Commodity Price Risk Management and Fiscal Policy in a Sovereign Default Model

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*The opinions expressed in this presentation are the authors' own and do not reflect the view of Banco de Mexico or its Board of Governors.

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Introduction

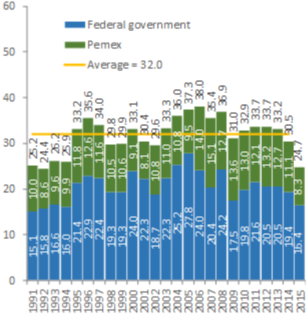
- Prices of commodities are an important driver of public finances and the business cycle in commodity exporting economies (Medina, 2010; Spatafora and Samake, 2012; Cespedes and Velasco, 2014).
  - Moreover, procyclicality of fiscal policy exacerbates fluctuations in economic activity (Villafuerte and L. Murphy, 2010; Pieschacon, 2012).
- This motivates the relevance of mechanisms that contribute to improve the stability of public finances and to make fiscal policy less procyclical and the business cycle less volatile.
- Different instruments to mitigate the impact of fluctuations in prices of commodities: sovereign funds, fiscal rules, financial derivatives (Borensztein et al., 2013; Caballero and Panageas, 2008).

Introduction

We motivate our model with the case of Mexico, where public revenues are reliant on oil related proceedings (approx. 1/3 of the total during the last decade), but results applicable to any commodity-exporter:

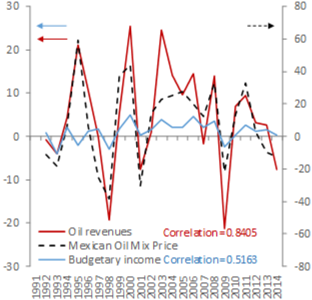
- Mexico has implemented policies to smooth the impact of oil price fluctuations: establishing a sovereign fund and the use of derivatives to cover the risk of oil prices.
- In 2009 these strategies allowed to offset negative effects of oil price drop: total oil revenues were 143.1 billion pesos (B.P.) lower than the revenues approved by Congress, from hedging strategy the public sector received 64.4 B.P., the federal govt. extracted 75 B.P. from Federal Oil Revenue Stabilization Fund (FEIP).
- The use of both strategies implied a loss of oil revenues of only 3.8 B.P., 2.7% of the revenue loss that the government would have incurred otherwise.

Oil Revenues/Budgetary Income
percentage



a: Observed data to August 2015.
Sources: Ministry of Finance and Ministry of Energy

Oil Revenues, Oil Price and Budgetary Income
real annual growth rate %



Introduction

We extend a standard model of sovereign default (Cuadra et al., RED 2010; Tavares, 2015) introducing stochastic endowment/revenues.

- The model provides a formal structure to understand the mechanisms through which shocks to commodity prices affect fiscal policy and economic activity.
- Govt. expenditure, the tax rate, level of debt and default decisions are endogenous variables controlled by the government.
- We evaluate the consequences of the utilization of instruments that moderate fluctuations in commodity-related revenues:
  - *business cycle behavior:* quantify the reduction of volatility in macroeconomic variables and lower correlation w.r.t. commodity prices,
  - *event analysis:* evolution of macroeconomic variables in front of large drop in commodity prices, comparing baseline scenario with the *risk-hedging economy*,
  - *welfare exercises:* calculations of how much the government is willing to pay for this type of insurance.

Outline of Model

A brief description of the model:

- features endogenous govt. expenditure, tax rates and debt levels as well as a default decision,
- representative household values govt. expenditures, private consumption and leisure (transmission channel: tax rate distorts household labor supply),
- stochastic endowment of commodity-revenues (fluctuations in prices, quantity is fixed),
- international lenders determine price of debt according to probability of default.

Household Preferences

Representative household preferences:

$$\mathbb{E}\left[\sum_{t=0}^{\infty} \beta^t\, u(c_t, g_t, 1 - l_t)\right]$$

where the per period utility function is:

$$u(c, g, 1 - l) = \pi\,\frac{g^{1-\sigma}}{1-\sigma} + (1-\pi)\,\frac{\left(c - l^{1+\psi}/(1+\psi)\right)^{1-\sigma}}{1-\sigma}$$

the household values private consumption c, public expenditures g and leisure $1 - l$.

Production Technology and Household Problem

Production technology:

- Tradable good produced using labor w/production technology $y_t = a_t f(l_t)$.
- Productivity evolves according to a transition matrix denoted by $\Lambda(a' \mid a)$, discretized AR(1) process.

Household problem:

- Private consumption is taxed by the government (transmission channel), the household makes decisions based on the budget constraint $(1+\tau)\, c_t = a_t f(l_t)$.
- Static optimal decision $\{c^*(a,\tau), l^*(a,\tau)\}$: government sets taxes, then household decides on labor supply. With the specified utility function $l^* = (a/(1+\tau))^{1/\psi}$.

Government Problem: Access to Credit Markets

The (benevolent) government decides on borrowing b', government expenditure g, the tax rate τ and debt default:

$$v_c(b, a, z) \quad = \max_{\{g, b', \tau\}} u(\cdot) + \beta \sum_{\{a', z'\}} \Lambda(a' \mid a)\, \Gamma(z' \mid z)\, \underline{v}(\cdot)$$

s.t. govt. budget constraint $g = \tau\, c + (b - q(b', a, z)\, b') + x$ and $\{c^*(\tau, a), l^*(\tau, a)\}$ (intra-period optimal household decision).

- Oil-revenues $x = \theta \cdot z$ evolve according to a transition matrix for the price process denoted by $\Gamma(z' \mid z)$ (no fluctuations in quantity θ).
- The decision to default is: $\underline{v}(b, a, z) = \max\{v_c(b, a, z), v_d(a, z)\}$.

Government Problem: Fiscal Policy Trade-Offs

The alternative govt. policies face different (standard) trade-offs:

- g (govt. expenditures) generates utility, but has to be financed with distortive taxes τ or debt b',
- τ (tax rate) can generate more income for govt. expenditures, but distorts private sector production (lowers consumption),
- b' (debt) allows to increase spending, but has to be paid in next period and can get economy close to default,
- default gets rid of debt obligations for the govt. (no recovery in this version), but implies exclusion from financial markets (loss in terms of capacity to smooth shocks) and efficiency loss in aggregate productivity.

Government Problem: Under Default

When govt. defaults, loses access to international credit markets, thus GBC is $g = \tau\, c + x$:

$$v_d(a, z) = \max_{\{g,\,\tau\}} u(\,\cdot\,) + \beta \sum_{\{a',\,z'\}} \Lambda(\,\cdot\,)\,\Gamma(\,\cdot\,)\left\{\mu\,\underline{v}(\,\cdot\,) + (1-\mu)\,v_d(\,\cdot\,)\right\}$$

takes as given decisions of the household $\left\{c_d^*(\tau, a), l_d^*(\tau, a)\right\}$, regains access to financial markets with probability μ.

During default, loss in aggregate productivity represented by function $h(a) \leq a$.

International Lenders and Interest Rates

Price of sovereign bonds determined by no-arbitrage condition w/stochastic disc. factor $M(a', a) = \exp(-\vartheta\, \varepsilon' - \frac{1}{2}\, \vartheta^2\, \sigma_a^2)$, and $\vartheta = \alpha + \delta \log a$, where ε is the shock to the aggregate productivity:

$$q(b', a, z) = \sum_{\{a', z'\}} M(a', a)\, \Lambda(\,\cdot\,)\, \Gamma(\,\cdot\,)\, (1 - d(b', a', z'))/(1 + r_f)$$

where international risk free rate is r_f, $d(b', a', z')$ equals to one in the states where the government defaults and zero otherwise.

Stochastic discount factor based on Arellano and Ramanarayanan (JPE 2012), motivated by the observation that spreads in emerging markets are higher during times of high risk aversion for international investors.

Table 1. Predetermined Baseline Parameters.

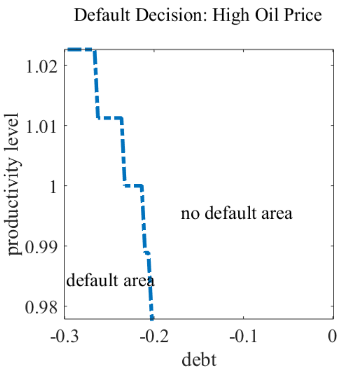
description of parameter	parameter	value
risk aversion	σ	2.00
discount factor	β	0.85
labor elasticity	ψ	1/2.2
risk free interest rate	r_f	0.02
financial markets re-entry probability	μ	1/3
loss of aggregate productivity in default	ϕ	0.99
stochastic discount factor parameter	δ	-141
stochastic discount factor parameter	α	11
autocorrelation oil price	ρ_z	0.940
volatility oil price shocks	σ_z	0.230
autocorrelation aggregate productivity	ρ_a	0.900

Calibration and Targets: Mexico

- π governs the extent to which the planner is willing to distort the economy through taxation to provide govt. exp., target is the total average consumption and labor tax wedge (Anton-Sarabia, 2005).
- cost of default function $h(a) = a - \omega$ when $a \leq \phi\, \bar{a}$, where ϕ is a parameter and $\bar{a}$ is the unconditional mean of productivity, we set ω to match the ratio of broad public sector debt to output for Mexico during the period 2004-2014,
- θ is set to match the average ratio of government oil-related revenues to total output during the period 2004-2014,
- σ_a drives aggregate volatility in this economy, the target is the volatility for consumption (logged and detrended, H-P filter, Mendoza, 2010),
- we modify matrix $\Gamma(z' \mid z)$ by adding probability to large drops in oil prices for the two top levels (by as much as 0.35).

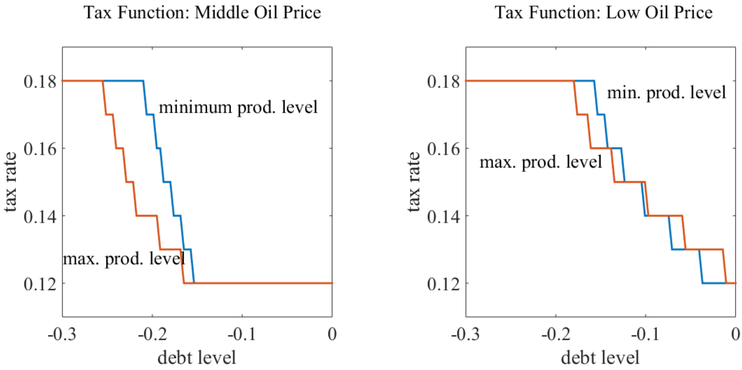
Table 2. Baseline Calibration.		
description of parameter	parameter	value
utility weight on govt. expenditures	π	0.500
loss of aggregate productivity in default	ω	0.051
average level of govt. oil revenues	θ	0.074
probability large oil drops	λ	0.350
volatility aggregate productivity shocks	σ_a	0.005
target statistics	data	model
average total tax wedge	0.155	0.156
average level govt. oil revenues/output	0.081	0.081
volatility of consumption	3.397	3.710
average debt/output ratio	0.241	0.236
frequency large oil drops (per decade)	see text	see text

Fig. 1: Default Decisions as a Function of Debt, Agg. Productivity and Oil Price



Default is more likely with more debt (more negative), lower productivity and lower oil prices.

Fig. 2: Tax Rate as a Function of Debt, Agg. Productivity and Oil Price



Taxes are higher with more debt (more negative), lower productivity, lower oil prices.

Financial Instruments

Selling forward (Borensztein et al., JDE 2013):

- the price for commodity is set one year in advance at *the conditional expected price*, if the price of oil in period t is z, oil revenues in period $t+1$ will be given by $s(z)\,\theta$,
- θ is the constant quantity produced, price $s(z)$ is set as the expected value for period $t+1$ with the information that is known at period t: $s(z) = \sum_{\{z'\}} \Gamma(z' \mid z)\, z'$.

Sale options:

- gives the government the right to sell at a given price,
- oil revenues are given by $x' = \theta \cdot \max\{z', s(z)\}$, we set the strike price at $s(z) = \sum_{\{z'\}} \Gamma(z' \mid z)\, z'$.

Commodity-Indexed Bonds

Brief description of commodity-indexed bonds:

- coupon and/or principal payments to the bearer of the bond are function of the price of a stated amount of the reference commodity,
- in our model specification the bond pays (in the case of no default) in the next period $\nu \cdot 1$ (fixed payment) plus $(1 - \nu) \cdot z$ (variable payment indexed to the price of the commodity z); $\nu \in [0, 1]$ determines degree of indexation,
- previous sovereign experience: in Mexico and Venezuela (petro-bonds and Brady Plan, see Durdu, JEDC 2009).

Outline of Results

We evaluate consequences of the utilization of different financial instruments that can moderate fluctuations in commodity-related revenues:

- *business cycle behavior:* quantify the reduction of volatility in macroeconomic variables and lower correlation w.r.t. commodity prices,
- *event analysis:* evolution of macroeconomic variables in front of large drop in commodity prices, comparing baseline scenario with the *risk-hedging economy*,
- *welfare exercises:* calculations of how much the government is willing to pay for this type of insurance.

Table 3. Business Cycle Moments: Standard Deviations.					
standard deviation *log-detrended w/HP filter*	base model	no oil shocks	indexed bonds	forward sale	sale option
production output	0.029	0.023	0.028	0.026	0.028
consumption	0.037	0.027	0.034	0.032	0.036
govt. expenditures	0.084	0.039	0.070	0.059	0.081
labor	0.026	0.019	0.024	0.022	0.025
tax rate	0.020	0.007	0.019	0.019	0.020
trade balance/total output	0.010	0.009	0.022	0.017	0.014

We quantify the reduction in the volatility of different macroeconomic variables.

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Table 4. Business Cycle Moments: Correlations.					
correlation *log-HP filter*	base model	no oil shocks	indexed bonds	forward sale	sale option
oil price-tax rate	-0.816	−−	-0.323	-0.540	-0.658
oil price-govt. exp.	0.853	−−	0.265	0.586	0.725
govt. exp.-total output	0.935	0.906	0.707	0.852	0.913
tax rate-prod. output	-0.782	-0.658	-0.699	-0.696	-0.780
tax rate-total output	-0.878	-0.659	-0.670	-0.739	-0.830

We quantify the reduction in the correlation of macroeconomic variables with the price of oil.

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Event Analysis

We conduct an event analysis (e.g., similar to sudden stops analysis in Mendoza, AER 2010) for drops in oil prices, which consists of:

- five-year event windows, centered on drops of oil prices (period $t = 0$), when oil prices are at or above the long-run average,
- we compare what happens in the baseline model and when we introduce different financial instruments.

Fig. 3: Baseline and Forward Selling Models

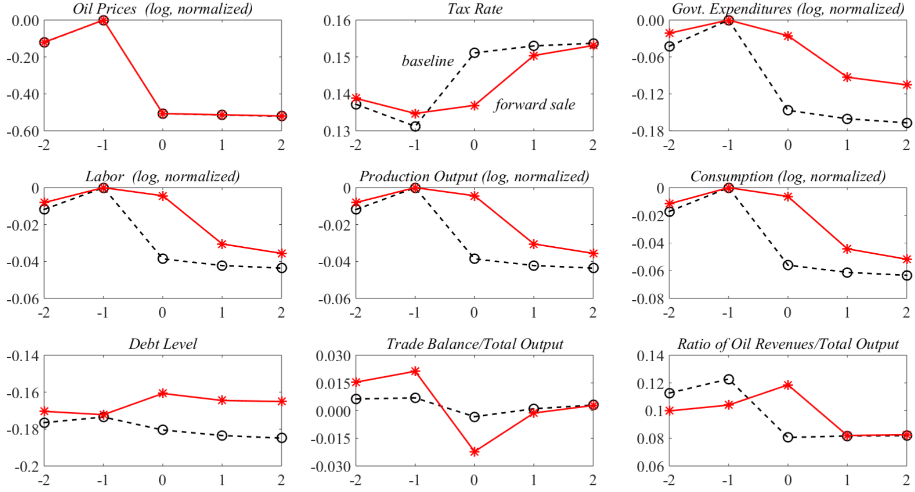
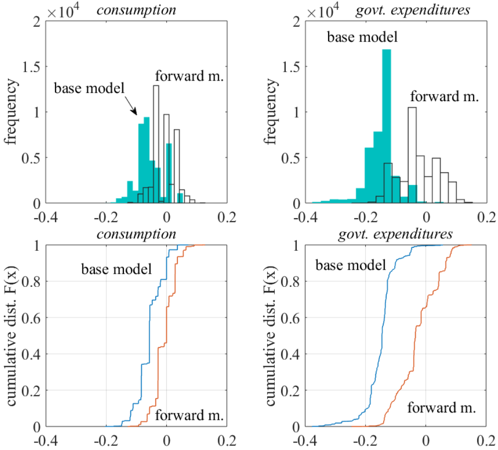


Fig. 4: Changes in Consumption and Govt. Expenditures Generated by the Fall in Oil Prices



Welfare Calculations

How much is the (benevolent) government willing to pay to reduce fluctuations in commodity revenues?

- Simulate and compute average welfare of <u>baseline</u> model.
- Simulate and compute average welfare of <u>alternative</u> scenario (e.g. no volatility, or with access to financial instrument).
- Welfare in <u>alternative</u> scenario is higher, reduce θ (fixed quantity of commodity revenues) until welfare is the same (reaches indifference).

Welfare Calculations: Discussion

The results are the following (interpretation similar to literature on the cost of business cycle):

- Financial instruments partially reduce volatility, the government is willing to pay approx. 5 percent of oil revenues in the case of options.
- Different instruments imply different costs: liquidity costs, designing a new instrument and setting up a new market, etc. (we do not introduce these costs directly in the model).
- Further caveats: transition can be costly if it implies reducing the debt levels (as is the case for indexed bonds).
- The determination of the debt level is key to determine welfare (Borensztein et al., NBER 2015).

Conclusion

We have exploited a sovereign default model to quantify the consequences of using financial instruments that moderate fluctuations in commodity-related revenues:

- *business cycle behavior:* quantify reduction of volatility in macroeconomic variables and correlation w.r.t. commodity prices,
- *event analysis:* evolution of macroeconomic variables in front of large drop in commodity prices (different scenarios),
- *welfare analysis:* discussion of welfare estimations and its limitations.

Some questions still (after some debate) on the table:

- systematic use of financial instruments by Mexico, but use in other emerging economies seems lower than what theory would prescribe (political frictions/risk, liquidity...)
- we have focused on one transmission channel (fiscal policy), alternative financial transmission: impact of interest rates on non-primary production sector.

Table 5. Business Cycle Moments: Averages.					
average (levels)	base model	no oil shocks	indexed bonds	forward sale	sale option
government expenditures	0.157	0.158	0.158	0.158	0.162
private consumption	0.628	0.628	0.630	0.630	0.635
tax rate	0.157	0.156	0.155	0.155	0.153
debt/total output ratio	-0.236	-0.253	-0.164	-0.209	-0.230

No significant changes in average levels in variables that determine utility (e.g., govt. expenditures), debt-level can be reduced (an unfavourable position in forwards, for example, can induce default as govt. reneges on all financial obligations).

Fig. 5: Baseline and Option Selling Models

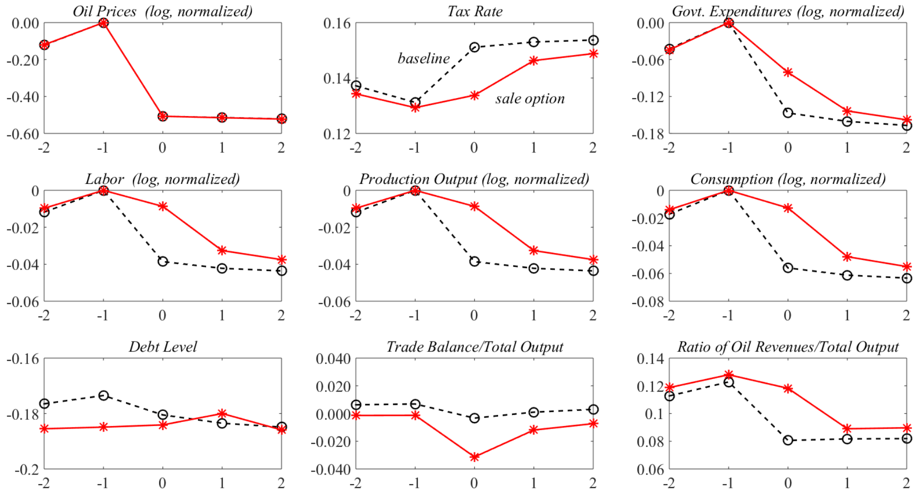


Fig. 6: Baseline and Indexed Bond Models

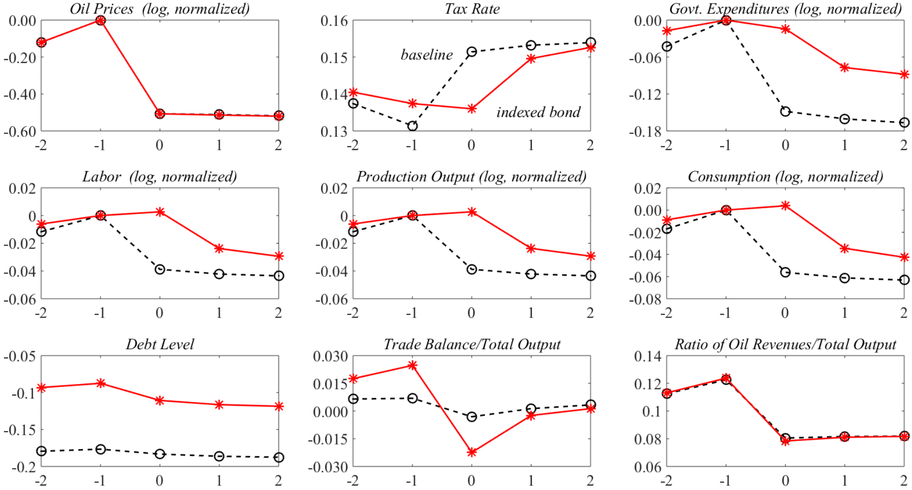


Fig. 7A: Properties of Indexed Bond Model

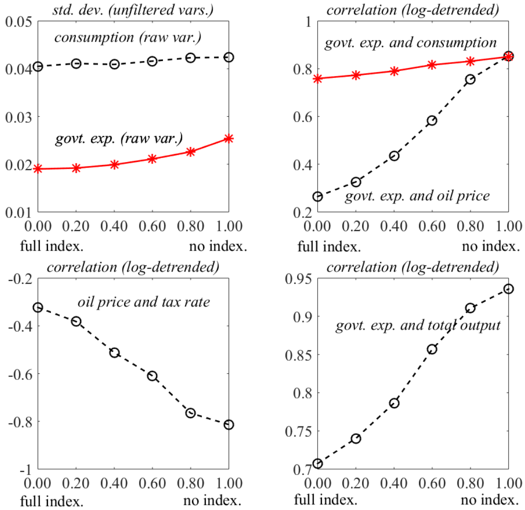
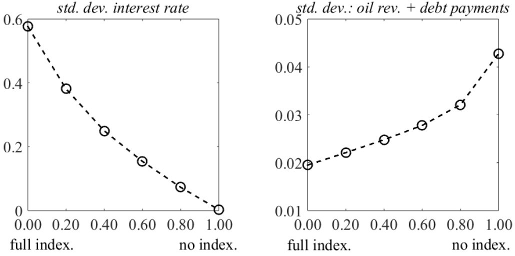


Fig. 7B: Properties of Indexed Bond Model



- Schmitt-Grohé and Uribe (2015) estimate that terms of trade shocks account for approximately 12 percent of consumption volatility and 17 percent of output volatility in the case of Mexico (their Table 2).
- Pieschacon (2012), also for the case of Mexico, estimates that oil price shocks account for 21.3 percent of the variance of consumption at a 4-quarter horizon (her Table 1), while the shares are 12.5 and 16.8 percent, respectively, for tradable and non-tradable output. The proportions of volatility of consumption and production (non-oil) output explained by oil shocks in our model, approximately 23 and 16 percent, are comparable to these empirical estimates (see Table 3).

- The correlation between tax changes and total output in our model is -0.46, close to the correlation estimated for Mexico by Vegh and Vuletin (2012). In their data, these correlation is driven by value added tax rates (see their Figs. 13 and 14).
- Using the tax-rate data from Anton-Sarabia (2005) for Mexico, for the period 1993-2001 for which different measures of both effective tax rates on consumption and labor income are available, the standard deviation of the sum (represented by the total tax rate in our model), is between 0.013 and 0.022, compared to 0.020 in our model.
- Exploiting a VAR methodology for the case of Mexico, Pieschacon (2012) estimates that for a 20 percent quarterly increase in the price of oil, private consumption increases as much as 2 percent, while government purchases increase by almost 4 percent (Fig. 2 in Pieschacon, 2012). These results are slightly more moderate but comparable in magnitude with our baseline annual model, with average falls of 5.6 percent in consumption and 14.7 in government expenditures in front an average oil-price drop of 50 percent.

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