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Terms of Trade and Total Factor Productivity: Empirical evidence from Latin American emerging markets

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Terms of Trade and Total Factor Productivity: Empirical evidence from Latin American emerging markets

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Abstract

In this paper we use quarterly data from Chile, Mexico and Peru to study the link between terms of trade and Total Factor Productivity (TFP). We estimate TFP using a stylized general equilibrium model for a small open economy model with quarterly data. Then, the TFP is decomposed into a domestic component and one external component linked to terms of trade using a structural VAR model as in Blanchard and Quah(1989). Our main results shows that the terms of trade has indeed not only short term but also medium and long term effects on TFP, being the short and medium term impact more predominant in the sample.

Resumen

En este documento usamos datos trimestrales para las economías de Chile, Perú y México para identificar, usando un método de dos etapas, la relación de corto y largo plazo entre los términos de intercambio y la productividad total de factores (PTF). En un primer paso, condicional con los datos y la estructura que impone un modelo DSGE para una economía pequeña y abierta, para cada uno de los países considerados, se estima la senda histórica de PTF. Luego, en un segundo paso, la PTF es decompuesta entre un componente doméstico y otro externo ligado a los términos de intercambio a través de la estimación de un modelo VAR estructural con restricciones de largo plazo, como en Blanchard y Quah(1989). Entre los principales resultados, se muestra que los choques de términos de intercambio han generado importantes ganancias de productividad en las economías consideradas, tanto en el corto plazo como en el largo plazo.

JEL Codes: C11, C13 , C51, F41
Keywords: Calibration, general equilibrium, terms of trade, total factor productivity

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1. Introduction

Emerging market economies such as Mexico, Chile, Peru and many others have benefited from high terms of trade during the last decade. Recent papers such as Castillo and Salas (2010) and García-Cicco et.al (2014) have documented that this evolution contributed to increase the long-term growth for Chile and Peru. However, given the high volatility of terms of trade, it is important to quantify not only its impact on short and long-term growth but also the channels through which it affects output. In particular is relevant to distinguish the direct impact that terms of trade have on investment from its indirect impact on total factor productivity (TFP). High terms of trade tend to increase profits not only for the private sector, but also for government, which can also contribute to boost public investment, such as infrastructure, and through this channel it has an indirect positive effect on total factor productivity. There is also spillover effects of the terms of trade, trough the input-output matrix, from the tradable to non tradable sector of the economy that also induces gains of TFP in the overall economy. Llosa (2013) highlights this channel and shows that the total factor productivity in the emerging economies is mainly due to the changes in terms of trade given exogenously.

In this paper we use a DSGE model for an small open economy and quarterly data set for the Chilean, Mexican and Peruvian economy in order to estimate a series of total factor productivity, using the Kalman filter conditional on the model and calibration. We then use the estimated series of TFP and terms of trade within a structural vector autoregressive model with long-run restrictions as in Blanchard and Quah (1989) to decompose TFP between a domestic factor and an external factor linked to the evolution of terms of trade. The DSGE model allows us to estimate the evolution of total factor productivity, consistent with the data and with the restrictions that profit maximization and consumption smoothing imposes on the general equilibrium.

The model features several characteristics typical of a small open economy. Thus, in the model a permanent increase in TFP generates a permanent increase in consumption, investment and output, a transitory fall in trade balance and a permanent cut in domestic debt. The model economy also has some frictions that the literature has found relevant to explain the data in small open economies, such as imperfect access to the international capital markets, which generates an endogenous risk premium, one linked to the evolution of the foreign net debt position and another linked to expected changes in productivity of the economy, adjustment costs in capital accumulation, and variable capital utilization, which allows the capture of short-term dynamics of investment and output more accurately.

Main results show that terms of trade shocks had indeed generated important gains in TFP for the Chilean, Mexican and Peruvian economy, in particular during the period 2001-2007. During this period positive terms of trade shocks explain more than 25 percent of the average growth rate of TFP. The estimation results also shows how important was the deterioration of the terms of trade on the TFP during the last recession of 2008-2009. Another interesting finding is that although the long-run effects of the terms of trade on TFP are not negligible, the short-run and medium-run terms impact are more predominant.

In particular, the decomposition exercise shows that the higher volatility of the terms of trade has also been transmitted to a volatile evolution of TFP.

Other papers have studied the effects of terms of trade shocks in small open economies using DSGE models. One of the first papers is Mendoza (1995), who finds that terms of trade, using a calibrated DSGE, can explain between 45 to 60 percent of output fluctuations but differently from Mendoza (1995) we use a model with estimated parameters that also admits permanent TFP shocks. Llosa (2013) looks at the effects of changes in terms of trade shocks on the total factor productivity which is also captured by the Solow residual. This paper does the analysis for both large and small economies. However, the result that becomes relevant for this paper is how the total factor productivity in the emerging economies is mainly due to the changes in terms of trade given exogenously. More recently Garcia-Cicco et.al (2014), using a DSGE model of a small open economy model for the Chilean economy, find that in the presence of financial frictions, external factors, and in particular commodity price shocks, have had an important contribution in explaining the evolution of most macro variables during the 2000s decade. Unlike these papers, in this paper we find that terms of trade shocks has not only short term impacts but also medium and even long term effect on TFP, and through these channels it can generate meaningful business cycle fluctuations in emerging market economies.

Also our paper is close to García-Cicco et. al (2010), who find, using a estimated DSGE model with Argentine and Mexican data, that preference shocks, country premium shocks and a realistic debt elasticity of the country premium are important factors to explain the data and that permanent productivity shocks play a minor role. Other papers that have analyzed business cycles in emerging economies are Aguiar and Gopinath (2007), who argue that a standard RBC model with a permanent shock in productivity can explain well business cycles in emerging market economies; Chang and Fernández (2013), that bring in the role of financial frictions with a random interest rates that is a combined effect of country specific spread and the world interest rate. The authors show that temporary productivity shocks are important and can not be done away with but the shocks to the interest rate also have a substantial effect on the variances of consumption, output and trade balance to output ratio. Also it is highlighted that financial frictions enlarge the effects of shocks to productivity.

The remainder of the paper proceeds as follows: In Section 2, the benchmark model is presented. In Section 3, the data and implementation is described. In Section 4, the results TFP estimation, and TPF decomposition are reported. Finally, conclusions are presented in Section 5.

2. The Model

Our framework follows a standard RBC model for a small open economy similar to Chang and Fernández (2013) and García-Cicco et.al (2010). Thus, we consider an economy populated by a continuum of identical agents who consume tradable goods, supply labor to firms, take investment decisions and save using both a domestic and foreign one year zero coupon bond. Firms in the domestic economy produce the consumption good by using a constant returns to scale production function. The model economy also has some frictions that the literature has found relevant to explain the data in small open economies, such as imperfect access to the international capital markets, which generates an endogenous risk premium, one linked to the evolution of the foreign net debt position and another linked to expected changes in productivity of the economy. Furthermore, we extend this basic setup by including additional features that help us to fit the data better, such us variable capacity utilization, as in Greenwood et.al (1988) and King and Rebelo (1999). This feature allows us to have more realistic moments for investment, since what it permits, in the model, is that firms can expand output not only by hiring more workers but also by using capital more intensively.

2.1. Technology

We assume that the production function, as presented in García-Cicco(2010), is affected by a permanent productivity shock, A_t, and a transitory TFP shock, a_t. The production function for producing final tradable goods is defined as follows:

$$Y_t = a_t \left(U_t K_t\right)^{\alpha} \left(A_t N_t\right)^{1-\alpha}, \tag{1}$$

where Y_t denotes output in the period t, K_t denotes capital in period t and decided in period $t-1$, U_t denotes capital utilization in period t, N_t denotes hours worked in t; and α represents the share of capital in total output. The permanent productivity shock A_t is assumed to follow a random walk in logs:

$$\frac{A_t}{A_{t-1}} = X_t,$$

Whereas the growth rate of productivity follows a stationary autoregressive process that obeys the following law of motion:

$$lnX_t = (1-\rho_x)ln(X) + \rho_x lnX_{t-1} + \epsilon_t^x \ , \epsilon_t^x \sim N(0, \sigma^x) \, .$$

We also assume that the transitory productivity shock, a_t, follows a stationary autoregressive stochastic process of the following type:

$$lna_t = \rho_a lna_{t-1} + \epsilon_t^a \ , \epsilon_t^a \sim N(0, \sigma^a) \, ,$$

where the parameters $\rho_a, \rho_x \in (0,1)$ rule the persistence of X_t and a_t and σ^x, σ^a denote the standard deviations of the two productivity shocks previously defined. As mentioned in García-Cicco et.al(2010) both X_t and a_t, can not only be interpreted as exogenous aggregate disturbances that affect the total factor productivity of the economy, but also they include other sources of variation like shocks to terms of trade. This interpretation is particulary valuable for our purposes since we plan to decompose the effect of the terms of trade on evolution of the total factor productivity. The stock of capital, K_{t+1}, evolves according the following law of motion:

$$K_{t+1} = I_t + (1 - \delta_t)K_t - \frac{\psi_K}{2}\left(\frac{K_{t+1}}{K_t} - X\right)^2 K_t\,,$$

where I_t denotes the investment at time t. The cost of using capital more intensively generates a cost for firms under the form of a larger depreciation rate. Depreciation therefore is described by the following law of motion:

$$\delta_t = \delta U_t^{\varphi}\,,$$

where $\varphi > 1$, $\delta_t' > 0$ and $\delta_t'' > 0$. Note also that, we assume that investment is subject to adjustment costs, and introduced by the parameter ψ_k of the following form:

$$\frac{\psi_K}{2}\left(\frac{K_{t+1}}{K_t} - X\right)^2 K_t\,.$$

Under this specification for adjustment costs, costs increase when investment increases at rate higher than its long-run growth rate.

2.2. Preferences

Households have preferences over consumption, and leisure, and they seek to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{[C_t - \tau A_{t-1} N_t^{\upsilon}]^{1-\sigma}}{1-\sigma} \tag{2}$$

where, C_t denotes consumption levels, N_t represent household's working hours, $\beta \in (0, 1)$ is the discount factor, σ is the coefficient of risk aversion, τ is a constant related to the allocation of time, and υ is a preferences parameter related to the supply elasticity of labor. Finally, $\mathbb{E}_0$ is the conditional expectation operator at time $t = 0$. A_{t-1} is allowed in the utility function to secure balanced growth. It should be noticed that we imposed the contemporaneous utility function of the Greenwood, Hercowitz and Huffman (1988) form (GHH preferences henceforth). As discussed by Neumeyer and Perri (2005) and pointed out by Chang and Fernández (2013) GHH preferences helps reproducing some emerging economies' business cycles facts by allowing the labor supply to be independent of consumption levels.

Households can smooth consumption using a foreign bond that pays a real interest rate, R_t between period t and $t + 1$. We follow Schmitt-Grohe and Uribe (2003) in assuming that the domestic and foreign interest rate R_t^*, are linked through the following function,

$$R_t = R_t^* S_t + \psi_D\left(e^{\widetilde{D}_{t+1} - D} - 1\right) \tag{3}$$

where $\widetilde{D}_{t+1}$ is the level of average percapita external debt, and S_t, similar to Nuemeyer and Perri (2005) and Chang and Fernández (2013), is a country specific spread that depends on the fundamentals of the economy, thus $R_t^* S_t$ is a country specific interest rate. The $\psi_D \left(e^{\widetilde{D}_{t+1} - D} - 1 \right)$ function assumes that domestic agents have to pay a premium that is increasing in the level of debt relative to its steady state in order to take funding from abroad. This assumption allow us to generate a well defined level of foreign domestic liabilities for the domestic economy. Schmitt-Grohe and Uribe (2003) show that this device, among others, has negligible effects on the business cycle properties of the model.

We allow deviation of foreign interest rate with respect to its long-run level to follow an AR(1) process:

$$ln(R_t^*/R^*) = \rho_{r^*} ln(R_{t-1}^*/R^*) + \epsilon_t^{r^*} \ , \epsilon_t^{r^*} \sim N(0, \sigma^{r^*}) \,, \tag{4}$$

where $\rho_{r^*} \in (0,1)$ and σ^{r^*} denotes the standard deviation of the shock to the foreign interest rate. Following Chang and Fernández (2013) we allow both permanent and transitory shocks to affect the country specific spread, by the following relationship

$$ln(S_t/S) = \eta \mathbb{E}_t (lnX_{t+1} + a_{t+1}) \,, \tag{5}$$

where S is the steady state of the country specific spread.

Since the model economy does not suffer any distortion, we solve for the social planner problem, which maximizes the utility of the representative household, subject to the production flows and to the aggregate budget constraint, defined as follows:

$$\frac{D_{t+1}}{R_t} = D_t - Y_t + C_t + \left[K_{t+1} - (1 - \delta(U_t))K_t + \frac{\psi_K}{2} \left(\frac{K_{t+1}}{K_t} - X \right)^2 K_t \right] , \tag{6}$$

where D_{t+1} is the stock of debt issued in period t; jointly with a non-Ponzi game constraint, $\lim_{j\to\infty} \mathbb{E}_t (D_{t+j} / \prod_{k=0}^{j} R_{t+k}) \leq 0$.

Finally, each period t the trade balance to GDP ratio, denoted by TBY_t is determined by

$$TBY_t = \frac{Y_t - C_t - I_t}{Y_t} \,. \tag{7}$$

2.3. Equilibrium conditions

The first order conditions which result from maximizing (2) subject to (3) and (6) are presented next,

$$1 = \beta \mathbb{E}_t \left(R_t \frac{U_{c,t+1}}{U_{c,t}} \right), \tag{8}$$

$$\tau \upsilon A_{t-1} N_t^{\upsilon - 1} = (1 - \alpha) \frac{Y_t}{N_t} \,, \tag{9}$$

where $U_{c,t} = [C_t/A_{t-1} - \tau N_t^{\upsilon}]^{-\sigma}$ denotes the marginal utility of consumption at period t. These two previous conditions define the optimal choice of household of savings and labor supply. In the first case, this condition is the typical Euler that equalizes the marginal benefit of savings given by the future return of the investment with its marginal cost. The second equation represents the equilibrium in the labor market. The labor market equilibrium implies that the marginal rate of substitution between consumption and leisure, which given GHH preferences is independent of C, is equal to the marginal product of labor.

The next three equations denote the optimal decisions of investment, where firms equalize the cost of increasing in one unit investment with its marginal benefit, given by the present discounted value of the marginal productivity of the capital. The second equation determines the evolution of the investment, which depends not only on future expectations of labor productivity, but also on the intensity of capital utilization.

$$1 + \psi_k \mathbb{E}_t \left(\frac{K_{t+1}}{K_t} - X \right) = \beta \mathbb{E}_t \left\{ \frac{U_{c,t+1}}{U_{c,t}} \left[\alpha \frac{Y_{t+1}}{K_t} + 1 - \delta U_{t+1}^{\varphi} + \frac{\psi_k}{2} \left(\left(\frac{K_{t+2}}{K_{t+1}} \right)^2 - X^2 \right) \right] \right\}, \tag{10}$$

$$I_t = K_{t+1} - (1 - \delta U_t^{\varphi}) K_t + \frac{\psi_K}{2} \left(\frac{K_{t+1}}{K_t} - X \right)^2 K_t, \tag{11}$$

$$\alpha \frac{Y_t}{U_t} = \varphi \delta U_t^{\varphi - 1} K_t. \tag{12}$$

The third equation says that the optimal rate of capital utilization equates its marginal benefit to its marginal cost.

2.4. Competitive equilibrium

In this economy, given initial conditions K_0, D_0 and A_{-1} and the exogenous stochastic processes $\left\{X_t, a_t, R_t^*\right\}_{t=0}^{\infty}$ a competitive equilibrium is the set of stationary processes along a balanced growth path for allocations $\left\{C_t, K_{t+1}, D_{t+1}, Y_t, N_t, I_t, U_t, TBY_t\right\}_{t=0}^{\infty}$ and price $\left\{R_t\right\}_{t=0}^{\infty}$ that satisfy the optimality conditions (3), (8), (9) ,(10), (11) and (12); the production function (1); the budget constraint (6); the trade balance-to-GDP definition (7) and the country specific risk premium, S_t, (5).

3. Data and estimation strategy

In this section, we describe the data for the Mexican, Chilean and Peruvian economy; and our estimation strategy that involves 2 stages. Thus, first, we describe the methodology used to estimate the non-observable total factor productivity (TFP), conditional on the model and calibration. Our strategy is similar to Chang and Fernández (2013), García-Cicco (2010) and Aguiar and Gopinath (2007) and we use 4 observable variables to estimate the TFP path. Second, we explain the econometric methodology used to decompose the TFP obtained previously into a factor driven only by domestic technology shocks and a second one linked to the evolution of terms of trade. In this last stage, we use observable quarterly times series of terms of trade.

3.1. Data

The economic data were obtained mainly from central banks of Chile, Mexico and Peru. Quarterly series are used for real GDP, real private consumption, real private investment, trade balance and terms of trade. An annual series of population were obtained from the International Monetary Fund statistics' data bases. All domestic data is seasonally adjusted and normalized in per capita terms[1]. Output, consumption, investment, and terms of trade data is transformed by taking natural logs and first differences in order to render them stationary. The ratio trade balance to GDP is also taken in first differences.

For Chile the sample period covers from 1996.I to 2013.IV. For Mexico the sample period is from 1980.I to 2013.IV[2]. Finally, for Peru the sample period covers from 1980.I to 2013.IV for estimation of TFP, but for the VAR estimation the period 1990.I-2013.IV is considered, as the quarterly series of terms of trade is only available from 1990.I.

Figures 2, 3 and 4, in the appendix A, depict the evolution of the observable series throughout the sample period for each country. From the figures we observe that for Peru and Mexico, the volatility of the aggregate variables has been lower since the end of the 90s. For Chile, as the sample is shorter we can not give a similar conclusion. Also, from the figures the big impact of the last financial crisis in all variables and countries is evident. The table 4, in the appendix A, also shows relevant second moments of the data. As pointed out by Aguiar and Gopinath (2007), we observe in the sample that the investment and consumption are more volatile than output and the net exports are highly counter-cyclical. Finally, as expected the terms of trade is highly volatile.

3.2. Estimation framework for the TFP

In our first stage we use the Kalman filter to get estimates of non-observable series of the total factor productivity. To do so, first we scale the variables that have a trend in equilibrium by dividing them by the lagged level trend of the permanent productivity shock, A_{t-1} (e.g $\widetilde{Y} = Y_t/A_{t-1}$), so the system of non-linear equation characterizing the

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[1] Central Banks of Chile and Mexico already provide seasonally adjusted data of output, consumption and investment. For Peru, the raw data is adjusted seasonally using TRAMO-SEATS.

[2] The Statistics of output, consumption, investment and trade balance for Mexico, provided by the Central Bank of Mexico, are only available since 1993.I. However, we extended backward the sample until 1980.I by using data from Aguiar and Gopinath (2007), and available on the web page of Gita Gopinath.

equilibrium of the model economy regards only stationary variables. Next, the stationary dynamic system of equations is log-linearized, and it can be written as part of a canonical state-space form.

In general a canonical state-space form system can be written as:

$$\begin{array}{llcl} \text{Measurement equation} & \mathbf{y}_t & = & \mathbf{Z}\alpha_t + \mathbf{d} + \mathbf{G}_y\mathbf{u}_t \,, \\ \text{Transition equation} & \alpha_t & = & \mathbf{T}\alpha_{t-1} + \mathbf{c} + \mathbf{G}_\alpha\mathbf{v}_t \,, \end{array} \tag{13}$$

where $\mathbb{E}(\mathbf{u}_t) = \mathbb{E}(\mathbf{v}_t) = \mathbf{0}$, $\mathbb{V}(\mathbf{u}_t) = \mathbf{H}$, $\mathbb{V}(\mathbf{u}_t) = \mathbf{Q}$ and $\mathbb{E}(\mathbf{u}_t\alpha_0{}') = \mathbb{E}(\mathbf{v}_t\alpha_0{}') = \mathbf{0}$ for all t.

Where the goal is to estimate the vector α_t, of dimension $s \times 1$, containing non observable *state variables*. The transition matrix $\mathbf{T}$ has dimension $s \times s$ and $\mathbf{c}$ is an $s \times 1$ vector. $\mathbf{G}_\alpha$ is an $s \times g$ matrix and the vector of disturbances $\mathbf{v}_t$ has dimension $g \times 1$. $\mathbf{y}_t$ is $n \times 1$ vector containing , observed data at time t. The matrix $\mathbf{Z}$, with dimension $n \times s$, match state vector with the vector of observed data. $\mathbf{d}$ is an $n \times 1$ vector, $\mathbf{G}_y$ an $n \times n$ matrix and the vector of disturbances $\mathbf{u}_t$ has dimension $g \times 1$.

Given a representation of a system in its state-space form, the Kalman filter allows us get prediction about α_t. The Kalman filter jointly with a smoother filter enable us to use the signals from the observable variables to infer the evolution of the non observable variables (For more details about the Kalman filter see Hamilton, 1994 and Harvey, 1989).

In our particular case, this technique is suitable for our purposes as based on observable variables and conditional in our model economy described before, we can estimate the path of the total factor productivity overtime. Then, we need to build the state-space form.

As mentioned before, after log-linearizing the non-linear system of equilibrium conditions described earlier, we get a dynamic system that can be described in a matrix form by[3]

$$\Gamma_0\mathbf{W}_t + \Gamma_1\mathbb{E}_t\mathbf{W}_{t+1} + \Gamma_2\mathbf{W}_{t-1} + \Gamma_\varepsilon\,\varepsilon_t = 0$$

where the $\mathbf{W}_t$ vector includes the set of predetermined and non-predetermined variables of the model, ε_t consider all the shocks of the log-linear system, and Γ matrices contain the parameters associated with the log-linear system.

Next, after applying a method of solution of difference equations, such as Blanchard and Kahn (1980), we obtain the following reduced form:

$$\mathbf{W}_t = \mathbf{A}\mathbf{W}_{t-1} + \mathbf{B}\varepsilon_t \,. \tag{14}$$

On the other hand, having a counterpart observable data vector $\mathbf{y}_t$ that can be expressed as a linear combination of the state variables in $\mathbf{W}_t$ by

$$\mathbf{y}_t = \mathbf{Z}\mathbf{W}_t + \mathbf{d} + \epsilon_t \,, \tag{15}$$

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[3] The appendix B presents the log-linear version of the model equilibrium's conditions.

where $\mathbf{Z}$ is conformable matrix that maps the observable data vector $\mathbf{y}_t$ to their theoretical counterpart in $\mathbf{W}_t$ each period t, and ϵ_t is i.i.d measurement error conformable vector, we are ready to represent the state-space form of our system.

From the general state-form system in (13), we observe that (14) is the transition equation, with $\alpha_t = \mathbf{W}_t$, and (15) the measurement equation. Given these two equations we can use the Kalman filter, jointly with a smoother, to build recursively the estimates for the times series of the total factor productivity, $TFP_t = a_t A_t^{(1-\alpha)}$, based on estimates of the non observable variables a_t and X_t.

As mentioned earlier, we use quarterly data of gross domestic product (Y), consumption (C), investment (I), and the trade balance-to-GDP (TBY) for the three countries considered here. We transformed these variables, as explained in the previous section, to use observations of:

$$\mathbf{y}_t = \{\Delta lnY_t, \Delta lnC_t, \Delta lnI_t, \Delta TBY_t\}'$$

for each period t. Given this observable variables, the map of observable data to state variables in the model, and given by the measurement equation system, in (15), is defined by:

$$\begin{aligned}
\Delta lnY_t &= y_t - y_{t-1} + x_{t-1} + lnX + \epsilon_t^Y, \\
\Delta lnC_t &= c_t - c_{t-1} + x_{t-1} + lnX + \epsilon_t^C, \\
\Delta lnI_t &= i_t - i_{t-1} + x_{t-1} + lnX + \epsilon_t^I, \\
\Delta lnTBY_t &= tby_t - tby_{t-1} + \epsilon_t^{TBY},
\end{aligned}$$

where Δ denotes the first difference operator, lower case variables denote the variables in log deviations from its steady state (e.g $i_t = ln(\tilde{I}_t/\tilde{I})$) and ϵ_t^j are i.i.d measurements shocks with zero mean and standard deviation σ_j for $j = \{C, Y, I, TBY\}$. Given our representation of the measurement equation, we avoid the discussion about how to deal with the trend of the observable variables. Note also that we use measurements errors to deal with measuring problems of aggregate macroeconomics variables in emerging markets, as discussed in Chang and Fernández (2013).

3.3. TFP decomposition framework

In a second stage, and based on TFP series estimated in the first stage, we decompose it into a domestic component and an external one linked to the evolution of terms of trade. To achieve this objective we use a structural VAR model with long-run restrictions as in Blanchard and Quah (1989). In the VAR model both TPF and terms of trade (TOT) are modelled to be determined by moving average of domestic and terms of trade shocks, but where domestic shocks do not have a long-run effect over terms of trade, as follows:

$$\begin{bmatrix} \Delta TOT_t \\ \Delta TFP_t \end{bmatrix} = B(L) \begin{bmatrix} \Delta TOT_{t-1} \\ \Delta TFP_{t-1} \end{bmatrix} + C_\varepsilon \begin{bmatrix} \varepsilon_t^{TOT} \\ \varepsilon_t^{TFP} \end{bmatrix}$$

where ε_t^{TFP} is a structural domestic shock, ε_t^{TOT} is a structural external shock, linked to the terms of trade; and $C_\varepsilon C_\varepsilon' = \Omega_u$ is the matrix of variance-covariance of the residuals in the reduced VAR. Then, the identification restriction implies that domestic TFP shocks do not affect terms of trade in the long-run, therefore, the long-run impact matrix $\Theta(1)$, for a VAR of lag order p, is restricted as follows:

$$\Theta(1) = \lim_{j\to\infty} (\mathbb{E}_t - \mathbb{E}_{t-1}) \begin{bmatrix} TOT_{t+j} \\ TFP_{t+j} \end{bmatrix} = (I - B_1 - ... - B_p)^{-1} C_\varepsilon = \begin{bmatrix} \sum_{s=0}^{s=\infty} \theta_{11}^{(s)} & 0 \\ \sum_{s=0}^{s=\infty} \theta_{21}^{(s)} & \sum_{s=0}^{s=\infty} \theta_{22}^{(s)} \end{bmatrix}$$

where $\theta_{ij}^{(s)}$ gives the dynamic multiplier or impulse responses of ΔTOT_t and ΔTFP_t to changes in ε_t^{TOT} and ε_t^{TFP} shocks s periods ahead (For more details about SVAR see Hamilton, 1994). Our identification assumption comes from the fact that terms of trade in the emerging markets reflect most of the time movements in the price of commodities, which are exogenously determined. Then, domestic shocks have little influence on terms of trade in the long run. Finally, once we estimate the SVAR and conditional in the identification, we decompose historically the TFP to get a new time series of TFP without term of trade shocks.

3.4. Calibration Benchmark

Table 1 shows the parameters' calibration of the DSGE model that we used, for each country. Conditional on these values, and in the model, we get estimates of the total factor productivity for each country.

Our calibration takes into account values of parameters that are standard in the literature to replicate business cycle for each country considered here. Thus, the calibration for Chile accounts mode estimates and calibration presented in García-Cicco et.al (2014) and Medina and Soto (2007). For Mexico, the calibration considers mode estimates and calibration reported in Chang and Fernández (2013). For Peru, mode estimates and parameters' calibrations showed by Castillo et.al (2012) were considered. For each country, the mode of estimated parameters reported by the authors were obtained using Bayesian methods and county-specific data. The parameters that were not estimated reflect more or less their historical values for each country and values that help to replicate moments in the data. Thus, although we do not estimate the parameters of the model, most of the parameter's values presented in Table 1 are already result of a process of estimation. Now, we describe the calibration of parameter for each country.

For Mexico, the ratio debt-to-GDP is set to 0.1 so it is consistent with steady-state trade balance-GDP ratio of about 0.3% percent. The annual growth rate of productivity in the long run is set to be 2.4 per cent. The risk aversion coefficient is set at 2, a standard value in the literature. The discount factor β is calibrated such that it implies a relatively high average annual real interest rate of about 5.9 percent. The depreciation rate in annual basis is set in 20%. The share of capital in income, α is set to be 0.3132. The parameter τ and ν are calibrated such that a third of time is allocated to labor market in the steady state and the elasticity of labor supply is equal to 1.67. The parameter of capital adjustment

TABLE 1. *Calibration Benchmark*

Parameter	Description	Chile	Mexico	Peru
β	Discount factor	0.9919	0.9975	0.9910
α	Share of capital on GDP	0.3300	0.3132	0.3000
δ	Depreciation rate	0.0150	0.0500	0.0250
σ	Risk aversion	1.0000	2.0000	1.0000
υ	Parameter for the labor supply elasticity : $1/(\upsilon-1)$	2.0000	1.6000	4.6200
X	Steady state of productivity growth	1.0063	1.0060	1.0050
$\frac{D}{Y}$	Debt to GDP ratio	0.6098	0.1000	0.4000
τ	Labor parameter	5.5366	1.7157	19.4506
ψ_k	Adjustment cost investment	21.8057	14.7600	12.8100
ψ_d	Sensitivity of country interest risk premium	0.0010	0.0010	0.0010
η	Spread elasticity w.r.t to expected productivity	0.7300	0.7300	0.7300
φ	Parameter for capacity utilization elasticity: $1-\varphi$	1.9667	1.2906	1.5651
ρ_a	Persistence of the transitory technology process	0.7500	0.8900	0.8000
σ_a	SD of the transitory technology shock	0.0055	0.0060	0.0170
ρ_x	Persistence of the permanent technology process	0.3500	0.7000	0.3500
σ_x	SD of the permanent technology shock	0.0030	0.0012	0.0090
ρ_{r^*}	Persistence of the foreign interest rate process	0.9600	0.8100	0.8700
σ_{r^*}	SD of the foreign interest rate shock	0.0011	0.0042	0.0028
N	Labor in steady state	0.2000	0.3333	0.3333
$\sigma_{\Delta Y}$	SD Measurement shock of GDP growth	0.0032	0.0006	0.0050
$\sigma_{\Delta C}$	SD Measurement shock of consumption growth	0.0033	0.0011	0.0029
$\sigma_{\Delta I}$	SD Measurement shock of investment growth	0.0110	0.0030	0.0175
$\sigma_{\Delta TBY}$	SD Measurement shock of difference of NX/GDP	0.0088	0.0008	0.0036

Note: For Chile, it accounts mode estimates and calibration presented in García-Cicco et.al (2014) and Medina and Soto (2007). For Mexico, it considers mode estimates and calibration presented in Chang and Fernández (2013). For Peru, mode estimates and parameters' calibrations in Castillo et.al others (2013) were used.

is calibrated such that the volatility of investment is more or less consistent with the data. All the exogenous processes are calibrated considering the estimated mode values reported by Fernández and Chang (2013). Both Aguiar and Gopinath (2007) and Chang and Fernández (2013) use the random walk component of the Solow residual,

$$RWC = \frac{\frac{\alpha^2\sigma_x^2}{(1-\rho_x)^2}}{\frac{2\sigma_a^2}{(1+\rho_a)^2} + \frac{\alpha^2\sigma_x^2}{(1-\rho_x)^2}},$$

to assess the role of permanent shocks. Given the importance of this exogenous process for our purposes, we consider it the value RWC as part of the calibration. For the Mexican economy, Chang and Fernández (2013) find a value of RWC of 0.2, and it is similar here. Thus, the role of trend shocks are not predominant.

For Chile, the ratio debt-to-GDP is set to 0.6098 so it is consistent with steady-state trade balance-GDP ratio of about 2% percent, the historical average for Chilean data. The annual growth rate of productivity in the long run is set at 3.5 per cent. The risk aversion coefficient is set at 1, so the preferences are in logarithm. The value assumed for the discount factor β implies a relatively high average annual real interest rate of about 5.9 percent. The depreciation rate in annual basis is set at 6%. The share of capital in income, α is set to be 0.33, a standard value in the literature. The parameter τ and ν are calibrated such that a fifth of time is spent working in the long run and the elasticity of labor supply is equal to 1. The parameter of capital adjustment is calibrated such that the volatility of investment is more or less consistent with the data. All the exogenous processes are calibrated with their estimated mode values presented in García-Cicco et.al (2014). For the Chilean economy the calculated random walk component of the Solow residual is 0.28, very similar to the one obtained for the Mexican economy.

For Peru, on annual basis the depreciation rate is set to be 10%. The share of capital in income, α is set to be 0.3. The ratio debt-to-GDP is set to 0.4 so it is consistent with steady-state trade balance-GDP ratio of around 1.4% percent, the historical average for Peru. The annual growth rate of productivity in the long run is set to be 2.0 per cent. The risk aversion coefficient is set at 1, so we also consider that preferences are in logarithm. The discount factor β is calibrated such that it implies an average annual real interest rate of about 5.7 percent. The parameter τ and ν are calibrated such that in steady state households allocate a third of their time to work and the elasticity of labor supply is equal to 0.28, very inelastic. The parameter of capital adjustment is also calibrated such that the volatility of investment is more or less consistent with the data. All the exogenous processes are calibrated with their estimated mode values presented in Castillo et.al (2013). For the Peruvian economy the calculated random walk component of the Solow residual, RWC, is 0.24, very similar to the values obtained for the Mexican and Chilean economy.

Next, for all countries, similar to Chang and Fernández (2013), we assign a small value, 0.001, to the parameter of sensitivity of country interest rate premium to deviations of external debt from trend, ψ_d, so it ensures independence of the deterministic steady state from initial conditions without affecting the short-run dynamics of the model. For all countries we also calibrate the interest rate spread country-specific elasticity to expected productivity, η, to be 0.73, the estimated mode that were obtained by Following Chang and Fernández (2013) with Mexican data. Also, in all the cases, the parameter that measures the elasticity of the depreciation to the capital utilization is calibrated such that in the long run the capacity utilization is equal to one.

Finally, following García-Cicco et.al (2010) we calibrated all standard deviation of the measurement shocks such that they absorb less than 6 percent of the variance of the corresponding observable time series[4].

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[4] Although Chang and Fernández (2013) report mode values for S.D of the measurement shocks, for Mexico; we do not use them, as their estimation is conditional with a small sample than considered here, and the volatility of the aggregate variables are different between samples.

4. Results

We present first the results of the calibration. Next, conditional on this calibration and the model, we present the estimation of the TFP process. Later, we show the results for the decomposition of this TFP process between a domestic factor and an external factor linked to the terms of trade.

4.1. Results of calibration

In the table 4, in the appendix A, we contrast the second moments generated by the model with those obtained in the data, in terms of standard deviations, correlations with output and the trade balance, and serial correlations. In general, the model performs well and it replicates most of the volatility of the aggregate variables observed in the data. In terms of relative moments, the model produces a more volatile path for consumption and investment with respect to output, as observed in the data. Also, it replicates the countercyclicality of the trade balance-to-GDP, with a negative correlation between consumption, investment and the net export share. On the other hand, the model lacks of ability to replicate the serial correlation of the variables in the data.

4.2. Total Factor Productivity estimation

The third column of table 3 and the figure 1, depicted with a continuous line, present the evolution of the estimated total factor productivity for Chile, Mexico and Peru.

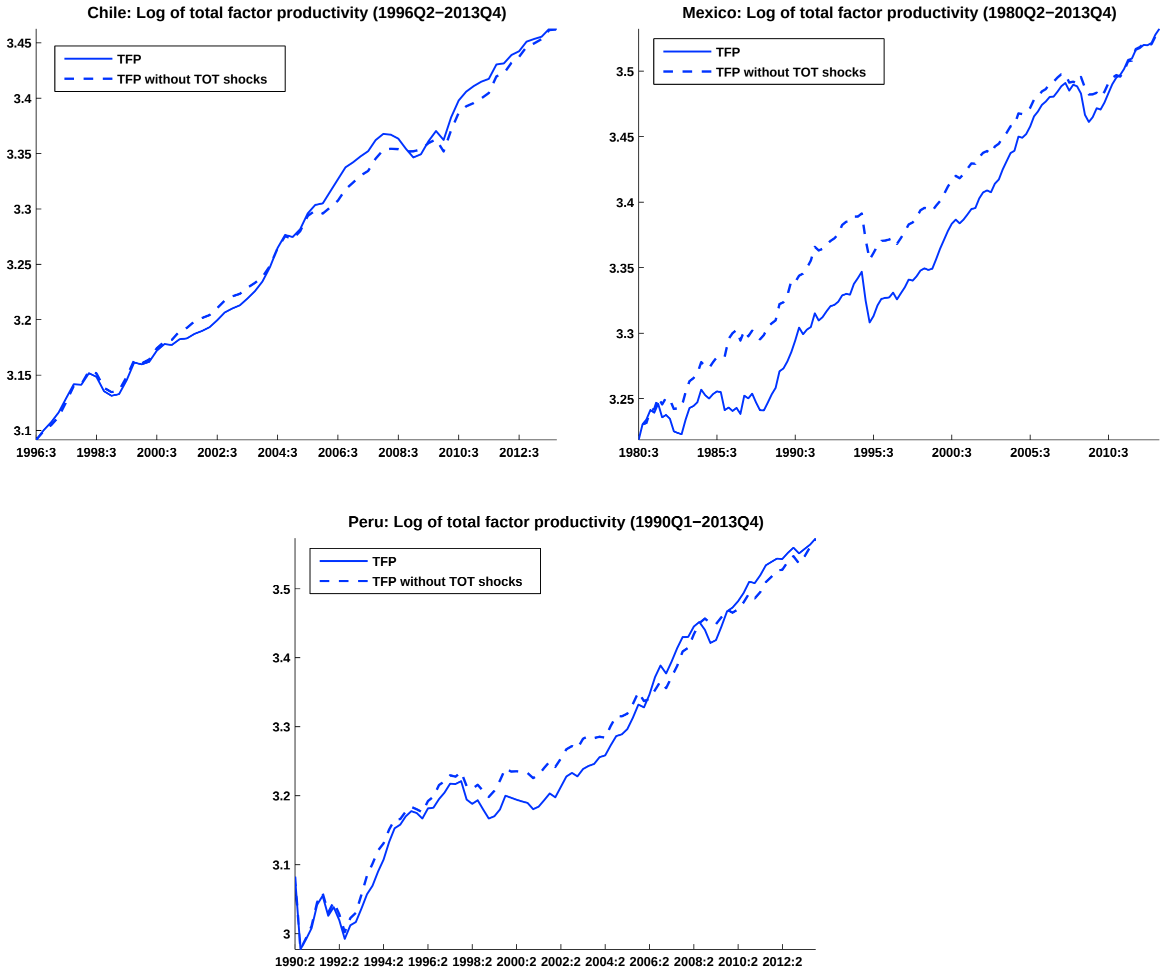
From the figure, we see that in all the countries the TFP has been volatile in the sample. For Chile and Mexico, the standard deviation of the TFP growth is estimated about 1.2 percent, but in Peru it is around 2.4 percent. The table 3 also shows the average TFP growth rate for the Latinamerican economies considered here: for Chile during the period 1998-2013 the TFP has grown in average around 2.1 percent per year; for Mexico in the period 1982-2013 the TFP has grown around 0.9 percent per year, and finally for Peru during the period 1992-2013 the average growth has been around 2.6 percent per annum. It is remarkable that for all countries, the highest average growth of productivity was experienced during the period 2001-2007.

In the sample, Chile has always experienced gains in productivity. In all the sub-periods showed in the table 3, the average TFP growth rate has been positive.

Similarly, the estimated TFP series for Mexico, shows that besides the ups and downs of the economy the Mexican economy has experienced gains in TFP in all decades. Also, during the period 2001-2007 the highest average TFP growth rate was experienced by this economy. Prior this interval of time, in the 90s, period of the Tequila crisis and after 2007, the gains in TFP was much lower. It should be mentioned that the Mexican economy, based on our estimates, is the economy that has suffered the highest reduction of TFP growth, with respect to the period 2001-2007.

From the estimated TFP series for Peru, we observe that this economy has experienced a persistent period of deterioration of TFP in the 80s and part of 90s (until 1993). During this period TFP fell on average at an annual rate of -2.4 percent during the 80s. Posterior to this period, the average growth of the TFP has been positive and the Peruvian economy experienced gains in TFP in all decades in average.

FIGURE 1. *Results of estimation: Total factor productivity*



4.3. VAR decomposition

The results of the TFP decomposition are shown next. These results are based on the SVAR estimation procedure mentioned earlier. As depicted in the table 3 a VAR(1) is considered for both Peru and Chile and a VAR(2) for Mexico. The lag for the VAR model is chosen based on the Hannan-Quinn information criterion, so parsimony and consistency criteria are taken into account on the lag order selection. Table 5 in the appendix C shows the statistics for this criterion among other information criteria statistics. Results of the

SVAR specification are presented in the tables 2, 3 and table 6 in the appendix C. We should mention that the TFP decomposition results we presented here is robust to the VAR lag order specification. Table 7 in the appendix C present similar results to those reported here, whereas the VAR(4) specification was considered for the three countries.

On the one hand, to talk about the long run effects of the terms of trade, table 2 presents the results in terms of variance decomposition of TFP. The estimated results show that the impact of terms of trade shocks are not negligible in the long run, and in fact can explain around 15 percent of the variance of the TFP in Chile, nearly 20 percent in Mexico and approximately 9 percent in Peru. Also, table 6, in the appendix C, shows the estimated long run matrix impact for each country is statistically different than zero, at 1% of significance level. Specifically, positive terms of trade shocks have permanent and positive impact on the level of the TFP. This results are consistent with those reported by Castillo and Salas (2010), who used a common trend model for Peruvian and Chilean data to find that the terms of trade explains a significant fraction of the long-term growth of GDP.

On the other hand, to focus on the medium and short run effects of the terms of trade, table 3 shows the results of the historical decomposition as on output of the SVAR exercise. In this table the fourth column, relative to the third column, presents the average growth rate of the TFP series but without terms of trade shocks. In this comparison, we try to analyze how the path of TFP would have been if there had not been terms of trade shocks. This comparison is relevant as the contribution of the terms of trade on the productivity can be known period by period, so the short run impact of the terms of trade can be known.

First, in terms of volatility, table 3 shows that the higher volatility of the terms has been also transmitted to the volatility of the total factor productivity. The estimation shows that without terms of trade shocks the unconditional standard deviation of the TFP growth for Chile would have been about 29 percent lower, for Mexico around 22 percent lower and for Peru around 21 percent lower. Thus, in the medium and short run term the influence of the terms of trade seems more important.

TABLE 2. *VAR results: Variance decomposition of TFP (in %)*

Horizon (k)	**Chile**		**Mexico**		**Peru**	
(quarters)	ε_t^{TOT}	ε_t^{TFP}	ε_t^{TOT}	ε_t^{TFP}	ε_t^{TOT}	ε_t^{TFP}
1	1.45	98.55	14.40	85.60	2.43	97.57
2	10.45	89.55	19.63	80.37	8.39	91.61
3	13.62	86.38	19.99	80.01	9.32	90.68
4	14.38	85.62	20.02	79.98	9.43	90.57
10	14.57	85.43	20.02	79.98	9.45	90.55
40	14.57	85.43	20.02	79.98	9.45	90.55

Note: Each number at horizon k gives the percentage of variance of the $k-$quarter ahead forecast error due to ε_t^{TOT} or ε_t^{TFP} shocks. For Chile the results correspond to a VAR(1), for Mexico to a VAR(2) and a VAR(1) for Peru.

TABLE 3. *TFP decomposition (Average annual growth rate, in %)*

	Terms of	TFP		
Period	Trade	DSGE estimation[1] **(a)**	Without ε_t^{TOT} shocks[2] **(b)**	Difference **(a) -(b)**
Chile, VAR(1)				
1998-2000	5.308	1.191	1.178	0.013
2001-2007	13.086	2.848	2.408	0.440
2008-2013	3.338	1.926	2.087	-0.161
2008	*-12.894*	*1.227*	*2.011*	*-0.784*
2009	*0.953*	*-0.628*	*0.371*	*-0.999*
2010	*23.308*	*3.092*	*1.885*	*1.208*
2011	*3.922*	*3.165*	*2.974*	*0.191*
2012	*-6.341*	*2.276*	*3.000*	*-0.724*
2013	*-2.740*	*1.770*	*2.227*	*-0.457*
1998-2013	5.422	2.117	2.089	0.028
STD(in %)	11.328	1.283	0.907	
Mexico, VAR(2)				
1982-1990	-5.378	0.721	1.144	-0.423
1991-2000	0.319	0.831	0.663	0.168
2001-2007	2.752	1.631	1.206	0.425
2008-2013	-0.317	0.781	0.648	0.133
2008	*1.235*	*0.046*	*-0.331*	*0.377*
2009	*-11.063*	*-2.021*	*-0.848*	*-1.173*
2010	*7.588*	*1.403*	*0.383*	*1.020*
2011	*6.820*	*2.079*	*1.255*	*0.824*
2012	*-3.640*	*1.534*	*1.612*	*-0.077*
2013	*-0.070*	*0.961*	*0.857*	*0.105*
1982-2013	-1.189	0.947	0.900	0.047
STD(in %)	8.240	1.181	0.920	
Peru, VAR(1)				
1981-1990	-3.887	-2.405	n.a	
1992-2000	-2.004	2.242	2.655	-0.413
2001-2007	8.060	3.625	2.449	1.176
2008-2013	1.823	2.421	2.331	0.090
2008	*-14.523*	*3.871*	*5.916*	*-2.045*
2009	*-3.095*	*-0.187*	*1.793*	*-1.980*
2010	*18.223*	*5.089*	*2.077*	*3.012*
2011	*5.526*	*3.618*	*2.504*	*1.114*
2012	*-4.957*	*2.473*	*3.377*	*-0.904*
2013	*-4.743*	*1.194*	*1.912*	*-0.719*
1992-2013	1.049	2.634	2.553	0.080
STD(in %)	9.156	2.371	1.882	

[1] This column correspond to our TFP, estimated with the Kalman filter, conditional on the model and calibration. [2] This column is result of the SVAR decomposition, and it shows the estimated TFP without the terms of trade shocks.

Notice that for the entire sample the impact of the terms of trade on the average TFP growth rate seems very small. Table 3 reports that without effects of terms of trade the average TFP growth rate could have been lower by 2.8 basic points in Chile during the period 1998-2013, by 4.7 basic points in Mexico period interval 1982-2013 and by 8 basic points for Peru during the period 1992-2013. Nevertheless, the lower importance of the terms of trade in the TFP seems to be a more recent phenomena. The fifth column of the table 3 shows that the influence of the terms of trade have on the TFP growth has been lower in the last 5 years, so domestic factors have been more important.

The relevance of terms of trade shocks in improving TFP is more obvious during the last decade, in particular for the period 2001-2007, where positive terms of trade shocks had very important effect on TFP growth rates; of around 44 basic points for Chile, 43 basic points for Mexico and 1.2 percentages points for Peru. In the sample, during this period the gains of TFP were the highest in the three countries.

In general, as exporters of primary commodities, these countries enjoyed very good terms of trade as commodity prices were very high. As pointed out by Llosa (2013) with higher terms of the positive spillover effects from the tradable sector to the non tradable sector results gains in TFP. Note that for other periods, the impact of the terms of trade are not homogeneous. During the 90s, terms of trade improved TFP in around 0.2 percent for Mexico, but in Peru it deteriorated the TFP by about 0.4 percent. In the 80s terms of trade had a negative impact of TFP of 0.42 percent in Mexico.

How much was the impact of the terms of trade during the period 2008-2013 on the TFP for the Latin American emerging economies?

During the last 6 years, after the beginning of the Great Recession period in 2007, the higher volatility of the terms of trade has been an important concern for most of the emerging economies. A sharp decline in commodity prices during the crisis that bounced back later to very high levels, but with no clear trend has opened the question of how important the terms of trade are. In this sense, we discuss the results of the historical decomposition in the during the last 6 years to see how the TFP has been affected.

During the 2008-2009 recession the three countries experienced high negative terms of trade shocks and as a consequence the TFP growth began to drop relative to its average during 2001-2007. As table 3 shows, the estimated negative contribution of terms of trade shocks to TFP has been of around 1 percent point in both Chile and Mexico (but only in 2009), whereas for Peru it was of about 2 percent points. In this period, terms of trade shocks among other foreign shocks had substantial effects on the TFP and the long-run growth of these economies, with indirect effects on other domestic factors. These results are consistent with the findings of García-Cicco et.al (2014), for Chile, who find that commodities prices had an important role in explaining the reduction on consumption, investment, output and trade balance during the 2008-2009 recession.

However, these effects were transitory, as in the posterior bounce back of the terms of trade, in 2010, there were also important gains in TFP linked to the terms of trade, for the three countries, but the trend of these effects did not last long. In fact, during the last two years, 2012-2013, new negative terms of trade shocks have been reflected in TFP losses, in particular for Chile and Peru. For Mexico, the role of terms of trade on TFP has diminished.

In general, we find that gains in TFP that are linked to terms of trade shocks, which imply that these shocks not only have short-term effects on output but also permanent effects. There are several ways we can rationalize how positive terms of trade can have not only short or medium term effects but also permanent impact of TFP. A first channel is through their impact on the government's capacity to invest in infrastructure. During periods of high commodity prices, governments revenues improve significantly since gains linked to the commodities producing sectors increase. As it is documented in the literature, better infrastructures in turn generates positive externalities on private investment. A second channel is directly through investment, since high terms of trade induce larger volumes of investment, TFP can improve when investment generates also a process of learning by doing.

5. Conclusions

In this paper we use quarterly data for the Mexican, Chilean and Peruvian economy to study the link between terms of trade and TFP. We estimated TFP using a DSGE model of an open economy. Then TFP is decomposed into permanent domestic and external components using a structural VAR model as in Blanchard and Quah(1989).

Main results show that terms of trade shocks had indeed generated important gains in TFP for the Chilean, Mexican and Peruvian economy, in particular during the 2000s decade. During these periods positive terms of trade shocks explain more than 25 percent of the average growth rate of TFP. The estimation also shows that the periods of negative terms of trade had also important influence on the losses of TFP, in particular during the recession period of 2008-2009.

Our decomposition of TFP exercise also shows that the terms of trade has both short-run and long-run effects on the TFP. The short-run effects seem more predominant. In particular, the higher volatility of the terms of trade was also transmitted to volatile evolution of TFP. In the long-run, the variance decomposition shows that the terms of trade are more important for Mexico and Chile; whereas for Peru the short-run effects seems more important.

However, we should mention that our analysis still remains incomplete as we do not differentiate explicitly the impact of the terms of trade in the long-run and short-run of components of the productivity. To make this differentiation, we think that more structure and additional assumptions are required. Also we recognize that the analysis of the impact of terms of trade shock on other aggregate macro variables such as consumption, investment and output is still missing.

On the other hand, including the terms of trade explicitly in the small open economy, as in Llosa (2013), can be another alternative that need to be explored. However, in order to do that, we believe that the non-stationary nature of the terms of trade should be considered. Finally, we recognize that using a stylized model to identify TFP series can be risky, as the model is still incomplete in capturing the broad dynamics of the economies considered here. However, as showed by Aguiar and Gopinath (2007) the total factor productivity obtained from DSGE model, using a simpler model with only permanent and transitory productivity shocks, fits very well with implied moments of the classical Solow residual; in terms of autocorrelation, volatility and predictions.

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Appendices

A. Data and Second moments

TABLE 4. *Second moments*

Statistics : **Mexico**

Data					Model			
$\Delta ln(Y)$	$\Delta ln(C)$	$\Delta ln(I)$	$\Delta TB/Y$	$\Delta ln(ToT)$	$\Delta ln(Y)$	$\Delta ln(C)$	$\Delta ln(I)$	$\Delta TB/Y$
Standard deviation (in %)								
1.645	1.981	5.104	1.269	4.874	1.884	1.920	5.791	1.335
Relative S.D w.r.t $\Delta ln(Y)$								
1.000	1.205	3.103	0.772	2.963	1.000	1.019	3.073	0.709
Correlation with $\Delta ln(Y)$								
1.000	0.827	0.742	-0.374	0.255	1.000	0.969	0.905	-0.672
Correlation with $\Delta TB/Y$								
-0.374	-0.431	-0.568	1.000	0.134	-0.672	-0.824	-0.918	1.000
Serial correlation								
0.167	0.181	0.395	0.278	0.150	-0.046	-0.052	-0.063	-0.079

Statistics : **Chile**

Data					Model			
$\Delta ln(Y)$	$\Delta ln(C)$	$\Delta ln(I)$	$\Delta TB/Y$	$\Delta ln(ToT)$	$\Delta ln(Y)$	$\Delta ln(C)$	$\Delta ln(I)$	$\Delta TB/Y$
Standard deviation (in %)								
1.287	1.333	4.471	2.084	4.974	1.285	1.656	4.789	1.812
Relative S.D w.r.t $\Delta ln(Y)$								
1.000	1.036	3.474	1.619	3.865	1.000	1.289	3.727	1.410
Correlation with $\Delta ln(Y)$								
1.000	0.783	0.591	0.030	0.223	1.000	0.763	0.693	-0.301
Correlation with $\Delta TB/Y$								
0.030	-0.149	-0.410	1.000	0.487	-0.301	-0.721	-0.759	1.000
Serial correlation								
0.169	0.384	0.321	0.268	0.484	-0.114	-0.087	-0.076	-0.030

Statistics : **Peru**

Data					Model			
$\Delta ln(Y)$	$\Delta ln(C)$	$\Delta ln(I)$	$\Delta TB/Y$	$\Delta ln(ToT)$[\1]	$\Delta ln(Y)$	$\Delta ln(C)$	$\Delta ln(I)$	$\Delta TB/Y$
Standard deviation (in %)								
2.909	3.366	10.090	2.104	4.226	2.925	3.534	10.566	2.768
Relative S.D w.r.t $\Delta ln(Y)$								
1.000	1.157	3.469	0.723	1.746	1.000	1.208	3.612	0.946
Correlation with $\Delta ln(Y)$								
1.000	0.790	0.564	-0.276	0.139	1.000	0.888	0.871	-0.611
Correlation with $\Delta TB/Y$								
-0.276	-0.320	-0.350	1.000	0.320	-0.611	-0.878	-0.874	1.000
Serial correlation								
0.360	0.203	0.011	-0.051	0.303	-0.068	-0.090	-0.087	-0.084

Note: [\1] For Peru, as quarterly data for terms of trade is only available since 1990.I, the second moments in data reported here for this variable covers only the period 1990.2-2013.IV.

FIGURE 2. *Mexico: Quarterly data*

FIGURE 3. *Chile: Quarterly data*

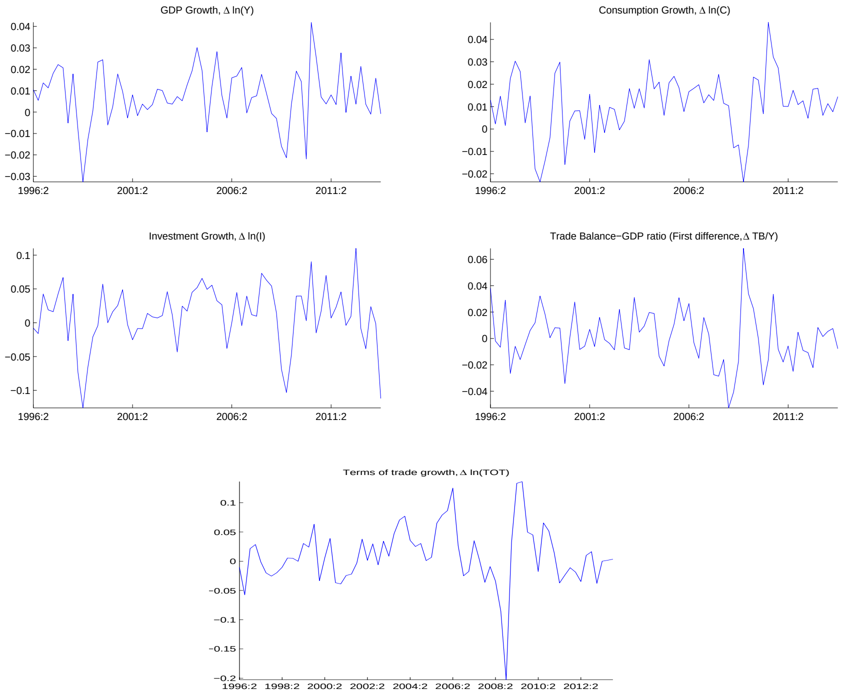

FIGURE 4. *Peru: Quarterly data*

B. Loglinearization of equilibrium conditions

First, because of the unit root of A_t, the model requires to be stationarized by

- Scaling most of the real variables, say: $Z_t/A_{t-1} = \widetilde{Z}_t$, but
- the labor hours, the capacity utilization and the gross interest rate.

Log-Linearization of any variable $\widetilde{Z}_t$ around its steady state is defined by $\widetilde{Z}$: $z_t = ln\widetilde{Z}_t - ln\widetilde{Z} \approx (\widetilde{Z}_t - \widetilde{Z})/\widetilde{Z}$.

- Marginal utility of consumption:

$$\widetilde{C}c_t - \tau N^{\upsilon}\upsilon n_t = -\lambda^{-1/\sigma}\frac{1}{\sigma}\widehat{\lambda}_t \tag{16}$$

- Euler equation

$$\widehat{\lambda}_t = E_t\left(\widehat{\lambda}_{t+1} + r_t - \sigma x_t\right) \tag{17}$$

- Labor market equilibrium

$$\upsilon n_t = y_t \tag{18}$$

- Investment decision

$$\begin{aligned} \widehat{\lambda}_t + \psi_k X \mathbb{E}_t(k_{t+1} - k_t + x_t) &= \mathbb{E}_t\Big(\widehat{\lambda}_{t+1} - \sigma x_t + \alpha\beta X^{-\sigma}\frac{\widetilde{Y}}{\widetilde{K}}(y_{t+1} - k_{t+1}) \\ &- \beta X^{-\sigma}\delta(\varphi u_{t+1}) + \psi_k \beta X^{2-\sigma}(k_{t+2} - k_{t+1} + x_{t+1})\Big) \end{aligned} \tag{19}$$

- Capacity utilization

$$y_t - k_t = \varphi u_t \tag{20}$$

- Investment

$$\frac{\widetilde{I}}{\widetilde{K}}(i_t + x_t) = X(k_{t+1} + x_t) - (1 - \delta)k_t + \delta\varphi u_t \tag{21}$$

- Production function

$$y_t = \ln(a_t) + \alpha(u_t + k_t) + (1 - \alpha)(n_t + x_t) \tag{22}$$

- Aggregation condition

$$y_t = \frac{C}{Y}c_t + \frac{I}{Y}i_t + \frac{D}{Y}d_t - \frac{D}{Y}\frac{X}{R}(d_{t+1} - r_t + x_t) \tag{23}$$

- Trade balance-output ratio

$$tb_t = (1 - \frac{TB}{Y})y_t - \frac{C}{Y}c_t - \frac{I}{Y}i_t \tag{24}$$

- Real domestic interest rate

$$r_t = r_t^* + s_t + \psi_D R^{-1} D d_{t+1} \tag{25}$$

- Country specific spread rate

$$s_t = -\eta(a_{t+1} + x_{t+1}) \tag{26}$$

- Exogenous processes

$$x_t = \rho_x x_{t-1} + \varepsilon_t^x \tag{27}$$

$$r_t^* = \rho_{r^*} r_{t-1}^* + \varepsilon_t^{r^*} \tag{28}$$

$$\ln(a_t) = \rho_g \ln a_{t-1} + \varepsilon_t^a \tag{29}$$

C. VAR estimation

TABLE 5. *VAR lag order selection criteria*

Chile, Sample: 1996Q3 2013Q4

Lag	AIC	SC	HQ
1	-10.70155*	-10.49570*	-10.62073*
2	-10.69501	-10.35193	-10.56031
3	-10.6592	-10.17888	-10.47061
4	-10.64841	-10.03085	-10.40594
5	-10.69015	-9.935361	-10.3938
6	-10.60669	-9.714667	-10.25646
7	-10.5507	-9.521442	-10.14659
8	-10.4572	-9.290705	-9.999203

Mexico, Sample: 1980Q3 2013Q4

Lag	AIC	SC	HQ
1	-10.86475	-10.72969*	-10.80988
2	-10.9249	-10.69979	-10.83344*
3	-10.89847	-10.58333	-10.77044
4	-10.98603*	-10.58084	-10.82141
5	-10.93629	-10.44106	-10.73509
6	-10.89647	-10.31121	-10.6587
7	-10.86118	-10.18588	-10.58683
8	-10.81103	-10.04568	-10.50009

Peru, Sample: 1990Q2 2013Q4

Lag	AIC	SC	HQ
1	-9.754982*	-9.584920*	-9.686503*
2	-9.694971	-9.411533	-9.580839
3	-9.653641	-9.256828	-9.493857
4	-9.581453	-9.071265	-9.376016
5	-9.569319	-8.945756	-9.318229
6	-9.543076	-8.806137	-9.246333
7	-9.51423	-8.663917	-9.171835
8	-9.640793	-8.677105	-9.252746

Note: $*$ indicates lag order selected by the criterion. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion.

TABLE 6. *SVAR results: Long-run impact matrix estimate:* $\widehat{\Theta}(1)$

	Chile	**Mexico**	**Peru**
$\widehat{\Theta}_{11}$	0.08217 ***	0.05880 ***	0.05847 ***
	(0.007)	(0.00361)	(0.00426)
$\widehat{\Theta}_{21}$	0.00495 ***	0.00402 ***	0.00920 ***
	(0.00096)	(0.00057)	(0.002)
$\widehat{\Theta}_{22}$	0.00713 ***	0.00594 ***	0.01829 ***
	(0.00061)	(0.00036)	(0.00133)

Note: Standard errors in parenthesis. * indicates $p < 10\%$, ** $p < 5\%$ and *** $p < 1\%$.

TABLE 7. *Robustness of TFP decomposition: VAR(4) for all countries (Average annual growth rate, in %)*

Period	Terms of Trade	TFP DSGE estimation	TFP Without ε_t^{TOT} shocks
Chile			
1999-2000	4.889	2.546	2.394
2001-2007	13.086	2.848	2.373
2008-2013	3.338	1.926	2.239
2008	*-12.894*	*1.227*	*1.703*
2009	*0.953*	*-0.628*	*1.098*
2010	*23.308*	*3.092*	*2.195*
2011	*3.922*	*3.165*	*2.550*
2012	*-6.341*	*2.276*	*2.793*
2013	*-2.740*	*1.770*	*2.566*
1999-2013	5.400	2.281	2.259
STD(in %)	11.755	1.165	0.550
Mexico			
1983-1990	-4.899	0.858	1.343
1991-2000	0.319	0.831	0.644
2001-2007	2.752	1.631	1.114
2008-2013	-0.317	0.781	0.592
2008	*1.235*	*0.046*	*-0.264*
2009	*-11.063*	*-2.021*	*-0.835*
2010	*7.588*	*1.403*	*0.460*
2011	*6.820*	*2.079*	*0.994*
2012	*-3.640*	*1.534*	*1.470*
2013	*-0.070*	*0.961*	*0.885*
1983-2013	-0.930	0.987	0.904
STD(in %)	8.248	1.180	0.874
Peru			
1981-1990	-3.887	-2.405	n.a
1992-2000	-2.004	2.242	2.571
2001-2007	8.060	3.625	2.632
2008-2013	1.823	2.421	2.330
2008	*-14.523*	*3.871*	*5.932*
2009	*-3.095*	*-0.187*	*1.445*
2010	*18.223*	*5.089*	*1.974*
2011	*5.526*	*3.618*	*3.042*
2012	*-4.957*	*2.473*	*3.388*
2013	*-4.743*	*1.194*	*1.816*
1992-2013	1.049	2.634	2.571
STD(in %)	9.156	2.371	1.905