7374	0.9740	-0.0486	0.5276	0.0376	0.0019	0.0128
Thailand	0.6171	1.2616	-0.1072	0.4672	0.0352	-0.0006	0.0120
Turkey	0.3270	0.6590	-0.0523	0.5190	0.0445	-0.0004	0.0130
Median	0.5654	0.6590	-0.0346	0.5269	0.0783	0.0002	0.0127
Med Abs Dev.	0.0664	0.5987	0.0176	0.0192	0.0093	0.0016	0.0003

A3. The theoretical model:Calibrated and estimated parameters

Table 8: Sector shares by country

Country	$\rho*$	s_m	s_x	s_n
Argentina	5.9	21	29	49
Brazil	1.9	30	17	53
Colombia	5.7	14	36	51
Costa Rica	15	30	35	35
India	4	19	31	50
Indonesia	15	13	35	51
Korea	8.5	20	30	50
Malaysia	15	31	45	25
Mexico	5.8	19	31	50
Morocco	15	38	21	42
Peru	10	27	26	48
Philippines	14	40	11	49
Sth Africa	14	15	36	50
Thailand	15	22	37	41
Turkey	17	23	26	51
Average	10.8	24.1	30.3	45.9
Std Dev.	5.1	8.2	8	7.3

Note: Sector size s_m, s_x, and s_n are all expressed in percentage.

Table 9: Country specific calibrated parameters

Country	$D*$	B_m	B_x	B_n	θ_m	θ_x	θ_n
Argentina	0.2	1.65	2.04	2.05	53	48	28
Brazil	0.23	2.02	1.85	2.2	58	56	42
Colombia	0.22	1.67	1.98	2.15	58	46	35
Costa Rica	0.16	1.87	1.79	1.87	47	56	31
India	0.16	1.69	1.91	2.05	51	52	38
Indonesia	0.06	1.48	1.63	1.65	61	52	41
Korea	0.07	1.6	1.75	1.8	59	65	42
Malaysia	0.036	1.59	1.63	1.50	59	69	50
Mexico	0.11	1.6	1.83	1.72	60	45	28
Morocco	0.19	1.89	1.87	1.92	47	59	31
Peru	0.16	1.85	1.78	2.06	45	62	37
Philippines	0.17	1.98	1.5	2.04	55	70	33
Sth Africa	0.15	1.7	1.82	2.07	64	60	47
Thailand	0.1	1.75	1.77	1.9	61	61	42
Turkey	0.13	1.65	1.95	1.98	53	60	47
Average	0.14	1.7	1.9	1.9	55	57	38
Std Dev.	0.06	0.1	0.1	0.2	5.9	7.9	7.2

Table 10: Share of final consumption

Country	ω_m^C	ω_x^C	ω_n^C	C^*/Y^*
Argentina	25	25	50	0.87
Brazil	24	20	56	0.85
Colombia	20	30	50	0.9
Costa Rica	35	26	40	0.79
India	14	36	50	0.82
Indonesia	20	23	57	0.58
Korea	18	18	64	0.63
Malaysia	25	34	41	0.51
Mexico	27	20	53	0.72
Morocco	27	30	43	0.82
Peru	22	20	58	0.82
Philippines	45	5	50	0.86
South Africa	13	31	56	0.82
Thailand	17	34	49	0.71
Turkey	26	21	54	0.75

Table 11: Shares of investment

Country	ω_m^I	ω_x^I	ω_n^I
Argentina	26	11	63
Brazil	19	20	61
Colombia	24	12	65
Costa Rica	32	65	3
India	20	19	61
Indonesia	21	3	77
Korea	14	29	57
Malaysia	33	22	44
Mexico	10	27	63
Morocco	48	5	48
Peru	37	1	62
Philippines	35	15	50
South Africa	29	22	48
Thailand	32	25	43
Turkey	31	11	57

Table 12: Shares of intermediate consumption

Country	$\omega_m^{V_m}$	$\omega_x^{V_m}$	$\omega_x^{V_m}$	$\omega_m^{V_x}$	$\omega_x^{V_x}$	$\omega_n^{V_x}$	$\omega_m^{V_n}$	$\omega_x^{V_n}$	$\omega_n^{V_n}$
Argentina	25	56	19	46	33	21	35	25	40
Brazil	33	48	19	63	19	18	43	21	36
Colombia	25	56	19	46	33	21	27	18	55
Costa Rica	54	38	8	63	11	26	39	30	30
India	25	42	33	56	28	17	30	27	43
Indonesia	16	40	44	39	28	33	30	30	39
Korea	25	63	13	60	22	18	29	26	45
Malaysia	33	66	1	22	67	11	37	39	24
Mexico	33	48	19	57	29	14	39	24	37
Morocco	47	41	12	75	11	14	63	21	17
Peru	29	42	29	66	9	25	34	19	47
Philippines	50	42	8	71	5	24	65	10	25
South Africa	22	54	24	35	38	27	19	31	50
Thailand	26	53	21	61	30	9	34	38	28
Turkey	26	57	17	51	27	22	25	23	52

Table 13: Country specific estimates

Country	ϕ_m	ϕ_x	ϕ_n	ψ	σ	ρ_n	π^n	π^n_{lag}	ρ_ξ	π^ξ
Argentina	2.12	1.08	2.04	5.13	0.95	0.05	0.05	0.05	0.54	-0.21
Brazil	8.02	0.13	7.95	7.11	0.95	0.1	0.09	0.03	0.99	-0.02
Colombia	15.5	2.26	0.1	5	0.5	0.35	0.02	0.03	0.995	0.01
Costa	10.79	15.65	10.41	0.31	0.25	0.31	-0.05	-0.01	0.975	-0.005
India	4.05	3.98	4	25	0.75	0.51	0.045	0.03	0.65	0.05
Indonesia	24.1	25.78	25.08	4.95	0.2	0	0.06	0.02	0.88	0.05
Korea	24.87	25.02	23.56	0.25	0.1	0.45	0	0.03	0.85	-0.015
Malaysia	44.78	4.2	43.1	15	0.15	0.3	0.07	0	0.5	0.045
Mexico	24.1	25.1	25.61	10	0.95	0.05	0.03	0.03	0.51	-0.02
Morocco	4.02	1.1	3.95	4.06	0.95	0.05	-0.015	-0.015	0.5	-0.02
Peru	0.6	4	0.45	5	0.95	0.9	0.015	0.015	0.95	0.06
Philippines	4.21	2.1	1.94	10	0.95	0.95	-0.01	0.045	0.9	0.05
South Africa	1.95	10	4.1	2.02	0.2	0.1	0.03	0.005	0.99	0.02
Thailand	15.62	14.16	4.5	10	0.95	0.99	-0.03	-0.02	0.99	-0.04
Turkey	0.5	0.11	0.1	15	0.5	0.15	0.03	0	0.71	-0.02
Mediane	8.02	4	4.1	5.13	0.75	0.3	0.03	0.02	0.88	-0.1

Note: Parameters are computed using the CMA-ES and Csminwel algorithm. Interval bounds are constrained to [0.01, 50]. Remind also that $\sigma_{CES} = \sigma_C = \sigma_I = \sigma_V$, $\forall j = m, x, n$.

A6. The theoretical model: Resolution

Producers

The production function is given by:

$$Q_{jt} = B_{jt}[K_j(X_t)^{\alpha}(A_t L_{jt})^{1-\alpha}]^{1-\theta} V_j(X_t)^{\theta} \tag{24}$$

where Q_{jt}, $V_j(X_t)$, $K_j(X_t)$, and L_{jt} denote respectively gross production, aggregate intermediate consumption, aggregate fixed capital, and labor employed by sector j at time t. The level of aggregate capital and intermediate consumption in each sector is expressed as a function of quantities of goods produced in the economy $X_t = (X_{mt}, X_{xt}, X_{nt})$. Producers chose $V_j(X_t)$, $K_j(X_t)$, and L_{jt} so as to maximize:

$$\Pi_{jt} = p_{jt}Q_{jt} - u_{jt}K_j(X_t) - w_{jt}L_{jt} - P_t^{V_j}V_j(X_t)$$

where u_{jt} denotes the capital remuneration rate paid by sector j, $P_t^{V_j}$ is the price index of the intermediate good basket used by sector j, w_{jt} is the wage rate paid, and p_{jt} denotes the price of good j at time t. The first-order conditions of the Producer are given by:

$$p_{jt}Q_{jK}[K_j(X_t), L_{jt}, V_j(X_t)] = u_{jt} \tag{25}$$

$$p_{jt}Q_{jL}[K_j(X_t), L_{jt}, V_j(X_t)] = w_{jt} \tag{26}$$

$$p_{jt}Q_{jV}[K_j(X_t), L_{jt}, V_j(X_t)] = P_t^{V_j} \tag{27}$$

Households

Households maximize the following objective function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{[C_t - G(L_{mt}, L_{xt}, L_{nt})]^{(1-\gamma)} - 1}{1-\gamma} \tag{28}$$

where C_t is given by:

$$C_t = (\zeta_m C_{mt}^{\rho} + \zeta_x C_{xt}^{\rho} + \zeta_n C_{nt}^{\rho})^{1/\rho} \tag{29}$$

and where:

$$G(L_{mt}, L_{xt}, L_{nt}) = \frac{L_{mt}^{\tau_m}}{\tau_m} + \frac{L_{xt}^{\tau_x}}{\tau_x} + \frac{L_{nt}^{\tau_n}}{\tau_n} \tag{30}$$

Simplifying notations with $K_{jt} = K_j(X_t)$ and $I_{jt} = I_j(X_t)$, the sequential budget constraint is defined as:

$$P_t^C C_t + \sum_j P_t^{I_j} I_{jt} + \phi_j(K_{jt+1} - K_{jt}) = \frac{\epsilon_{t+1} D_{t+1}}{1 + r_t} - \epsilon_t D_t + \sum_j u_{jt} K_{jt} + w_{jt} L_{jt}, \tag{31}$$

The law of motion for capital K_{jt} is given by:

$$K_{jt+1} = (1 - \delta) K_{jt} + I_{jt} \tag{32}$$

This equation is to be substituted in the previous sequential budget constraint.

Derivation of first order conditions:

First order conditions with respect to consumption:

$$\frac{U_C(C_t, L_{mt}, L_{xt}, L_{nt})}{P_t^C} = \lambda_t \tag{33}$$

where U_C refers to the marginal utility of consumption C_t. First order conditions with respect to labor L_{jt}:

$$-U_{L_j}(C_t, L_{mt}, L_{xt}, L_{nt}) = \lambda_t w_{jt} \tag{34}$$

which means

$$L_j^{\tau_j - 1} = \frac{w_{jt}}{P_t^C} \tag{35}$$

First order conditions with respect to external debt:

$$\lambda_t \xi_t = \beta(1 + r_t) E_t \lambda_{t+1} \xi_{t+1} \tag{36}$$

First order conditions with respect to capital K_{jt+1}, $\forall j = m, x, n$:

$$\lambda_t [P_t^{I_j} + \phi_j(K_{jt+1} - K_{jt})] = \beta E_t \lambda_{t+1} [u_{jt+1} + (1 - \delta) P_{t+1}^{I_j} + \phi_j(K_{jt+2} - K_{jt+1})] \tag{37}$$

At this step the steady-state equilibruim value of K^*, C^*, Y^* and I^* are conditionnal on values of P_t^C and $P_t^{I_j}$. In other words, if index prices are known, then steady-state values of macro variables can be easily solved for.

Intra-temporal General equilibrium:

During eah period t, the following system of equation holds.

$$\omega_{it}^C P_t^C C_t + \sum_j \omega_{it}^{I_j} P_t^{I_j} I_{jt} + \sum_j \omega_{it}^{V_j} P_t^{V_j} V_{jt} + NX_{it} = p_{it} Q_{it} \tag{38}$$

for $i, j = m, x, n$. The amount NX_{it} denotes net exports of good i at time t, and ω_{it}^C, $\omega_{it}^{I_j}$, and $\omega_{it}^{V_j}$ denote respecively optimal budget shares of final consumption, investment, and interemdiate consumption spent on good i. Letting $C(X_t)$, $I_j(X_t)$, and $V_j(X_t)$ be given by a CES Argminton aggregator, Armington, 1969), and assuming that $I_j(X_t)$ is the same $\forall j$:

$$C_t = (\zeta_m C_{mt}^\rho + \zeta_x C_{xt}^\rho + \zeta_n C_{nt}^\rho)^{1/\rho} \tag{39}$$

where C_{mt} is the domestic quantity of consumption of the import good (note that C_{mt} is more convenient than $C(X_{mt})$)

$$I_t = (\kappa_m I_{mt}^\rho + \kappa_x I_{xt}^\rho + \kappa_n I_{nt}^\rho)^{1/\rho} \tag{40}$$

$$V_j t = \left(\nu_{mj} V_j(X_{mjt})^\rho + \nu_{xj} V_j(X_{xjt})^\rho + \nu_{nj} V_j(X_{njt})^\rho\right)^{1/\rho}, \tag{41}$$

Households chose C_{mt}, C_{xt}, C_{nt} which maximize C_t, or equation (39) under the budget constraint:

$$p_{mt} C_{mt} + p_{xt} C_{xt} + p_{nt} C_{nt} = P_t^C C_t \tag{42}$$

Households chose I_{mt}, I_{xt}, I_{nt} which maximize I_t under the budget constraint:

$$p_{mt} I_{mt} + p_{xt} I_{xt} + p_{nt} I_{nt} = P_t^I I_t \tag{43}$$

Households chose $V_j(X_{mjt})$, $V_j(X_{xjt})$, and $V_j(X_{njt})$ which maximize $V_j t$, $\forall j = m, x, n$ under the budget constraint:

$$p_{mt} V_j(X_{mjt}) + p_{xt} V_j(X_{xjt}) + p_{nt} V_j(X_{njt} = P_t^{V_j} V_j t \tag{44}$$

It will be shown next that maximizing (39), (40), and (41), with respect to (42), (43), and (44) gives:

$$P_t^C = \left(\sum_i \zeta_i^\sigma p_{it}^{1-\sigma_C}\right)^{1/(1-\sigma)} \quad \omega_{it}^C = \zeta_i^\sigma \left(\frac{P_t^C}{p_{it}}\right)^\sigma, \tag{45}$$

$$P_t^{I_j} = \left(\sum_i \kappa_{ij}^{\sigma_{I_j}} p_{it}^{1-\sigma}\right)^{1/(1-\sigma)} \quad \omega_{it}^{I_j} = \kappa_i^\sigma \left(\frac{P_t^{I_j}}{p_{it}}\right)^\sigma, \tag{46}$$

and

$$P_t^{V_j} = \left(\sum_i \nu_{ij}^{\sigma_{V_j}} p_{it}^{1-\sigma}\right)^{1/(1-\sigma)} \quad \omega_{it}^{V_j} = \nu_{ij}^\sigma \left(\frac{P_t^{V_j}}{p_{it}}\right)^\sigma, \tag{47}$$

where ω_{it}^C, ω_{it}^I, and $\omega_{it}^{V_j}$ represent optimal shares of respective budgets $P_t^C C_t$, $P_t^I I_t$, and $P_t^{V_j} V_j t$ and where $\sigma = \frac{1}{1-\rho}$. We can now solve for all steady-state variables and deduce values of NX_i^* so that the system of equations 38 is satisfied.

Derivation of the consumption price index:

Let λ_t be the lagrange multiplier. The first order condition with respect to C_{kt} $\forall k = m, x, n$ is:

$$[C_t - G(L_{mt}, L_{xt}, L_{nt})]^{(-\gamma)} \left(\sum_{i=m,x,n} \zeta_i C_{it}^{\rho} \right)^{1/\rho - 1} \gamma_k c_{kt}^{\rho-1} = \lambda_t p_{kt} \tag{48}$$

If I let:

$$\xi_t = \lambda_t [C_t - G(L_{mt}, L_{xt}, L_{nt})]^{\gamma}$$

then, I obtain same conditions as those of the standard static optimzation program of the consumer with a CES utility function. We have:

$$\left(\sum_i \zeta_i C_{it}^{\rho} \right)^{1/\rho - 1} \zeta_k c_{kt}^{\rho-1} = \xi_t p_{kt} \tag{49}$$

Multiplying this condition by c_{kt} and summing over k gives:

$$\left(\sum_{i=m,x,n} \zeta_i C_{it}^{\rho} \right)^{1/\rho - 1} \sum_{k=m,x,n} \zeta_k c_{kt}^{\rho} = \xi_t \sum_{k=m,x,n} p_{kt} c_{kt}$$

which means:

$$C_t = \xi_t P_t^C C_t$$

or,

$$\frac{1}{\xi_t} = P_t^C$$

We thus need to solve equation (40) for ξ_t. We can rewrite this equation as:

$$c_{kt}^{\rho-1} = \frac{1}{\zeta_k} \xi_t p_{kt} (\sum_i \zeta_i C_{it}^{\rho})^{1-1/\rho}$$

We then raise each side to the power $\frac{\rho}{\rho-1}$ and multiply by ζ_k to obtain:

$$\zeta_k c_{kt}^{\rho} = \xi_t^{\frac{\rho}{\rho-1}} \zeta_k^{\frac{-1}{\rho-1}} p_{kt}^{\frac{\rho}{\rho-1}} (\sum_i \zeta_i C_{it}^{\rho})$$

Summing now over k gives the consumption price index:

$$P_t^C = \left(\sum_i \zeta_i^{\frac{1}{1-\rho}} P_{it}^{\frac{-\rho}{1-\rho}} \right)^{\frac{\rho-1}{\rho}}$$

A5. The role of the exchange rate regime

Responses to terms-of-trade shocks should differ according to the exchange rate regime of a country. Precisely, under a flexible exchange regime, external shocks should be damped through the equilibrium adjustment mechanism. In other words, the volatility of macro variables in response to external shocks should be attenuated. Figue 10 illustrates this phenomenon. Countries with a fixed exchange rate tend to experience large fluctuations around the equilibrium with a more persisten impact.

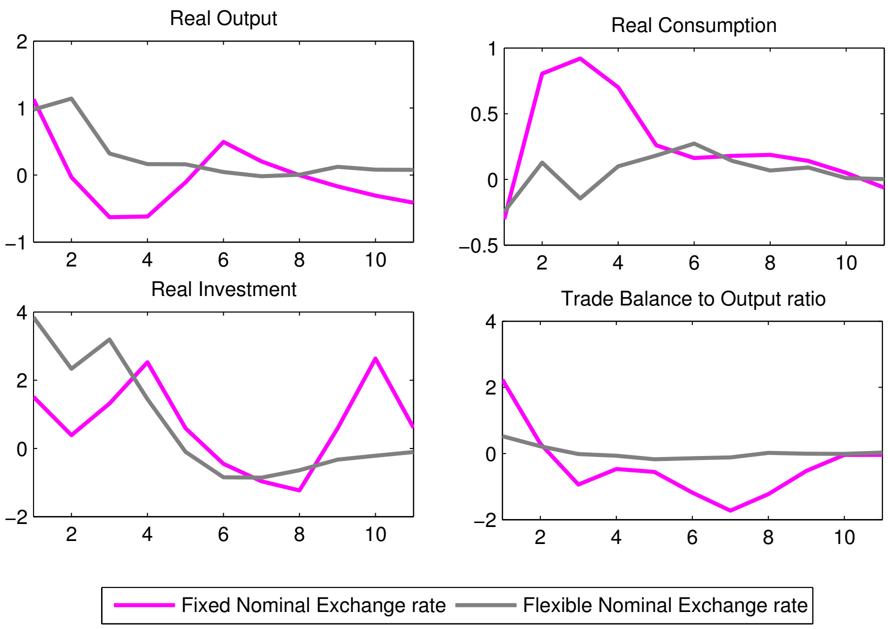
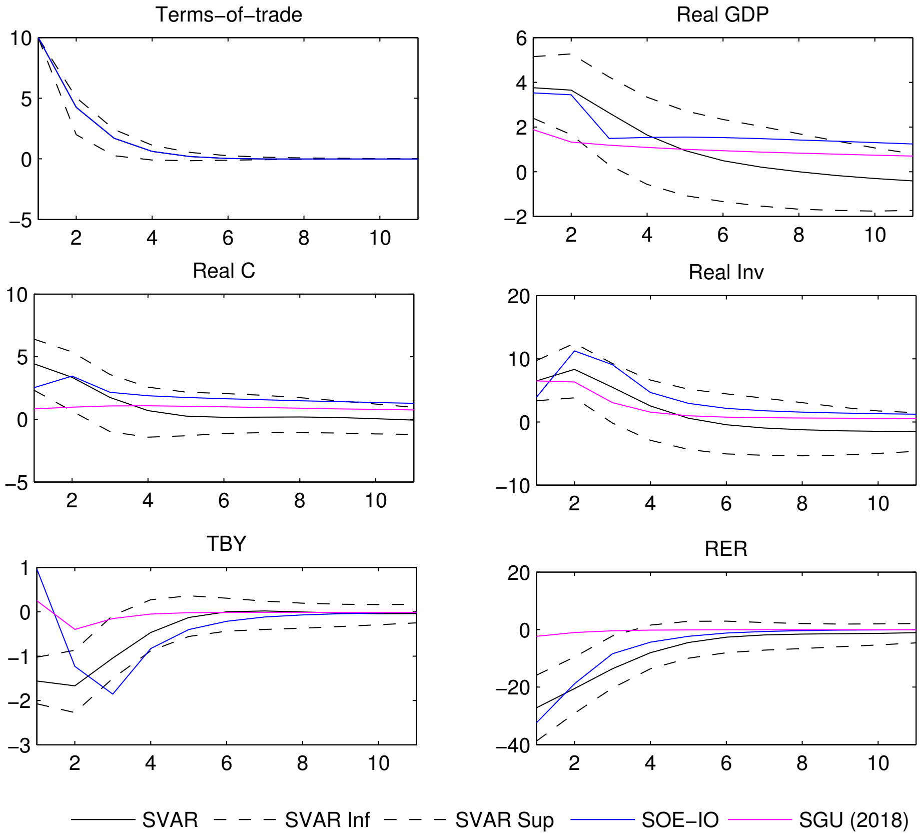


Figure 10: SVAR Impulse responses : Role of the exchange rate regime

Note: Impulse responses are represented as point-by-point medians across countries (which are classified according o their respective exchange rate regime). Fixed exchange rate countries over the period are Argentina, Malaysia and Thailand. Impulse responses are generated by a 10% terms-of-trgade shock.

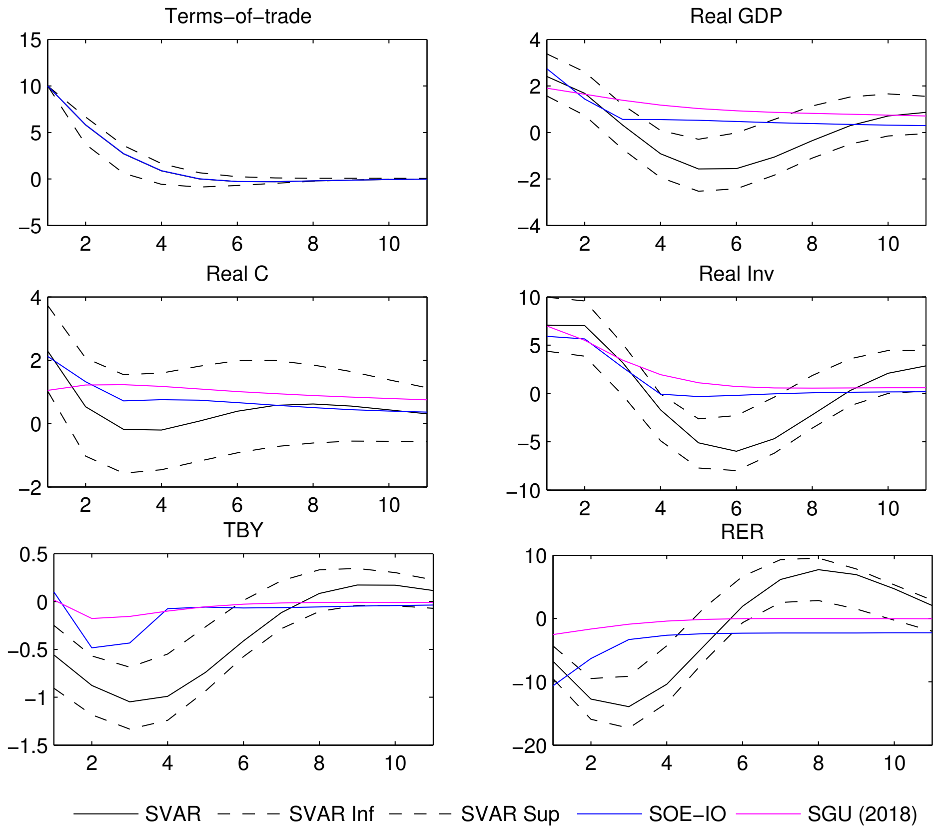
A7. Country-by-country impulse responses

Figure 11: Impulse Responses of the Models : Argentina



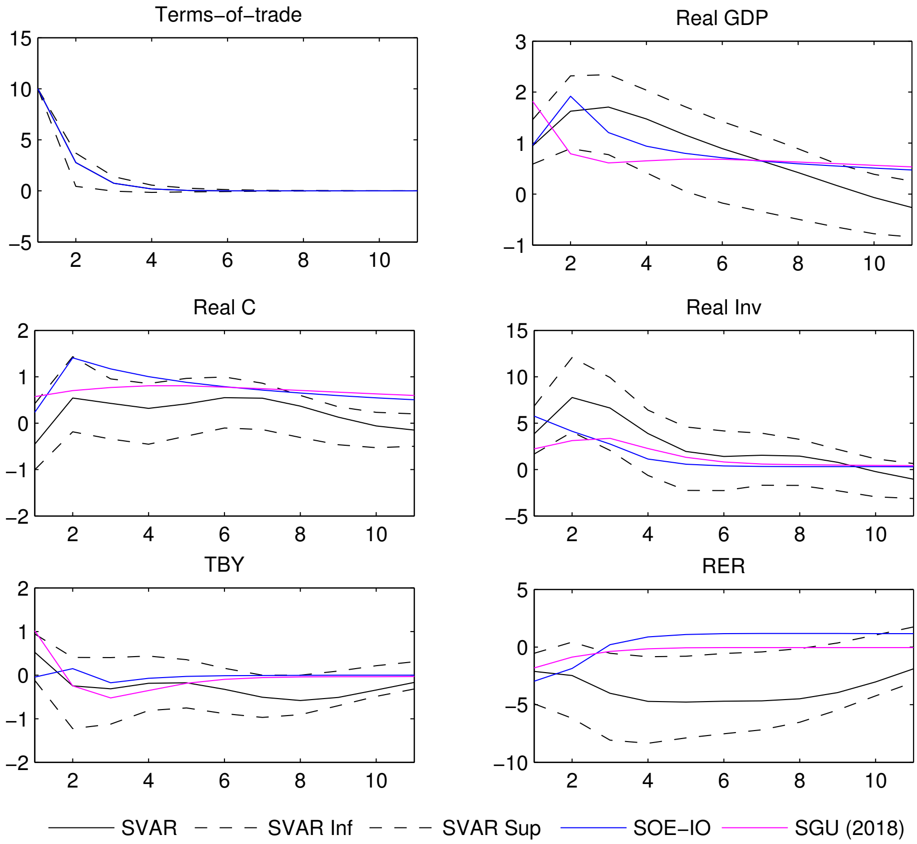
Note: Dashed lines correspond to the 66% confidence band.

Figure 12: Impulse Responses of the Models : Brazil



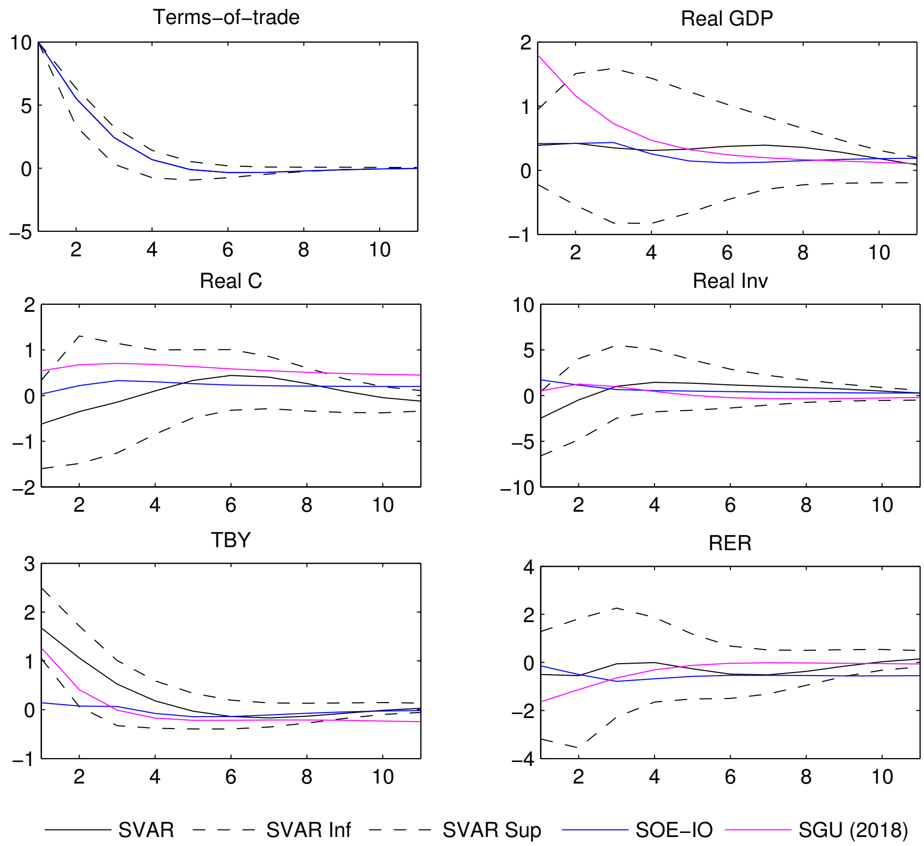
Note: Dashed lines correspond to the 66% confidence band.

Figure 13: Impulse Responses of the Models : Colombia



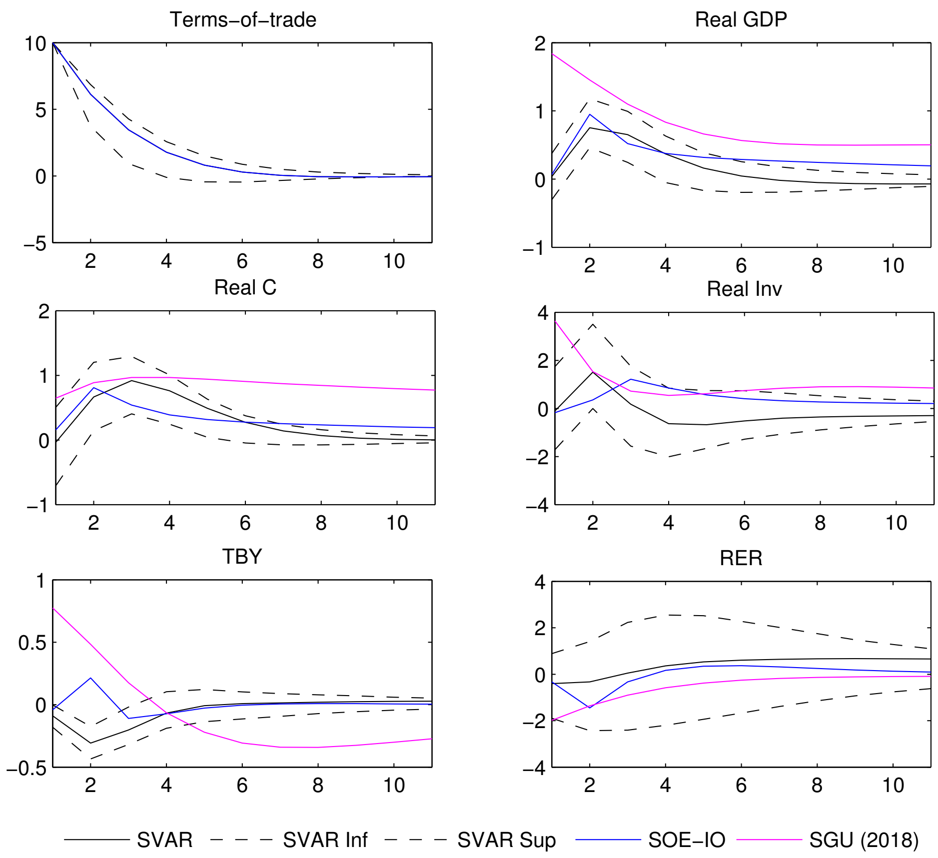
Note: Dashed lines correspond to the 66% confidence band.

Figure 14: Impulse Responses of the Models : Costa Rica



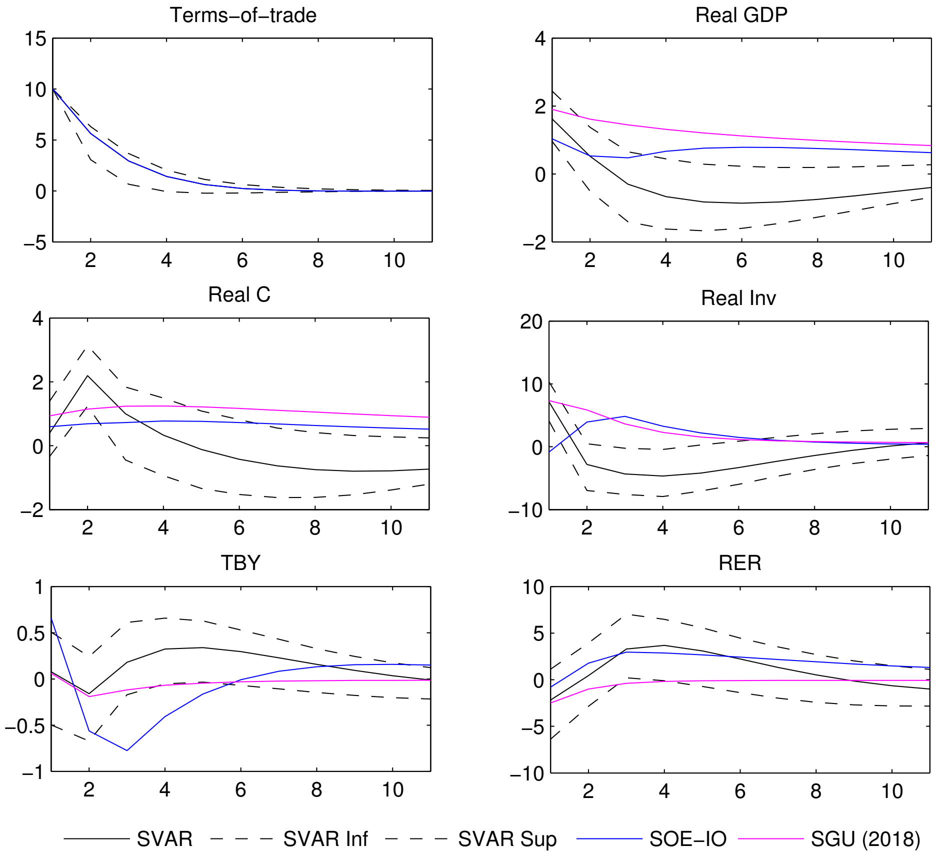
Note: Dashed lines correspond to the 66% confidence band.

Figure 15: Impulse Responses of the Models : India



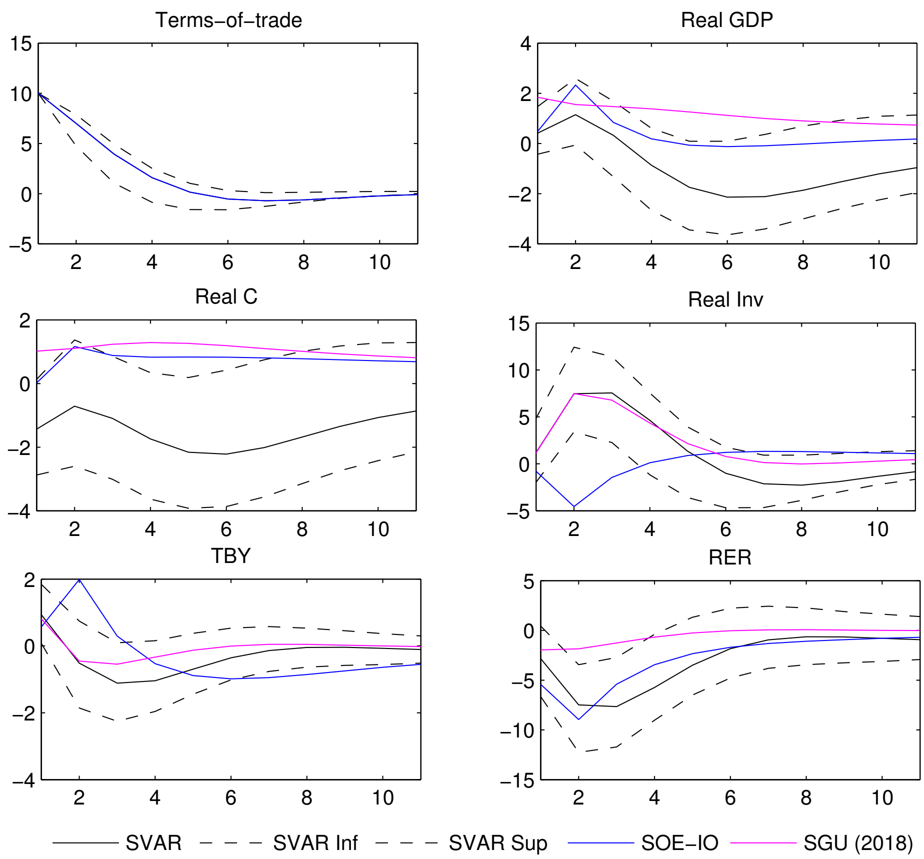
Note: Dashed lines correspond to the 66% confidence band.

Figure 16: Impulse Responses of the Models : Indonesia



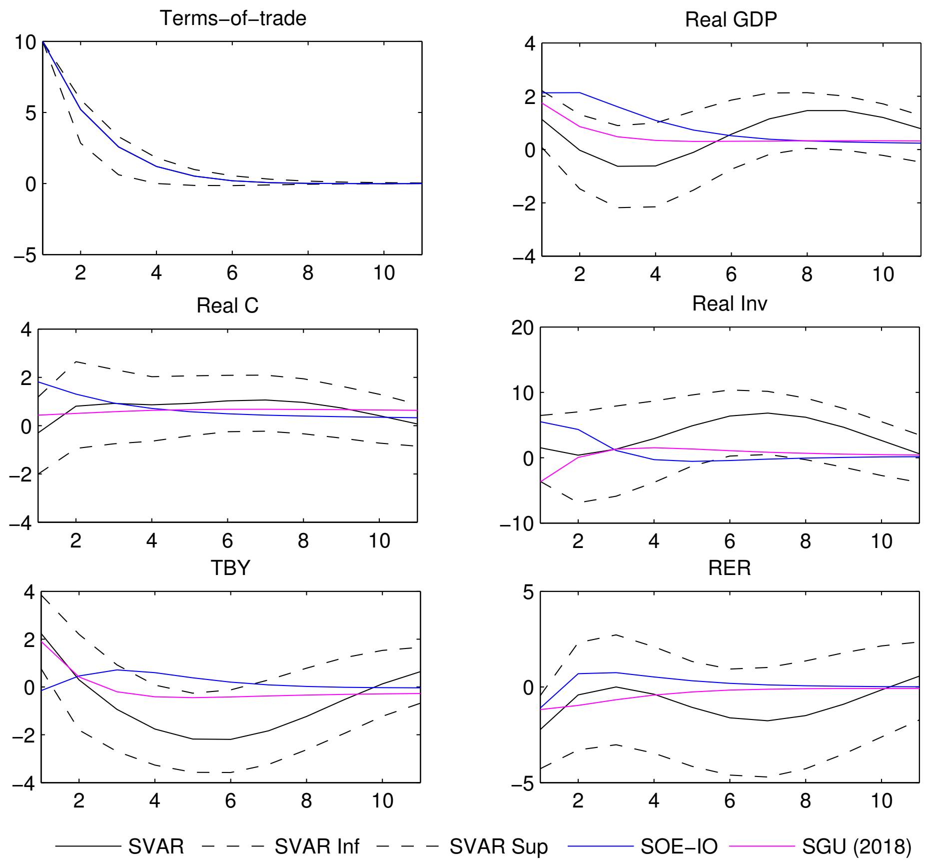
Note: Dashed lines correspond to the 66% confidence band.

Figure 17: Impulse Responses of the Models : South Korea



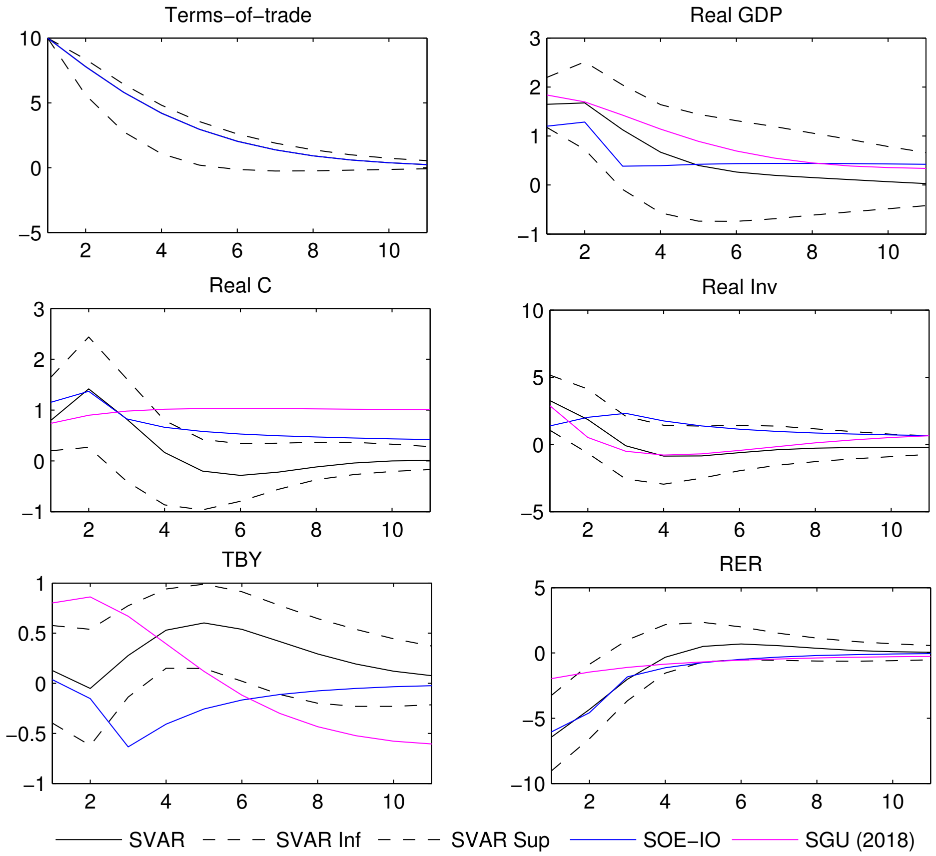
Note: Dashed lines correspond to the 66% confidence band.

Figure 18: Impulse Responses of the Models : Malaysia



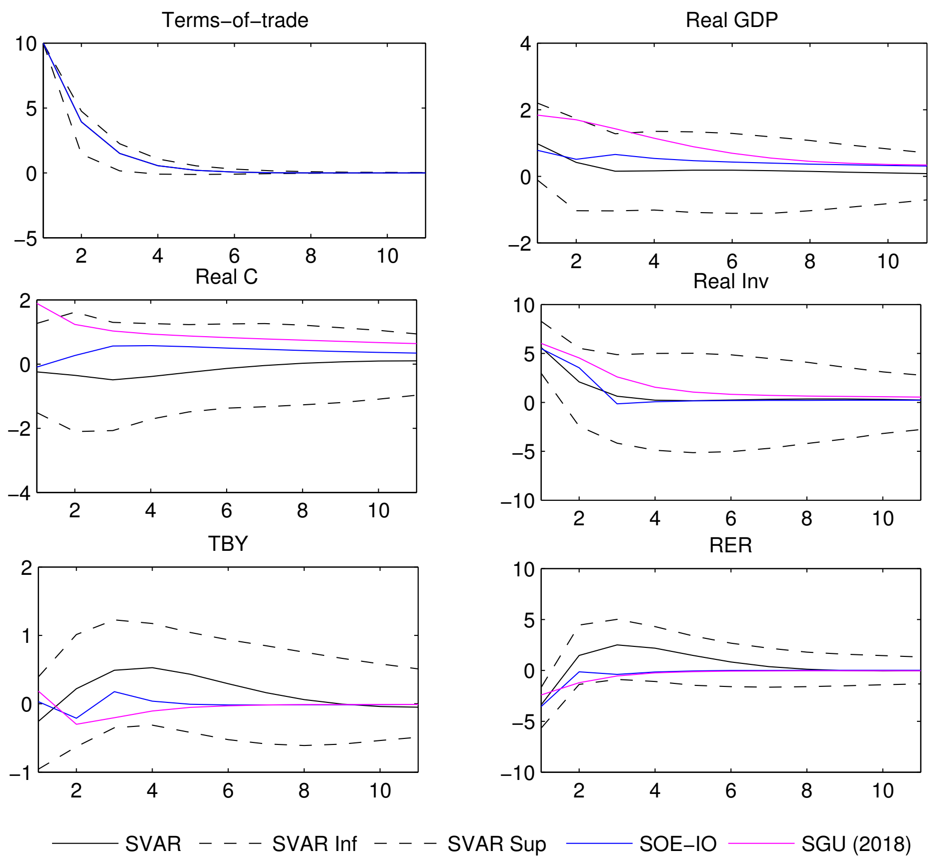
Note: Dashed lines correspond to the 66% confidence band.

Figure 19: Impulse Responses of the Models : Mexico



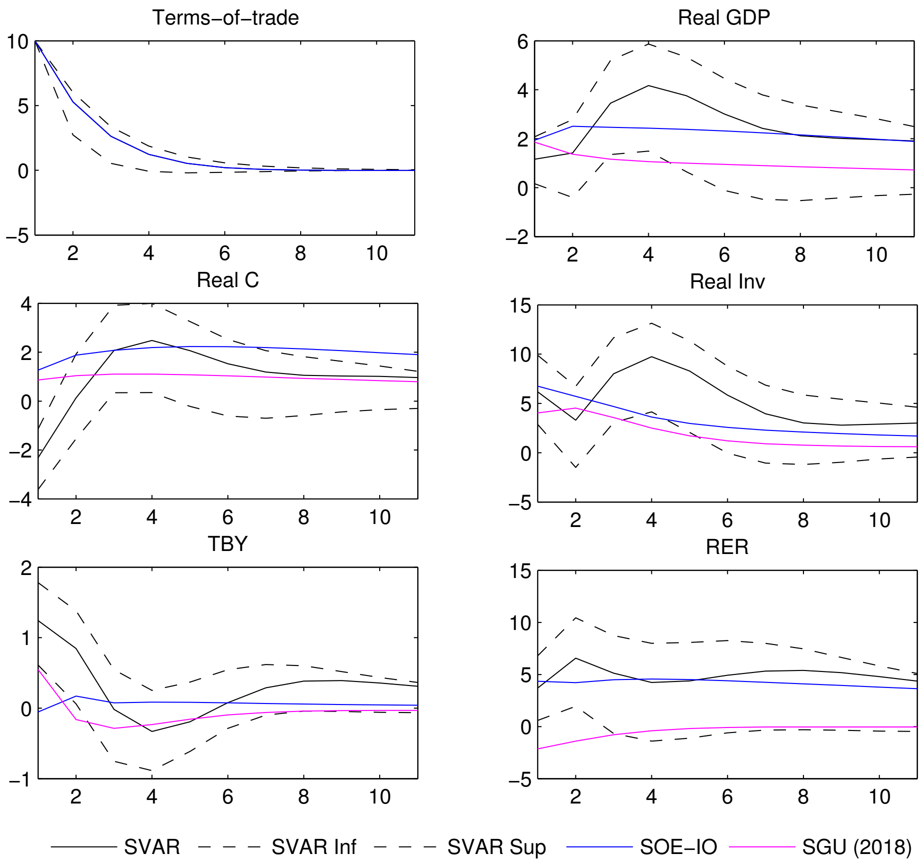
Note: Dashed lines correspond to the 66% confidence band.

Figure 20: Impulse Responses of the Models : Morocco



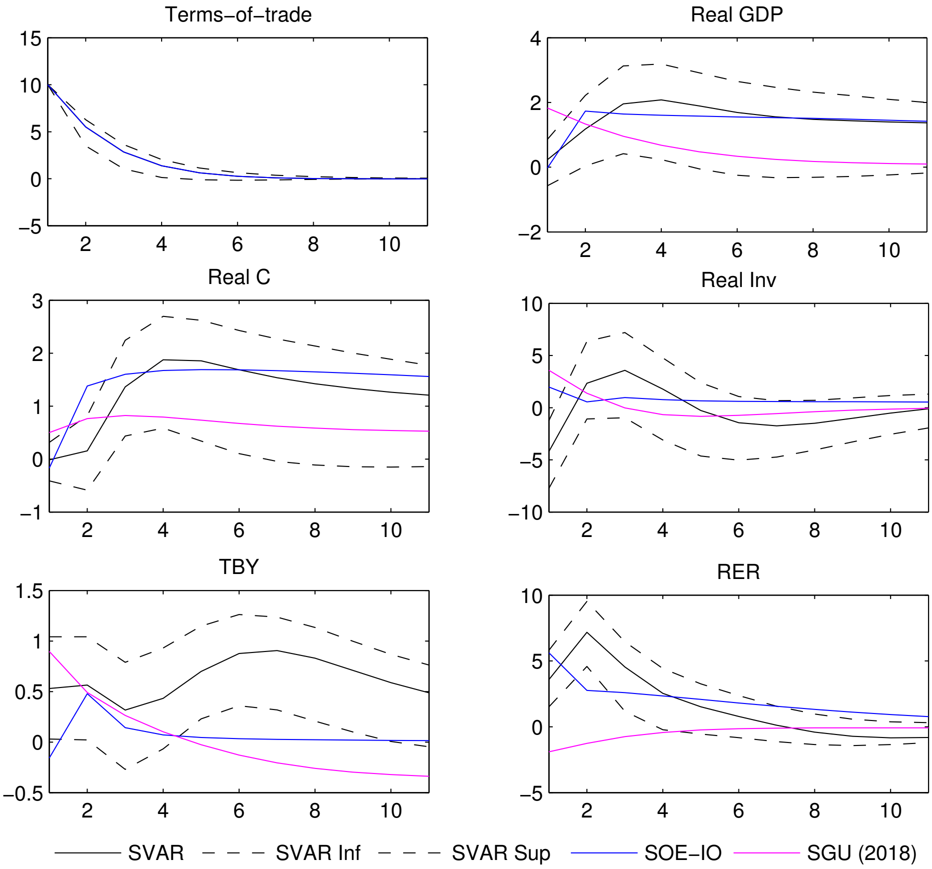
Note: Dashed lines correspond to the 66% confidence band.

Figure 21: Impulse Responses of the Models : Peru



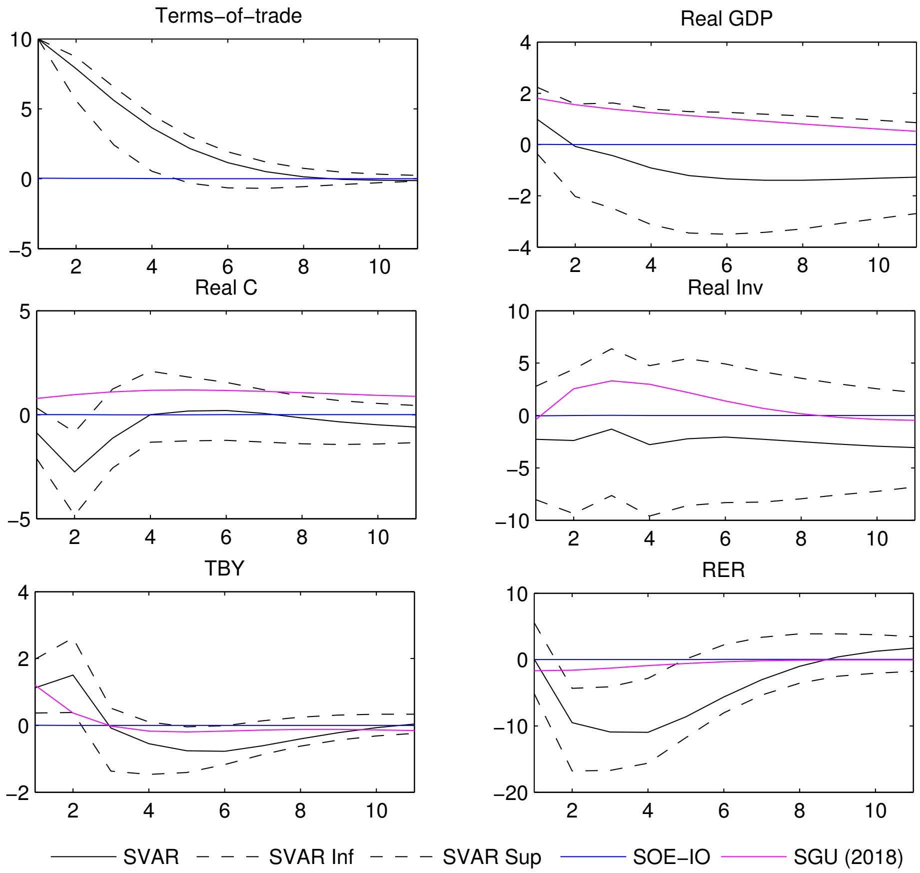
Note: Dashed lines correspond to the 66% confidence band.

Figure 22: Impulse Responses of the Models : The Philippines



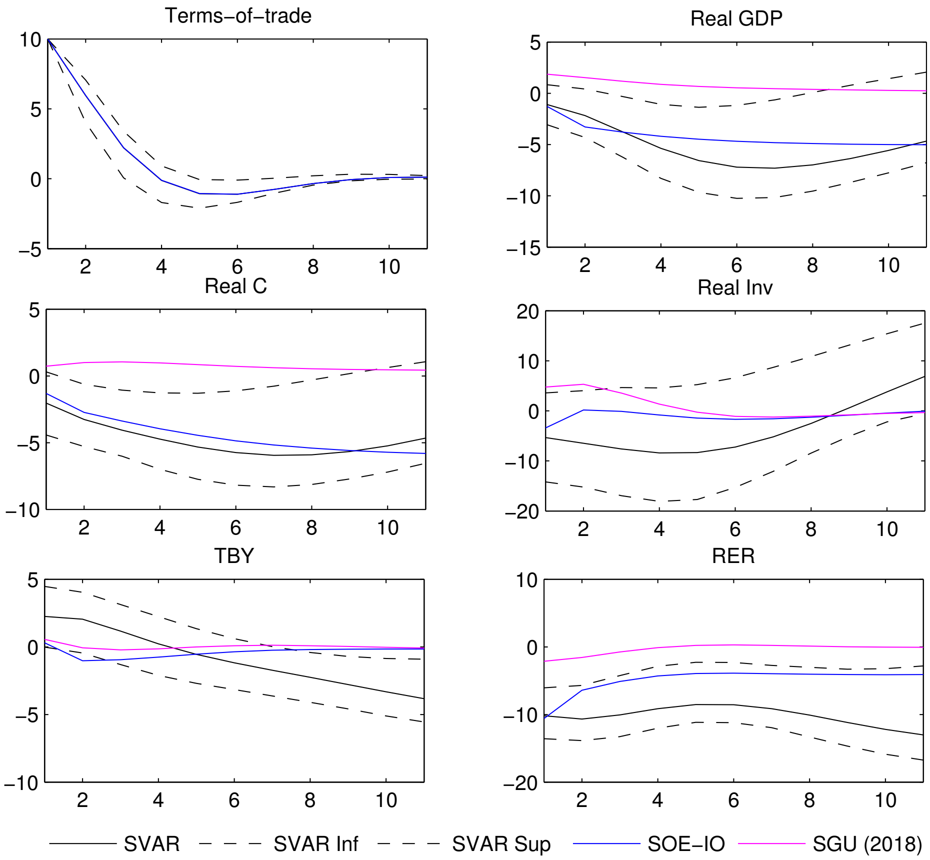
Note: Dashed lines correspond to the 66% confidence band.

Figure 23: Impulse Responses of the Models : South Africa



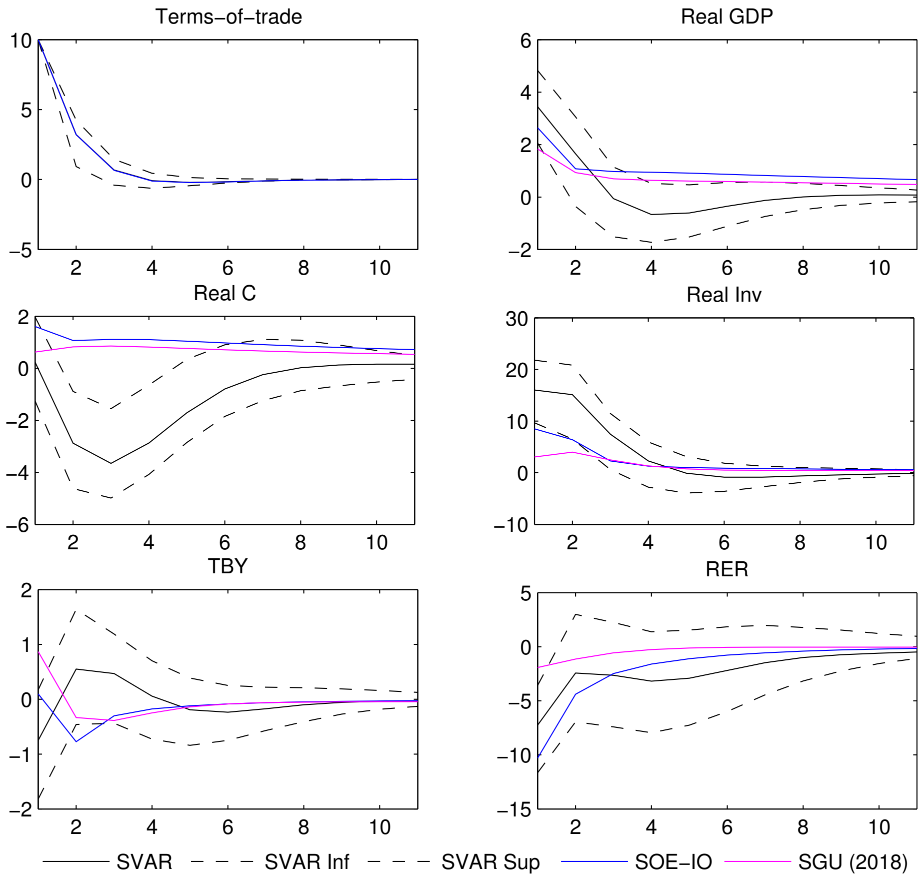
Note: Dashed lines correspond to the 66% confidence band.

Figure 24: Impulse Responses of the Models : Thailand



Note: Dashed lines correspond to the 66% confidence band.

Figure 25: Impulse Responses of the Models : Turkey



Note: Dashed lines correspond to the 66% confidence band.