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CONVENTIONAL CALIBRATION VERSUS EDF CALIBRATION

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Resumen

En este trabajo analizamos el impacto de emplear diversas metodologías para calibrar parámetros en modelos de equilibrio general en el contexto de una aplicación particular. Al estudiar las implicancias que distintas parametrizaciones tienen sobre los equilibrios de largo plazo para Chile, encontramos que el impacto de acuerdos comerciales sobre variables macroeconómicas de interés depende de la elección del enfoque metodológico. Sin embargo, la mejora de bienestar en estado estacionario producto de los tratados es robusta a las distintas parametrizaciones.

Abstract

In this paper we analyze the impact of using alternative parameter calibration methodologies for general equilibrium models in the context of a particular application. When studying implications of different parameterizations on long-run equilibria for Chile, we find that the impact of free trade agreements on macroeconomic variables of interest is contingent on the choice of methodological approach. Nevertheless, steady state welfare gains due to the treaties are robust to different parameterizations.

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1 Introduction

Dynamic stochastic general equilibrium models (*DSGE*) have become a cornerstone of quantitative macroeconomics, its wide usage lies on the advantages they offer in terms of internal consistency, coherence with economics, and recently, with noticeable reduction of computation costs, among other reasons. However, despite these advantages and breakthroughs, several open questions remain, as a survey Fernandez-Villaverde and Rubio-Ramirez (2006) point out three of these currently open avenues,

1. how to determine the value of parameters that define preferences and technology (also known as deep parameters),

2. how to measure the goodness of fit of the model, and

3. how to establish which theory better takes account of the data.

This paper addresses the first question, studying the sensitivity of our simulations to different parameterizations coming from alternative methodologies. We use a three sector DSGE model proposed by Chumacero et al. (2004) for which parameters are obtained using three different approaches, in the first place there is unconditional moments calibration *(CI)*, following Chumacero et al., parameters are set in order to match certain previously chosen moments to some stylized facts observed for the chilean economy. Second, following Hansen and Singleton (1982), a subset of parameters is estimated[1] by the generalized method of moments with instrumental variables *(GMMIV)*, under this scheme certain moments are previously selected in order to match the data. Finally, according to Gallant (2001) effective calibration is used (*EDF calibration* as named by Gallant). This approach differs from the previous ones regarding the lack of an ex-ante selection of moments carried out by the researcher, instead the whole data distribution is matched with the one coming from model simulations.

As it will be discussed in this paper, each methodology used has advantages and shortcomings which poses them as alternatives. Besides putting into practice these different approaches, the focus of the paper is on the implications of choosing among them. A sensitivity analysis is carried out in the context of a model originally designed to study the effects of the adoption of free trade agreements (FTAs) between Chile and two of its main commercial

[1] Later it will become clear how the size of this subset is conditional on data availability.

partners (United States of America and European Union). Stationary states are computed for the chilean economy before and after the treaties, after which the equilibriums obtained under the three proposed methodologies are compared.

In Cabezas (2003) there is a survey of studies measuring the impact of the FTA with the US on the chilean economy. According to the general approach, these effects on economic growth are classified into those who consider only the traditional channel (trade creation net of diversion and improved market access) and those who also include alternative channels (reduced country risk premium, increased capital returns, larger capital stock, positive externalities associated to new capital goods exchange, etc.). Among the reviewed studies, the effect of the FTA on gross domestic product (GDP) growth differs, Brown et al. (1992) calculate an effect on GDP growth of 0.37 and 5.15% for the traditional and alternative channels respectively, while according to Hinojosa-Ojeda et al. (1997) these two effects would be 0.2 and 1.3%. Harrison et al. (1997; 2001) obtain for the traditional channel figures ranging between 0.43 and 1.23% and 8.4% for the alternative. Finally Coeymans and Larraín (1994) report the largest effects associated to the signature of FTAs, with 0.26 and 10% for the traditional and alternative approaches.

The papers reviewed in Cabezas (2003) use multi-sectorial computable general equilibrium *CGE* which are static since they measure the change between steady states before and after the FTA signature, without taking into account the transitional dynamics between states. Therefore their results can only be read as long term effects. The author's survey evidences high heterogeneity in the results for Chile, however, the variance of the results for the traditional effects is significantly lower than that for the alternative channels (almost 70 times lower).

Chumacero et al. develop a *DSGE* model which allows the comparison of steady states, and also of the transitional dynamics between them. The authors calibrate their model's deep parameters in order to match certain stylized facts of the Chilean economy (unconditional calibration from here on), the remaining parameters are set according to the FTAs specific features, taking 2002 as base year. They find that in the long term, the treaty signature has an effect slightly higher that 1% over the original real GDP growth. In this paper we use Chumacero et al. unconditional parametrization as a *benchmark*.

The paper is organized as follows. Section 2 presents the *DSGE* model to be solved. Section 3 describes the main aspects of the methodologies employed for calibration and estimation and shows the parameters obtained. Section 4 reports and compares the steady states under different parameterizations. Section 5 summarizes the main findings and conclusions.

2 The Model

This section presents the dynamic stochastic general equilibrium model developed by Chumacero et al. which is used to measure the effect of the FTAs on certain variables of interest for the Chilean economy. In this framework, FTAs are modelled as changes in taxes and tariffs and their inherent effect on fiscal policy.

The model has three sectors, exportable, importable and non tradable. Next, some of its main aspects are datailed.

2.1 The Households

It is assumed that the economy is inhabited by an infinitely lived representative agent who maximizes the expected value of lifetime utility. The problem to be solved is given by

$$\max E_0 \sum_{t=0}^{\infty} \beta^t u(c_{m,t}, c_{n,t}) \tag{2.1}$$

$$s.a$$

$$\begin{aligned} c_m + c_n p + i + (1+\tilde{r})b \leq rk + b_{+1} + F + \pi_x + \pi_m + \pi_n \\ k_{+1} = (1-\delta)k + i \end{aligned} \tag{2.2}$$

considering tariffs and taxes, the budget constraint becomes

$$\begin{aligned} (1+\tau_m)(1+\tau_{c_m})c_m + (1+\tau_{c_n})c_n p + (1+\tau_m)(1+\tau_{c_m})i + (1+\tilde{r})b \leq \\ (1-\tau_k)(1+\tau_m)(1+\tau_{c_m})rk + b_{+1} + F + \pi_x + \pi_m + \pi_n \end{aligned} \tag{2.3}$$

where, $c_{m,t}$ is the consumption of importable goods (m) in t and $c_{n,t}$ is the consumption of non tradable goods (n) in t, notice that the exportable good (x) is not consumed by local agents. In the budget constraint with tariffs and taxes, τ_k is a tax on capital income levied by the government, τ_m is an import tariff, τ_{cm} and τ_{cn} are taxes on the consumption of importable and non tradable goods respectively, p is the relative price of non tradables in terms of importables, b is the external debt amount held by the private sector, $\tilde{r}$ is the net interest rate paid on b, r is the rental rate of capital stock at each sector, i is the investment which satisfies (2.2), F is a lump sum net transfer from the government to the households, π_x, π_m and π_n are the profits of the three sectors, besides, k is the capital stock and δ is the depreciation rate of the capital stock.

The household's problem, expressed in (2.1), (2.2) and (2.3), can be summarized into the value function that satisfies,

$$V(s_h) = \max_{c_m, c_n, b_{+1}, k_{+1}} \{u(c_m, c_n) + \beta E[V(s_{h,+1})]\} \tag{2.4}$$

s.t. (2.2), (2.3) and the perceived laws of motion of the states [2], named as s_h.

The first order optimality conditions for the households are,

$$\begin{aligned} \frac{1}{p} &= \frac{u'_{cm}}{u'_{cn}} \frac{(1+\tau_{cn})}{(1+\tau_m)(1+\tau_{cm})} \\ 1 &= \beta E\left[\frac{u'_{cm,+1}}{u'_{cm}} \frac{(1+\tau_m)(1+\tau_{cm})}{(1+\tau_{m,+1})(1+\tau_{cm,+1})}(1+\tilde{r}_{+1})\right] \\ 1 &= \beta E\left[\frac{u'_{cm,+1}}{u'_{cm}}[(1-\tau_{k,+1})r_{+1} + 1 - \delta]\right] \end{aligned} \tag{2.5}$$

the first intratemporal FONC states that the relative price between tradable and importable goods must equal their corresponding ratio of marginal utilities. The next two intertemporal FONCs state that the marginal rate of substitution between consumption today and tomorrow must equal its relative price in terms of external debt and rate of return of capital, respectively.

The optimality conditions gathered in (2.5) will be useful later when the estimation process of certain parameters included is described.

[2]The states in this problem are: $\tau_m, \tau_{cm}, \tau_{cn}, p, \tilde{r}, \tau_k, r, k, b, F, \pi_x, \pi_m, \pi_n$.

2.2 The Firms

It is assumed that in all three sectors (x, m, n) there are representative firms, with production functions which only include capital as input. Labor is considered as a sector-specific input. Next, the firm problems for each sector are presented, as well as the fiscal balance, market clearance conditions and competitive equilibriums.

2.2.1 Importable Sector

The profits of the representative firm are given by,

$$\pi_m = (1+\tau_m)f(z_m, k_m) - (1+\tau_m)(1+\tau_{cm})rk_m \tag{2.6}$$

where, z_m is a productive shock and k_m is the amount of sector-specific capital demanded. The value function that summarizes the problem of the representative firm is,

$$V(s_m) = \max_{k_m}\{\pi_m + \beta E[V(s_{m,+1})]\} \tag{2.7}$$

s.t. the perceived laws of motion of the states grouped in $s_m = \{\tau_m, \tau_{cm}, r, z_m\}$.

The FONC for the previous problem is,

$$f'_{km}(z_m, k_m) = (1+\tau_{cm})r \tag{2.8}$$

2.2.2 Exportable Sector

The profits of the representative firm are given by,

$$\pi_x = (1-\tau_x)qf(z_x, k_x) - (1+\tau_m)(1+\tau_{cm})rk_x \tag{2.9}$$

where, τ_x is an export tax levied by the rest of the world, q is the relative price of exportables in terms of importables (terms of trade), z_x is a productive shock and k_x is the amount of sector-specific capital demanded. The value function that summarizes the problem of the representative firm is,

$$V(s_x) = \max_{k_x}\{\pi_x + \beta E[V(s_{x,+1})]\} \tag{2.10}$$

s.t. the perceived laws of motion of the states grouped in $s_x = \{\tau_x, \tau_m, \tau_{cm}, z_x, q\}$.

The FONC for the previous problem is,

$$(1 - \tau_x) q f'_{kx}(z_x, k_x) = (1 + \tau_m)(1 + \tau_{cm}) r \tag{2.11}$$

2.2.3 Non Tradable Sector

The profits of the representative firm are given by,

$$\pi_n = p f(z_n, k_n) - (1 + \tau_m)(1 + \tau_{cm}) r k_n \tag{2.12}$$

where, z_n is a productive shock and k_n is the amount of sector-specific capital demanded. The value function that summarizes the problem of the representative firm is,

$$V(s_n) = \max_{k_n} \{\pi_n + \beta E[V(s_{n,+1})]\} \tag{2.13}$$

s.t. the perceived laws of motion of the states grouped in $s_n = \{\tau_m, \tau_{cm}, p, z_n\}$.

The FONC for the previous problem is,

$$p f'_{kn}(z_n, k_n) = (1 + \tau_m)(1 + \tau_{cm}) r \tag{2.14}$$

2.3 The Government

In the model proposed by Chumacero et al. an objective function for the government is not specified, it is only assumed that it should satisfy the following constraint,

$$\begin{aligned} g + F = \tau_m [c_m + i - f(z_m, k_m)] + \tau_{c_m}(1 + \tau_m)(c_m + i) + \\ \tau_{c_n} c_n p + (1 + \tau_m)(1 + \tau_{c_m}) \tau_k r k \end{aligned} \tag{2.15}$$

it is also assumed that the government uses a fraction $\varkappa_t$ of its total expenditure in order to consume the non tradable good (n).

2.4 Market Clearing

Define the production of the three sectors by,

$$
\begin{aligned}
y_x &= f(z_x, k_x) \\
y_m &= f(z_m, k_m) \\
y_n &= f(z_n, k_n)
\end{aligned}
\tag{2.16}
$$

then, the market clearing conditions are given by,

$$
py_n = pc_n + \varkappa g \tag{2.17}
$$

$$
\begin{aligned}
CA \equiv -(b_{+1} - b) = &(1 - \tau_x)qy_x + y_m - \\
&c_m - (1 - \varkappa)g - k_{+1} + (1 - \delta)k - \tilde{r}b
\end{aligned}
\tag{2.18}
$$

where (2.17) determines the equilibrium in the non tradable goods market, in which local private agents and the government demand, and (2.18) describes the equilibrium in the importable goods market, where the current account balance (CA) must be compensated by the capital account balance.

In the model proposed by Chumacero et al., in order to avoid modeling the world credit market, they assume that the country faces an upward-sloping supply schedule for debt.

$$
\tilde{r} = \tilde{r}(b) \quad \tilde{r}' > 0.
$$

2.5 Competitive Equilibrium

A set of allocation rules is defined,

$$
\begin{aligned}
c_m &= C_m(s) \\
c_n &= C_n(s) \\
k_{+1} &= K(s) \\
b_{+1} &= B(s)
\end{aligned}
\tag{2.19}
$$

a set of price functions,

$$
\begin{aligned}
r &= R(s) \\
p &= P(s)
\end{aligned}
\tag{2.20}
$$

and the laws of motion of the exogenous state variables,

$$
s_{+1} = S(s) \tag{2.21}
$$

such that they fulfill a series of conditions detailed in Chumacero et al.

2.6 Functional Forms

Next the functional forms used for solving the model are presented, we also show the parameters used by Chumacero et al., obtained by unconditional calibration[3].

2.6.1 Preferences

The following functional form is considered for the utility function of the representative agent,

$$u(c_{m,t}, c_{n,t}) = \theta_m \ln c_{m,t} + \theta_n \ln c_{n,t}$$

where, $\theta_m, \theta_n > 0$ and $\theta_m + \theta_n = 1$.

2.6.2 Technology

The production function for the three sectors is assumed to be Cobb-Douglas,

$$f(z_{i,t}, k_{i,t}) = e^{z_{i,t}} k_{i,t}^{\alpha_i}$$

where, α_i is the compensation for capital (in terms of production) at sector i ($i = m, x, n$). It is also assumed that productive shocks follow an AR(1) process,

$$z_{i,t+1} = (1 - \rho_i)\bar{z}_{i,t+1} + \rho_i z_{i,t} + v_{i,t+1} \qquad v_{i,t+1} \backsim N(0, \sigma_i^2)$$

where productivity level changes are allowed for the shocks due to FTAs.

2.6.3 Fiscal Variables

The rule followed by government expenditures is,

$$\ln g_{t+1} = (1 - \rho_g)\bar{g}_{t+1} + \rho_g \ln g_t + v_{g,t+1} \qquad v_{g,t+1} \backsim N(0, \sigma_g^2)$$

where changes in the level of government expenditure, due to the FTAs, are allowed.

[3] For further details on this calibration, see Chumacero et al. (2004).

2.6.4 Taxes and Tariffs

For every tax and tariff affected by the signing of the FTA, it is assumed that they follow an AR(1) process. Initial and final levels are known, an autoregressive process is used in order to smoothen the transition.

2.6.5 Exogenous Prices

The laws of motion assumed for the terms of trade (q) and debt interest rate ($\tilde{r}$) are,

$$\begin{aligned} \ln q_{t+1} &= (1-\rho_q)\bar{q} + \rho_q \ln q_t + \upsilon_{q,t+1} & \upsilon_{q,t+1} &\backsim N(0,\sigma_q^2) \\ \tilde{r}_{t+1} &= (1-\rho_{\tilde{r}})\bar{r}_{t+1} + (1-\rho_{\tilde{r}})\varphi\frac{b_t}{y_t} + \rho_{\tilde{r}}\tilde{r}_t + \upsilon_{\tilde{r},t+1} & \upsilon_{\tilde{r},t+1} &\backsim N(0,\sigma_{\tilde{r}}^2) \end{aligned}$$

where, $\varphi > 0$ and $\bar{r}_{t+1}$ are set according to the terms of the treaties.

3 Estimation and Calibration of Parameters

In this section we describe the methodology used to estimate and calibrate certain deep parameters of the model. These parameterizations later will be used to simulate series from the aforementioned model.

As mentioned above, the sensitivity of the results obtained will be analyzed using three alternative parameterizations:

1. **Unconditional Calibration (UC)**, the same set of parameters obtained by Chumacero et al. (2004).

2. **Generalized Method of Moments with Instrumental Variables (GMMIV)**, proposed by Hansen and Singleton (1982) and used to estimate the parameters of this non linear model.

3. **EDF[4] Calibration**, also known as Effective Calibration, proposed by Gallant (2001).

[4]Empirical Distribution Function.

3.1 Data

All the data[5] was obtained from the web site of the Central Bank of Chile. Except for τ_{cm}, which was requested to the Internal Tax Administration Service (SII in Spanish), and a series of tariffs taken from Chumacero and Fuentes (2002). The period considered spans from 1970 to 2008 with real annual data.

3.2 Unconditional Calibration (UC)

The parametrization obtained and used by Chumacero et al. is shown here. This setup of parameters will be our benchmark for the simulations and comparisons carried out in Section 4. According to the authors, θ_m and θ_n are calibrated so as to reproduce the share of consumption on importables and non tradables over total consumption in steady state, β is coherent with an annual real interest rate of 3% (Table 1). The output-factor elasticities (α_i) were set to match the sectorial capital shares implicit in the Chilean national accounts, the autoregressive coefficients (ρ_i) and volatilities of sectorial shocks (σ_i) were set to match the autocorrelation of output and adjust the convergence speed towards steady state (Table 2).

3.3 GMMIV

In this part of the paper, we briefly present the methodology used and present the results associated to the estimation of parameters by means of GMMIV. This will become our second parametrization in the sensitivity analysis performed on the baseline model.

3.3.1 Methodology

Following Hansen and Singleton (1982) we use the Euler equations obtained from solving the households problem, by grouping them in the following setup,

$$E_t h(x_{t+n}, b_0) = 0$$

[5]The series used are, $\{c_n, c_m, \tau_{cn}, \tau_m, \tau_{cm}, \tilde{r}, k, p, q\}$.

Preferences			
$\beta = 0.97$	$\theta_m = 0.243$	$\theta_n = 0.757$	
Production Function			
$\alpha_x = 0.45$	$\alpha_m = 0.5$	$\alpha_n = 0.3$	$\delta = 0.06$
Technology Shocks			
$\rho_x = 0.9$	$\sigma_x = 0.01$		
$\rho_m = 0.9$	$\sigma_m = 0.01$		
$\rho_n = 0.9$	$\sigma_n = 0.01$		
Fiscal Variables			
$\varkappa = 0.92$	$\rho_g = 0.8$	$\sigma_g = 0.03$	
Exogenous Prices			
$\overline{q} = 0.25$	$\rho_q = 0.86$	$\sigma_q = 0.01$	
$\varphi = 0.06$	$\rho_{\tilde{r}} = 0.9$	$\sigma_{\tilde{r}} = 0.001$	

Table 1: Deep Parameters: Unconditional calibration (UC)

Before FTA	After FTA
Local Taxes	
$\tau_m = 0.039$	$\tau_m = 0.02$
$\tau_{cm} = 0.18$	$\tau_{cm} = 0.1875$
$\tau_{cn} = 0.18$	$\tau_{cn} = 0.1875$
Access to Markets	
$\tau_x = 0.057$	$\tau_x = 0.051$
Property Rights Protection	
$\Delta\tau_{cm} = 0$	$\Delta\tau_{cm} = 0.007$
Higher Administration Costs	
$\overline{g} = 1.75$	$\overline{g} = 1.773$
Increases in TFP	
$\overline{z}_x = 4.88$	$\overline{z}_x = 4.904$
$\overline{z}_m = 0.67$	$\overline{z}_m = 0.673$
$\overline{z}_n = 2.75$	$\overline{z}_n = 2.764$
Country Risk	
$\overline{r} = 0.01293$	$\overline{r} = 0.00893$

Table 2: Parameters associated to FTAs

where,

$$h(x_{t+n}, b_0) = \begin{bmatrix} \frac{1}{p} - \frac{u'_{cm}}{u'_{cn}} \frac{(1+\tau_{cn})}{(1+\tau_m)(1+\tau_{cm})} \\ 1 - \beta E\left[\frac{u'_{cm,+1}}{u'_{cm}} \frac{(1+\tau_m)(1+\tau_{cm})}{(1+\tau_{m,+1})(1+\tau_{cm,+1})}(1+\tilde{r}_{+1})\right] \\ 1 - \beta E\left[\frac{u'_{cm,+1}}{u'_{cm}}[(1-\tau_{k,+1})r_{+1} + 1 - \delta]\right] \end{bmatrix} \tag{3.1}$$

where, x_{t+n} is a k-dimension vector with realizations in period $t+n$, b_0 is an l-dimension vector of unknowns. Then, according Hansen and Singleton (1982),

$$u_{t+n} = h(x_{t+n}, b_0) \tag{3.2}$$

this can be interpreted as the error term of a regression in which,

$$E_t[u_{t+n}] = 0$$

then, let z_t be a q-dimension vector which contains instruments available in the information set. We can define a function f as,

$$f(x_{t+n}, z_t, b) = h(x_{t+n}, b) \otimes z_t \tag{3.3}$$

where the dimension of f is $r = m * q$, and $\otimes$ is the Kronecker product, then it is direct that,

$$E[f(x_{t+n}, z_t, b)] = 0 \tag{3.4}$$

with the r orthogonality conditions defined in (3.4) it is possible to obtain a vector of parameters given that $r \geq l$.

We use (3.4) to build an objective function which depends only on observable variables, defined as,

$$g_0(b) = E[f(x_{t+n}, z_t, b)] \tag{3.5}$$

then, the method of moments estimator of (3.5) is,

$$g_T(b) = \frac{1}{T}\sum_{t=1}^{T} f(x_{t+n}, z_t, b) \tag{3.6}$$

however, the objective function proposed by Hansen and Singleton is given by,

$$J_T(b) = g_T(b)' W_T g_T(b) \tag{3.7}$$

where W_T is a $r * r$-dimension weighting matrix, symmetric and positive definite. Matrix W_T is an estimate of W_0, the latter is defined as,

$$W_0^* = S_0^{-1}$$
$$S_0 = \sum_{j=-n+1}^{n-1} E[f(x_{t+n}, z_t, b_0) f(x_{t+n-j}, z_{t-j}, b_0)']$$

and the corresponding variance covariance matrix is,

$$(D_0' W_0^* D_0)^{-1}$$
$$D_0 = E\left[\frac{\partial h}{\partial b}(x_{t+n}, b_0) \otimes z_t\right]$$

Hansen and Singleton (1982) propose estimators for W_0 and D_0. However the superiority of the results obtained by alternative estimation techniques, e.g. Newey and West (1987; 1994) and Andrews and Monahan (1992) is known. There is also a broad literature about the estimation of HAC[6] matrices. For this matter, we follow Andrews and Monahan (1992) who propose the following steps:

1. The conditions obtained in (3.3) are pre-whitened by means of a VAR[7]
2. The VAR residuals are used to compute a standard HAC estimator using kernels[8]
3. The estimator obtained for W_0 is recolored with the parameters estimated in the first step.

After computing the estimators for W_0 and D_0, we proceed to estimate b in two steps. First, we obtain an estimator for W_0 with a starting sub-optimal identity weighting matrix. Second, this initial matrix is replaced by

[6]Heteroskedasticity and Autocorrelation Consistent.

[7]Vector Auto Regression.

[8]We alternatively used Quadratic Spectral and Parzen kernels, the results do not differ significatively. In this paper we present those obtained with the latter option.

that computed according to Andrews and Monahan, obtaining ultimately an estimator of b.

Given the data availability, the parameters included in this procedure are:

$$b = \{\theta_m, \beta, \delta\} \tag{3.8}$$

3.3.2 Results

After exploring a wide array of different alternative combinations of instruments[9] (including lagged exogenous and endogenous variables), we obtained estimates for the parameters in (3.8).

Table 3 shows some of the explored combinations of instruments. In all cases (even those not shown here) we reject the null hypothesis of fulfillment of over-identifying restrictions and, accordingly, reject the orthogonality between instruments and the "error" term given by (3.2). In short, the data rejects the structural model.

When comparing the parameters estimated by GMMIV with those obtained by Unconditional Calibration, we find that β is not considerably different between methodologies. In the case of δ, the value obtained by GMMIV is higher than 10% (in average), above the one calibrated by Chumacero et al., only comparable with their 6% in the particular case of the 9th set of instruments $(\tau_{m,-2}, p_{-2}, r_{-2})$. There are important differences in the estimation of θ_m. The result obtained by GMMIV is more than three times higher than the one corresponding to UC, this is found across all the different combinations of instruments.

In order to facilitate the display of results, from here on we will show only those obtained using GMMIV with the first combination of instruments $(\tau_{m,-1}, p_{-1}, r_{-1})$.

3.4 EDF Calibration

Here we briefly describe the methodology proposed by Gallant (2001) and used in order to obtain certain deep parameters of the model described in section 2. The resulting parametrization is also shown.

[9] Always including a constant among them, in order to assure that the Euler equations are satisfied just as shown in (2.5).

	Instruments	β	θ_m	δ	*J-stat*	*Prob*
1	$\tau_{m,-1}, p_{-1}, r_{-1}$	0.978	0.973	0.103	25.774	0.002
		(0.000)	(0.002)	(0.002)		
2	$\tau_{m,-2}, p_{-1}, r_{-1}$	0.977	0.998	0.119	22.139	0.008
		(0.000)	(0.002)	(0.001)		
3	$\tau_{k,-1}, p_{-1}, r_{-1}$	0.975	0.882	0.144	70.843	0.000
		(0.000)	(0.005)	(0.002)		
4	$\tau_{k,-1}, p_{-1}, r_{-1}$	0.978	0.987	0.119	31.221	0.000
		(0.000)	(0.005)	(0.003)		
5	$\tau_{c_m,-1}, p_{-1}, r_{-1}$	0.971	0.896	0.137	47.085	0.000
		(0.001)	(0.007)	(0.003)		
6	$\tilde{r}_{-1}, p_{-1}, r_{-1}$	0.976	0.900	0.154	71.789	0.000
		(0.000)	(0.005)	(0.002)		
7	$\tilde{r}_{-2}, p_{-1}, r_{-1}$	0.974	0.942	0.127	68.262	0.000
		(0.000)	(0.006)	(0.002)		
8	$\tau_{m,-1}, p_{-2}, r_{-1}$	0.976	0.921	0.254	292.876	0.000
		(0.000)	(0.003)	(0.001)		
9	$\tau_{m,-2}, p_{-2}, r_{-2}$	0.965	0.927	0.049	22.751	0.007
		(0.000)	(0.002)	(0.001)		
10	$\tau_{m,-1}, p_{-2}, r_{-2}$	0.971	0.963	0.025	149.014	0.000
		(0.000)	(0.001)	(0.001)		

Table 3: GMMIV Estimation Results (standard errors in parenthesis)

3.4.1 Methodology

Although data has rejected the model in the previous section (by definition this is conditional on the available data set), nonetheless there are reasons suggesting that it would be desirable to rely on a structural model. According to Gallant some of these reasons arise beyond the scope of the available data. In contrast with a reduced form model, which usually performs well in terms of in-sample goodness of fit but not so well out of sample, internal consistency could make structural models superior where there is no available data.

Methods based on specific moments are widely used and have intuitive appeal however, according to Gallant suffer from three criticisms:

1. the moments that they rely on could easily not exist,
2. calibrations are not invariant to changes of scale of measurement in the data,
3. calibrations are not objective because they are based on a researcher's individual preferences.

This criticism could be overcome if one matched to a collection of bounded moments instead of a subjective selection made by the researcher. Oppositely this should be done under an objective rationale invariant to changes in scale of measurement. These considerations underlie the proposal of Gallant which is based on step functions, defined as $r_u(y) = I_{(-\infty,u]}(y)$, or equivalently,

$$r_u(y) = \begin{cases} 0 & \text{if } y < u \\ 1 & \backsim \end{cases},$$

where $y \in \Re^d$ and $(-\infty, u]$ is a rectangle in $\Re^d$. Thus, the calibration proposed implies choosing parameters in order to match the moments of step functions for some values of u. The author states the equivalence of this procedure to matching the empirical distribution of the data $\hat{F}_n(u)$ to the distribution implied by the model $F(u|b_0)$, where the latter can be obtained by simulation. Matching simultaneously the whole collection $\{r_u\}_{u\in\Re^d}$ can be achieved by minimizing $||\hat{F}_n(u) - F(u|b_0)||$ respect to some norm $|| \centerdot ||$, e.g. Euclidean. Given this, the calibration $\hat{b_0}_n$ (named *EDF Calibration*) is the one that minimizes the sample objective function defined as,

$$s_n(b_0) = \frac{1}{n}\sum_{t=1}^{n}[\hat{F}_n(y_t) - F(y_t|b_0)]^2. \tag{3.9}$$

As said before, EDF calibration has intuitive appeal when the structural model is rejected by the data (as in the case shown in Section 3.3.2). Alternatively, when the structural model fits the data well there are other options such as simulated maximum likelihood, efficient method of moments, simulation based Bayesian methods, simulated method of moments, among others[10].

Minimizing (3.9) is not trivial, since $s_n(b_0)$ is not a smooth function on b_0 due to the indicator functions in the definition of $\hat{F}_n(y_t)$ and $F(y_t|b_0)$. Solving this problem is even more complex if the simulation process adds discontinuities or relies on discretizations (e.g. Markov chains). Having said this, it turns out to be useful to smooth the distributions before the optimization of (3.9) is carried out, then it is advisable to proceed recursively by solving the smoothed problem and using this solution as the starting value to solve the original problem (or the one smoothed on a lower degree).

The smoothing process suggested by Gallant is the quadratic squasher from the neural net literature. Given the distribution function,

$$S(u) = \frac{u^2 + u|u| + 2u + 2|u| + 4}{2u^2 + 4|u| + 8}$$

the quadratic squasher approximates the logistic distribution and is less costly in computing. Its scaled version is defined as,

$$S_\sigma(u) = S\left(\frac{u}{\sigma}\right) \tag{3.10}$$

where σ is the smoothing parameter, the function is symmetric in the sense that $S_\sigma(-u) = 1 - S_\sigma(u)$ and satisfies

$$\lim_{\sigma \to 0} S_\sigma(u) = \begin{cases} 0 & u < 0 \\ 1/2 & u = 0 \\ 1 & u > 0 \end{cases} .$$

Then, a smooth approximation to the empirical distribution $\hat{F}_n(y)$ is

$$\hat{F}_{\sigma,n}(v) = \frac{1}{n}\sum_{t=1}^{n}\prod_{i=1}^{d} S_\sigma(v_i - y_{it}),$$

[10]For a complete survey of methods see Gallant (2001).

by replacing this last expression into (3.9) the function to be minimized can be obtained.

As said above, the optimization process is not direct. It involves a sequential procedure, solving each time a less-smoothed version of the original problem. Each one of these sequences takes a considerable amount of computer time given the granularities present in the data, leading to divergence in some cases. In order to illustrate the sequence and the associated computing costs, we present the optimization algorithm:

1. Compute the unconditional empirical distribution function for the observed series[11] $\{y_{it}\}$ with an initial smoothing parameter $\sigma = 0.1$.
2. Solve the model[12] with an initial vector of parameters b_0, obtaining an estimate for the policy function.
3. Use the approximation to simulate series $\{y_{iS}|b_0\}$ of length S ($S = 1000$ in this case) with a Cholesky covariance matrix for the shocks.
4. Compute the conditional EDF of the simulated series $\{y_{iS}|b_0\}$.
5. Calculate the norm between the EDFs obtained in steps (1) and (4).
6. Iterate on steps (1) to (5) until parameter convergence is achieved on the norm[13].
7. Iterate on steps (1) to (6) reducing the smoothing parameter, using each time the previous vector of parameters found on convergence. Eventually solve the original problem without smoothing.

3.4.2 Results

In this particular case the focus when estimating parameters using EDF calibration will be on real exchange rate (according to the current notation it can also be expressed as $1/p$), using it as $\{y_{it}\}$. This choice is conditioned by data availability and supported by the nature of this variable, being this

[11]In this paper we setup a univariate version, however, EDF permits multivariate cases as well.

[12]In this particular case with a first order approximation.

[13]It took 72 hours for a PC processor of 2.4Mhz and 2Gb of RAM reaching to this point. Following iterations with smaller smoothing parameters took 36 hours in average.

a relative price which reflects the equilibrium between non tradable and importable goods markets it can be understood as a variable that summarizes the conditions which satisfy both goods and inputs markets. As said before, this univariate case can be trivially turned into a multivariate one when the required data is available.

Following the methodology outlined above, we can obtain the unconditional EDF for the actual RER data according to (3.10). In figure 1 we show the EDFs with and without smoothing, the latter is achieved using the quadratic squasher (dashed line in the figure).

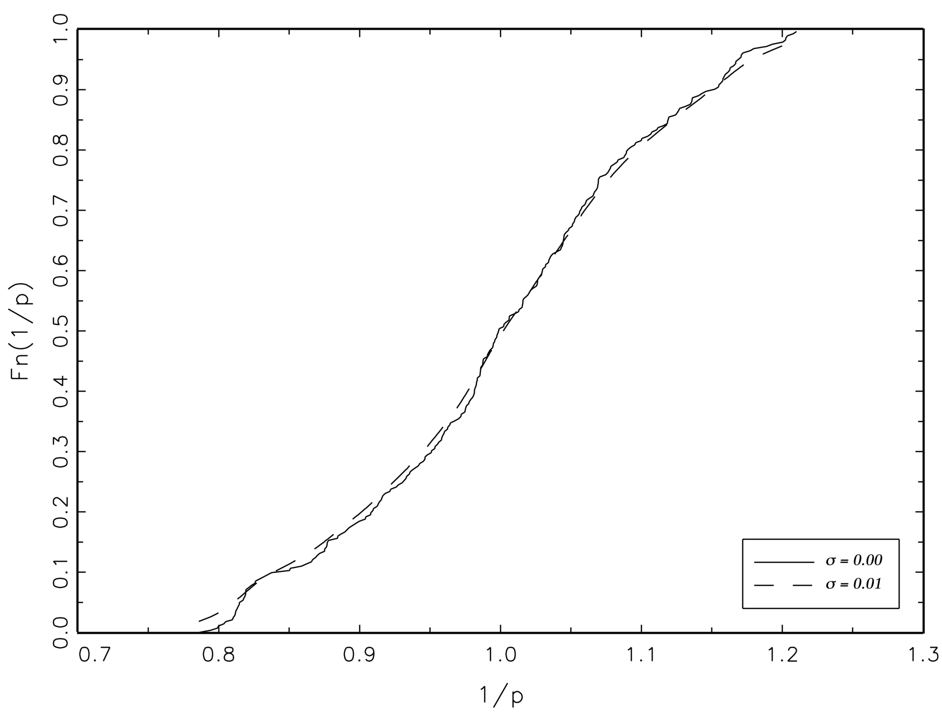

Figure 1: Real exchange rate EDF with ($\sigma = 0.01$) and without ($\sigma = 0$) smoothing

The vector of parameters b_0 for EDF calibration contains twelve elements and is given by,

$$b_0 = \{\beta, \theta_m, \delta, \alpha_m, \alpha_x, \alpha_n, \rho_m, \rho_x, \rho_n, \sigma_m, \sigma_x, \sigma_n\},$$

in order to minimize (3.9) we proceed sequentially as described before. Simulations with the structural model are carried out with an initial vector of parameters b_0 given by the unconditional calibration (UC) proposed by Chumacero et al.. With this setup we simulate 1000 observations. We begin smoothing the objective function with $\sigma_1 = 0.1$, the resulting vector of parameters obtained after convergence is $\hat{b}_1$. The latter is then used as initial value to minimize the smoothed objective function with $\sigma_2 = 0.01$, the resulting vector of parameters is called $\hat{b}_2$, and so on. The results shown here are those obtained using $\sigma_3 = 0.001$, with which $\hat{b}_3$ was obtained.

In figure 2 we show the EDFs corresponding to actual RER data (smoothed with $\sigma_3 = 0.001$) and to artificial series simulated with the model described in Section 2 evaluated at $\hat{b}_3$.

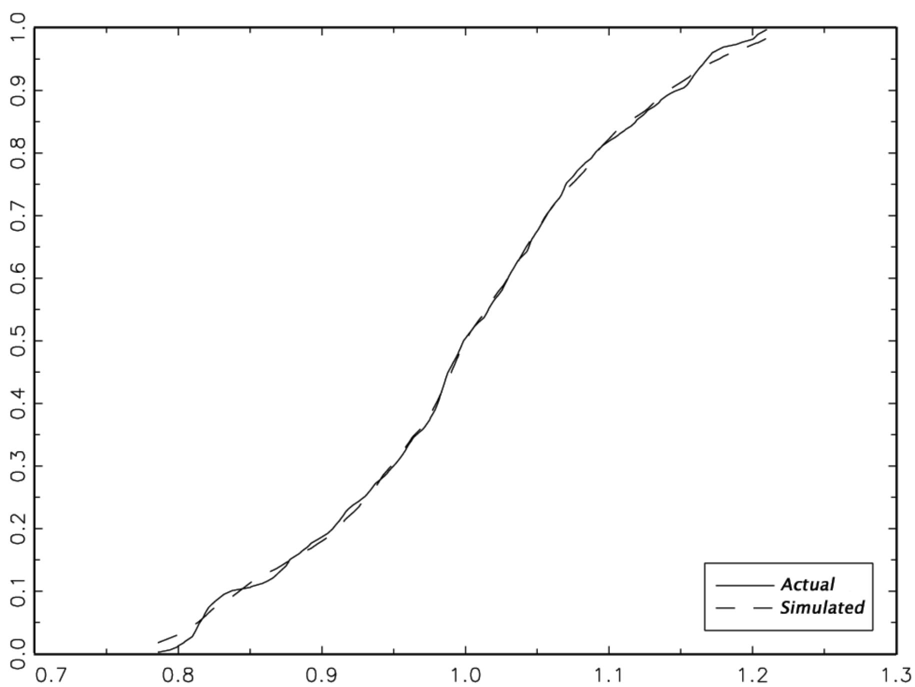

Figure 2: Real exchange rate simulated and actual EDFs, smoothed with $\sigma_3 = 0.001$

The vector of parameters estimated by EDF calibration (which underlie the simulation shown in Figure 2) are shown in Table 4. We have also included columns $EDF(\sigma_i)$ and $EDF(\sigma_i, \rho_i)$ which are analogous to EDF in methodological terms, their only difference being the vector of parameters used in each case. Meanwhile the EDF column considers the whole vector of parameters (including those related to preferences, depreciation rate, elasticities, shock volatility and persistence), $EDF(\sigma_i)$ and $EDF(\sigma_i, \rho_i)$ estimate a subset of this vector, the former only considers shock volatilities, while the latter adds shock persistence. The remaining parameters are set equal to those obtained by unconditional calibration (Chumacero et al.). This restricted setup intends to isolate the effect of these parameters (σ_i and ρ_i) on the fit achieved between unconditional and conditional empirical distribution functions. Results show that when fixing most of the parameters to their UC values, EDF estimated volatilities (σ_i) shown in columns named $EDF(\sigma_i)$ and $EDF(\sigma_i, \rho_i)$ grow noticeably compared to those obtained under unconstrained estimation. This suggests that UC (with smaller volatility coefficients) should fit poorly the unconditional EDF of real exchange rate (we carry out this exercise below).

In the last two rows of Table 4 we included the J statistic and the p-value corresponding to the over-identification null hypothesis. As reported before by the GMMIV results in Table 3, the model is rejected by the data under the GMMIV parametrization, as expected the same happens with UC and EDF parameterizations. When evaluating the moments in (3.1) at the parameters obtained with both approaches we obtain J-statistics larger than those associated to GMMIV, this is expected since by definition the method of moments delivers the vector of parameters that minimizes this particular metric.

On the other hand, when using these alternative parameterizations on Table 4 to solve the model, simulate RER series and compute the corresponding empirical distribution functions, we obtain further support to our previous finding. In Figure 3 it can be clearly seen how those EDFs computed using parameters from UC and GMMIV are notoriously different from both Effective Calibration (EDF Calibration) and actual data in Figure 2.

In Table 5 we present some stylized facts for both actual and simulated RER under different parameterizations. RER series have been previously normalized with their unconditional mean, hence in the first row they all have mean equal to one. Regarding standard deviation, EDF associated parameterizations are closer to actual data than the other approaches, in particular, RER series simulated from GMMIV results exhibit larger volatility (more than twice) than the actual data. This pattern repeats itself when compar-

Parameter	UC	$GMMIV$	EDF	$EDF(\sigma_i)$	$EDF(\sigma_i, \rho_i)$
β	0.97	0.97	0.99		
θ_m	0.24	0.98	0.27		
α_m	0.50		0.42		
α_x	0.45		0.44		
α_n	0.30		0.35		
δ	0.06	0.10	0.15		
ρ_m	0.90		0.99		0.97
ρ_x	0.90		0.84		0.94
ρ_n	0.90		0.98		0.96
σ_m	0.01		0.31	2.62	2.90
σ_x	0.01		0.07	0.93	0.87
σ_n	0.01		0.11	1.78	1.32
$J - stat$	6601.15	25.77	9586.34		
$Prob$	0.000	0.002	0.000		

Table 4: Summary of parameters

ing skewness and kurtosis, EDF derived results show the smallest distance to actual data and GMMIV the largest, followed by UC. However, in all cases the null hypothesis of normality (Jarque-Bera test) is rejected. First RER autocorrelation is closely replicated by EDF and EDF(σ_i, ρ_i), at a slightly higher distance by EDF(σ_i), this is not surprising since in this approach ρ was restricted to be equal to UC obtained value. Finally, quadratic norm is minimized ($||\,.\,||$) by definition under EDF, closely followed by its restricted versions (EDF(σ_i, ρ_i) and EDF(σ_i)) and further by UC and GMMIV in that order.

In summary, EDF derived parameterizations outperform the alternative approaches under the quadratic norm metric because they are supposed to do so (have been defined to minimize this distance). Accordingly, GMMIV beats all the alternatives when it comes to the J-statistic.

4 Results Comparison

Beyond methodological differences and the expected result of each parametrization "defeating" the others in its own "battleground", the focus of this sec-

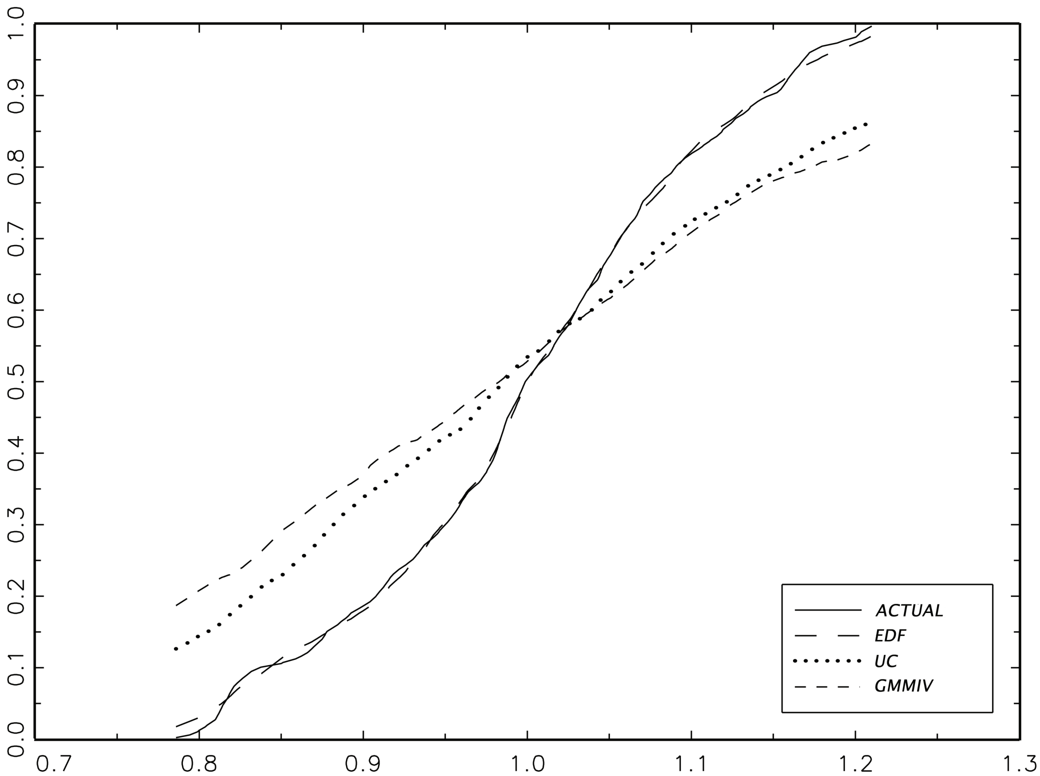

Figure 3: Distribution functions comparison under alternative parameterizations

	Actual	UC	$GMMIV$	EDF	$EDF(\sigma_i)$	$EDF(\sigma_i, \rho_i)$
Mean	1.000	1.000	1.000	1.000	1.000	1.000
Median	0.998	0.986	0.983	1.000	0.996	1.003
Max	1.210	1.748	1.931	1.264	1.356	1.287
Min	0.786	0.571	0.438	0.746	0.737	0.706
S.D.	0.104	0.194	0.238	0.107	0.111	0.108
$Skewness$	-0.097	0.522	0.631	-0.090	0.303	-0.169
$Prob : S = 0$	0.506	0.000	0.000	0.244	0.000	0.029
$Kurtosis$	2.296	3.336	3.550	2.495	3.091	2.718
$Prob : K = 3$	0.016	0.030	0.000	0.001	0.558	0.069
$J.B.$	6.267	50.071	79.043	11.990	15.683	8.104
$Prob$	0.044	0.000	0.000	0.002	0.000	0.017
γ_1	0.981	0.906	0.803	0.947	0.909	0.948
$\|\| \cdot \|\|$		1.0e-2	1.6e-2	5.5e-5	3.4e-4	9.7e-5

Table 5: RER stylized facts under alternative parameterizations

tion is on analyzing the implications that alternative approaches, regarding calibration or estimation, have on resulting long term equilibrium.

Depending on wether or not the equilibrium results are sensitive (and to which extent) to different parameterizations the choice between methodologies can turn into a relevant issue or be subject just to the researcher's preferences.

As discussed above, given the intractability of an analytical resolution, we proceed with a first order perturbation approximation as proposed by Schmitt-Grohé and Uribe (2001) in order to obtain the policy function and compute equilibria before and after the free trade agreements signature.

As our benchmark, in Table 6 we reproduce the long term equilibrium results obtained by Chumacero et al. in their Table 3, these are equivalent to those associated to UC approach in this paper and correspond to differential effects comparing equilibria after/before FTAs. Each row in Table 6 shows a different variable affected by the FTAs, last row corresponds to welfare compensation (expressed in terms of importable and non tradable goods) which should be given to the agents in order to leave them indifferent between their situation before and after the treaties. Each column contains the results to six exercises, first $\Delta\tau_m$ is the effect on the row variables of lower tariffs in Chile, $\Delta\tau_x$ is the effect of a tariff reduction applied by the US and EU, ΔVAT is an increase on value added tax required in order to compensate for lower tariffs, $\Delta\tau_{c_m}$ is the tax response to lowering piracy, Δg is an increase in customs administration costs and ΔTFP is an increase in total factor productivity. The last column on the right contains the combined effect of all the previous exercises.

According to UC parametrization, the FTAs imply an increase slightly over 1% of real product (Y). In general, treaties are welfare improving, associated to an increase in consumption of both importable (c_m) and non tradable (c_n) goods. Exportable (Y_x) and non tradable (Y_n) goods production increases in line with lower tariffs and higher TFP, as importable goods production (Y_m) drops because of higher taxes. Moreover, real exchange rate ($1/p$) slightly appreciates, 0.16%. The largest effect is identified on real imports (M), which grow around 3% in the long term mainly due to lower tariffs.

Var.	$\Delta\tau_m$	$\Delta\tau_x$	ΔVAT	$\Delta\tau_{c_m}$	Δg	ΔTFP	*Combined*
c_m	0.75	0.87	-0.24	-0.39	-0.13	1.04	1.91
c_n	0.09	0.36	-0.29	-0.10	-0.21	0.93	0.80
Y_x	1.52	0.52	-0.52	-0.48	0.00	0.91	1.96
Y_m	0.00	0.00	-0.63	-0.59	0.00	1.00	-0.22
Y_n	0.28	0.22	-0.25	-0.13	0.03	0.76	0.91
p	-1.18	0.50	0.05	0.29	0.08	0.10	-0.16
F	-0.54	0.11	0.61	0.21	-0.18	0.13	0.34
M	1.60	1.18	-0.53	-0.50	0.00	0.91	2.67
C	0.25	0.48	-0.28	-0.17	-0.19	0.96	1.06
Y	0.53	0.26	-0.35	-0.26	0.02	0.82	1.02
TU	0.25	0.48	-0.28	-0.17	-0.19	0.95	1.06

Table 6: Long term equilibrium comparison results: UC parametrization (Chumacero et al.), percentage points over scenario before FTAs

In Tables 7 and 8 we compare the long term results obtained under different parameterizations, the figures are expressed as differences respect to our benchmark approach (UC in Table 6). Starting with Table 7, which compares GMMIV with UC, regarding total production (Y) there is a larger effect on real product of 0.18 percentage point over the UC benchmark (i.e.

under GMMIV parametrization, real product increases 1.2% due to FTAs, instead of 1.02% as stated in Table 6). This is similar to the results obtained in Table 8 when comparing EDF with UC, in this case real product would increase 1.22% in the long run due to the treaties.

Var.	$\Delta\tau_m$	$\Delta\tau_x$	ΔVAT	$\Delta\tau_{c_m}$	Δg	ΔTFP	*Combined*
c_m	-0.14	0.08	-0.12	0.06	-0.09	0.06	-0.16
c_n	-0.74	0.56	-0.25	0.16	-0.88	0.65	-0.53
Y_x	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y_m	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y_n	0.26	-0.21	0.06	-0.05	0.34	-0.25	0.16
p	0.60	-0.48	0.13	-0.11	0.80	-0.57	0.37
F	-0.25	0.13	-0.26	0.11	-0.20	0.15	-0.35
M	-0.06	-0.01	0.01	0.02	0.00	0.00	-0.05
C	0.34	0.46	-0.09	-0.16	-0.05	0.15	0.65
Y	0.35	-0.02	-0.09	-0.15	0.10	-0.02	0.18
TU	0.33	0.45	-0.09	-0.16	-0.05	0.15	0.63

Table 7: Long term equilibrium comparison results: differences between GMMIV-UC, percentage points over scenario before FTAs

Although we find similar results in production between our alternative approaches, there are composition discrepancies. The larger increase of product under GMMIV is mainly due to a setup in which the agents' consumption is more intensive on importable goods (θ_m is more than three times larger in GMMIV than UC), hence the reduction of tariffs has a larger impact on product using the GMMIV parametrization. Unlike the previous case, under the EDF setup it is not so easy associating the difference to a single effect, the discrepancy regarding product is more homogeneous across all six exercises shown in the different columns.

Regarding consumption our results show less coincidences between approaches, according to GMMIV aggregate consumption (C) increases over 1.7% in the long term after the FTAs, almost twice that of UC and EDF. In terms of relative prices, GMMIV suggests a real depreciation meanwhile UC and EDF both point in the other direction (RER appreciation). Finally, UC and EDF coincide respect to welfare effects indicating that the FTAs would increase welfare over 1%, GMMIV suggests that the treaties have a larger effect on total utility, closer to 2%.

Var.	$\Delta\tau_m$	$\Delta\tau_x$	ΔVAT	$\Delta\tau_{c_m}$	Δg	ΔTFP	*Combined*
c_m	-1.75	0.34	0.92	0.73	-0.46	0.25	0.06
c_m	-1.22	0.39	0.49	0.47	-0.52	0.37	0.00
Y_x	-0.07	-0.02	0.02	0.02	0.00	-0.02	-0.07
Y_m	0.00	0.00	0.17	0.15	0.00	-0.13	0.19
Y_n	-0.21	0.03	0.16	0.11	0.04	0.00	0.14
p	-0.52	-0.05	0.43	0.27	0.06	-0.12	0.06
F	-0.44	0.09	-0.02	0.17	-0.13	0.08	-0.25
M	-0.23	-0.06	0.05	0.06	0.01	-0.02	-0.19
C	-1.35	0.39	0.61	0.53	-0.50	0.34	0.05
Y	0.07	0.05	0.05	0.01	0.01	0.01	0.20
TU	-1.36	0.38	0.61	0.53	-0.50	0.33	0.05

Table 8: Long term equilibrium comparison results: differences between EDF-UC, percentage points over scenario before FTAs

5 Conclusions

In this paper we attempt to shed light on one of the currently open research avenues in DSGE models literature, the one that relates with how to determine the value of parameters that define preferences and technology (also known as deep parameters).

Among many choices often faced by researchers, there is one related to which methodology to employ to obtain the parameters needed to solve and simulate structural or reduced-form models. There is available a wide array of alternative methods to accomplish this task, each one with weaknesses and strengths, each one satisfying different objectives.

Our findings obtained from comparisons between different parameterizations, derived from alternative approaches, indicate that the composition of effects associated to implementation of FTAs is not neutral to this choice. The differences found between long term equilibria are to a great extent related to discrepancies in use and consumption elasticities resulting from different methodologies. However, results coincide in many cases regarding aggregate effects on certain variables of interest, and they all suggest that FTAs are welfare improving, independent of the chosen approach.

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