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Abstract
The paper analyzes Chile's structural surplus fiscal rule in the face of shocks to the world copper price. Two results are obtained. First, Chile's current fiscal rule performs well if the policymaker (i) puts a premium on avoiding excessive volatility in fiscal instruments, and (ii) puts a relatively small weight on output volatility relative to inflation volatility in his/her objective function. A more aggressive countercyclical fiscal rule can attain lower output volatility, but there is a trade-o¤ with somewhat higher inflation volatility and much higher instrument volatility. The ranking of instruments between government spending and labor income taxes depends mainly on the instrument volatility the policymaker will tolerate. Second, given its then current stock of government assets, Chile's adoption of a 0.5% surplus target starting in 2008 was desirable because the earlier 1% target would have required significant further asset accumulation that could only have been accomplished at the expense of greater volatility in fiscal instruments and therefore in macroeconomic variables.

Resumen
Este artículo analiza la regla de superávit estructural chilena frente a los shocks al precio del cobre. Se obtienen dos resultados: primero, la actual regla fiscal funciona bien si la autoridad (i) premia por evitar una volatilidad excesiva de los instrumentos fiscales, y (ii) asigna una ponderación relativamente baja a la volatilidad del producto relativa a su función objetivo. Una regla fiscal contracíclica más agresiva puede reducir la volatilidad del producto, pero al costo de una volatilidad inflacionaria algo mayor y un instrumento mucho más volátil. El ránking de instrumentos entre gasto de gobierno e impuesto a la renta laboral depende principalmente de cuánta volatilidad tolera la autoridad para el instrumento escogido. El segundo resultado es que, dado su stock de activos de gobierno de entonces, la adopción de una meta de superávit fiscal de 0.5% a partir del 2008 era deseable porque la anterior meta de 1% habría demandado acumular más activos, algo que solo se habría podido lograr al costo de una mayor volatilidad de los instrumentos fiscales y, por lo tanto, de las variables macroeconómicas.

The views expressed in this paper are those of the authors and do not necessarily represent those of the IMF or IMF policy.

I. Introduction

Chile's fiscal policy since 2000 has been conducted in accordance with a structural-surplus rule.[1] The introduction of that rule confirmed and intensified Chile's commitment to fiscal responsibility since the mid-1980s by introducing a more explicit medium-term orientation. The rule was initially not enshrined in law, but this somehow changed with the 2006 Fiscal Responsibility Law, which also introduced new rules on the investment of accumulating assets. The structural-surplus rule only covers the central government. The main elements of the public sector left outside the rule are the central bank, public non-financial enterprises, the military sector, and municipalities.

The structural-surplus rule implies a counter-cyclical behavior of ex-ante government surpluses. It states that the central government's overall structural surplus should in every year equal 1% (0.5% effective 2008, 0% as a temporary measure starting in 2009) of actual GDP. The structural surplus equals structural revenues plus interest on net government assets (which are positive in Chile) minus actual expenditures on goods, services and transfers. Structural revenue reflects what tax revenue would have been if the economy had operated at potential rather than actual output, and what copper revenue would have been at a long-term reference world copper price rather than the actual price. Potential output and the long-term reference world copper price are determined by two independent panels of experts. The rule therefore specifies permissible annual expenditures on goods and services as a residual, given the values of the target, structural revenues, the level of government assets, interest rates, and GDP. The resulting counter-cyclicality of government deficits isolates government expenditures on goods and services from the cycle and keeps them growing with trend output.

A positive surplus target implies significant asset accumulation by the government. It was adopted to provide for future social commitments and to address contingent liabilities. The 2006 Fiscal Responsibility Law formalized this by establishing rules for the investment of surpluses. These rules envision investment in a government pension fund, gradual central bank recapitalization, and a Fund for Economic and Social Stabilization. In May 2007 a reduction in the surplus target from 1% to 0.5% of GDP was announced, effective in 2008. The additional resources that thereby became available for current spending were to be devoted primarily to education.

[1] The rule is described in detail in Marcel and others (2001).

In this paper we analyze the effects of Chile's structural-surplus rule on business cycle volatility. We inquire into two questions. The first is whether the performance of the rule could be improved through a more explicitly countercyclical stance, specifically by letting deficits respond more strongly to excess fiscal revenue than what is allowed under the current rule. While this gives up one clear advantage of the existing rule, namely the fact that it implies only small and gradual changes in fiscal instruments in response to shocks, it may have the offsetting benefit of smaller volatility of GDP. For example, in response to an increase in world copper prices the existing rule implies only small changes in tax rates in the short run (assuming tax rates are the fiscal tool of choice), while a more aggressive rule might respond to the post-shock increase in demand by raising tax rates and thereby dampening the boom. The second question we ask is whether there are advantages to aligning the level of the surplus target more closely with the existing stock of net government debt. There is a proportional long-run relationship between the surplus-to-GDP ratio and the government-assets-to-GDP ratio, so that if the targeted surplus-to-GDP ratio is inconsistent with the current assets-to-GDP ratio, actual short-run surpluses will have to vary over time until assets reach their long-run value. This leads to a fiscal policy driven business cycle even in the complete absence of shocks.

The analytical framework employed is a 2-country version (Chile and rest of the world) of the IMF's Global Integrated Monetary and Fiscal Model (GIMF). This is a state-of-the-art dynamic general equilibrium model of the kind that is increasingly being deployed at central banks around the world, but with a far wider range of fiscal features. Like a conventional business cycle model, GIMF incorporates a range of nominal and real rigidities that are useful for short-run business cycle analysis, and an interest rate reaction function that is common in Inflation-Targeting countries such as Chile. In addition GIMF incorporates multiple and powerful non-Ricardian features that give an important role to fiscal policy, because in a non-Ricardian model the timing of taxes and transfers affects economic activity. These features include: overlapping generations of agents; life-cycle income profiles; liquidity-constrained households; and multiple distortionary taxes. This framework makes it meaningful to also incorporate a fiscal policy reaction function, specifically Chile's structural-surplus rule.

We use a two-country version of GIMF that is carefully calibrated to reproduce structural features of the Chilean economy. These include the breakdown of GDP into its expenditure and income components, the breakdown of trade into its raw materials, intermediates and finished goods components, debt-to-GDP ratios of the public and private sectors, trend real and nominal growth rates, the composition of tax revenue between labor, consumption, capital income, and other taxes, and the composition of government outlays between productive and unproductive expenditures on goods and services, transfers and interest expenses.

The key addition to the standard version of GIMF in this paper is a world copper market. This is critical due to the importance, especially most recently, of cyclical copper revenue for Chile's fiscal performance. Global copper output is modeled as an endowment, 38% of which accrues to Chile, as in the data. The copper price fluctuates with shocks to foreign industrial demand for copper, and the world copper market exhibits perfect price arbitrage. Total copper income is divided between the domestic private sector, the domestic government, and foreigners, approximately in the proportion observed in the data.

Our results show that while monetary policy is most efficient at reducing the volatility of inflation, fiscal policy can be very effective at reducing the volatility of output. One main finding is that Chile's structural-surplus rule greatly reduces output volatility, and also fiscal instrument volatility, relative to a balanced-budget rule. This is similar to the results of Medina and Soto (2007), García and Restrepo (2007), García, Restrepo and Tanner (2008), and Desormeaux, García and Soto (2009). The main value added of this paper is to consider a wider array of fiscal rules, in fact an entire continuum, that also includes rules that are more aggressively countercyclical than a structural-surplus rule. We also stress an additional set of variables that is always of great concern to policymakers, the volatility of fiscal instruments, deficits and debt that is implied by different rules. Policymakers generally dislike, or are simply not able to practically implement, policies that imply very volatile spending or taxes. We show that if this is the overriding concern, structural-surplus rules can be superior to all alternatives. But if some additional fiscal volatility can be tolerated, a more aggressively countercyclical fiscal rule can attain lower output volatility than a structural-surplus rule, at the cost of somewhat higher inflation volatility.

The rest of this paper is organized as follows. Section II briefly presents the model, leaving much of the detail to the working paper version (Kumhof and Laxton (2009a)). Section III discusses calibration. Section IV analyzes the effects of different parameterizations of the structural-surplus rule on business cycle and fiscal instrument volatility. Section V analyzes the consequences of choosing a government surplus target that is not aligned with the existing debt stock. Section VI concludes.

II. The Model

The world consists of 2 countries, Chile and Foreign, where Foreign represents the rest of the world. In our exposition we will ignore country indices except when interactions between the two countries are concerned, in which case Foreign variables are denoted by a superscript asterisk. Figure 1 illustrates the flow of goods and factors in the model.

Countries are populated by two types of households, both of which consume final retailed output and supply labor to unions. First, there are overlapping generations households with finite planning horizons as in Blanchard (1985), and exhibiting external habit persistence. Each of these agents faces a constant probability of death $(1-\theta)$ in each period, which implies an average planning horizon of $1/(1-\theta)$. Second, there are liquidity-constrained households who do not have access to financial markets, and who consequently are limited to consuming their after tax income in every period, as in Gali, Lopez-Salido and Valles (2007). The share of these agents in the population equals ψ. We will denote variables pertaining to these two groups of households by the superscripts OLG and LIQ. The total numbers of agents at time t equals Nn^t, where N is a country specific constant and n is the worldwide population growth rate. From a purely theoretical point of view, a model with only OLG households, or alternatively a model with infinitely-lived households combined with a significant share of LIQ households, would be sufficient to generate non-Ricardian savings behavior. But there are good reasons for instead choosing a combination of OLG and LIQ households. First, GIMF requires LIQ households for realism, as they amplify the short-run effects of fiscal interventions, especially for tax- and transfer-based measures.[2] Second, GIMF requires OLG households with realistic planning horizons[3] in order to generate meaningful results on the long-run crowding-out effects of higher deficits. In addition to finite planning horizons households also experience labor productivity that declines at a constant rate over their lifetimes. This simplified treatment of lifecycle income profiles is justified by the absence of explicit demographics in our model, and adds another powerful channel through which fiscal

[2] This has been an important issue in the debate about fiscal stimulus. For example, Coenen and others (2010) compares seven models that have been used by policymaking institutions around the world to simulate the short-run effects of stimulus. All of them incorporate a significant share of liquidity-constrained agents.

[3] Gali, Lopez-Salido and Valles (2007) interpret the complete inability of liquidity-constrained households to smooth consumption as (among other possible interpretations) extreme myopia, or a planning horizon of zero. We adopt the same interpretation for the average planning horizon of the finite-horizon model. We therefore allow for the possibility that agents may have a shorter planning horizon than what would be suggested by their biological probability of death.

policies can have non-Ricardian effects. Households of both types are subject to a uniform labor income tax and a uniform consumption tax.

Firms are managed in accordance with the preferences of their owners, OLG households, and they therefore also have finite planning horizons. Each country's primary production is carried out by manufacturers producing tradable and nontradable goods. Manufacturers buy investment goods from distributors, labor from unions and copper from the world copper market. Unions buy labor from households and set wages subject to nominal rigidities. Manufacturers are subject to nominal rigidities in price setting as well as real rigidities in investment. Manufacturers' domestic sales go to domestic distributors. Their foreign sales go to import agents that are domestically owned but located in each export destination country. Import agents in turn sell their output to foreign distributors. When the pricing-to-market assumption is made these import agents are subject to nominal rigidities in foreign currency. Distributors first assemble nontradable goods and domestic and foreign tradable goods, where changes in the volume of imported inputs are subject to an adjustment cost. This private sector output is then combined with a publicly provided capital stock (infrastructure) as an essential further input. This capital stock is maintained through government investment expenditure that is financed by tax revenue. The combined domestic private and public sector output is then combined with foreign final output to produce domestic final output. Foreign final output is purchased through a second set of import agents that can price to the domestic market, and again changes in the volume of imported goods are subject to an adjustment cost. This second layer of trade at the level of final output is critical for allowing the model to produce the high trade-to-GDP ratios typically observed in small, highly open economies. Domestic final output is sold to domestic consumption goods retailers, domestic manufacturing firms (in their role as investors), the domestic government, and to final goods import agents located in foreign economies. Distributors are subject to another layer of nominal rigidities in price setting. This cascading of nominal rigidities from upstream to downstream sectors amplifies the effects of sectorial nominal rigidities on aggregate inflation. Retailers, who are also monopolistically competitive, face real instead of nominal rigidities. While their output prices are flexible they find it costly to rapidly adjust their sales volume. This feature contributes to generating inertial consumption dynamics.

The world economy experiences constant positive trend growth $g = T_t/T_{t-1}$, where T_t is the level of labor augmenting world technology, and constant positive population growth n.

When the model's real variables, say x_t, are rescaled, we divide by the level of technology T_t and by population, but for the latter we divide by n^t only, meaning real figures are not in per capita terms but rather in absolute terms adjusted for population growth. We use the notation $\check{x}_t = x_t/(T_t n^t)$, with the steady state of $\check{x}_t$ denoted by $\bar{x}$. An exception to this is quantities of labor, which are only rescaled by n^t.

Asset markets are incomplete. There is complete home bias in government debt, which takes the form of nominally non-contingent one-period bonds denominated in domestic currency. The only assets traded internationally are nominally non-contingent one-period bonds denominated in the currency of Foreign. There is also complete home bias in ownership of domestic firms, except in the copper sector which is partly foreign-owned. In addition equity is not traded in financial markets, instead households receive lump-sum dividend payments. It can be shown that this assumption is required to support our assumption that firm and not just household behavior features myopia.

A. Overlapping Generations Households

A representative OLG household of age a at time t derives utility from consumption $c_{a,t}^{OLG}$ relative to the consumption habit $h_{a,t}^{OLG}$ and leisure $(1-\ell_{a,t}^{OLG})$ (where 1 is the time endowment). Lifetime expected utility has the form

$$E_t \sum_{s=0}^{\infty} (\beta\theta)^s \left[\frac{1}{1-\gamma} \left(\left(\frac{c_{a+s,t+s}^{OLG}}{h_{a+s,t+s}^{OLG}} \right)^{\eta^{OLG}} \left(1-\ell_{a+s,t+s}^{OLG}\right)^{1-\eta^{OLG}} \right)^{1-\gamma} \right] , \tag{1}$$

where E_t is the expectations operator, β is the discount factor, $\theta < 1$ is the survival probability, $\gamma > 0$ is the coefficient of relative risk aversion, and $0 < \eta^{OLG} < 1$. As for money demand, we make the cashless limit assumption advocated by Woodford (2003). The external consumption habit equals lagged per capita consumption of OLG households. Consumption $c_{a,t}^{OLG}$ is given by a CES aggregate over retailed consumption goods varieties $c_{a,t}^{OLG}(i)$, with elasticity of substitution σ_R, and the aggregate retail price level is P_t^R.

A household can hold two types of bonds, domestic government bonds $B_{a,t}$ denominated in domestic currency and paying an interest rate i_t in period $t+1$, and foreign bonds $F_{a,t}$ denominated in the currency of Foreign and paying an interest rate $i_t^*(1+\xi_t^f)$ in period $t+1$, where ξ_t^f is the foreign exchange risk premium. Participation by households in financial markets requires that they enter into an insurance contract with companies that pay a premium of $\frac{(1-\theta)}{\theta}$ on a household's financial wealth for each period in which that household is alive, and that encash the household's entire financial wealth in the event of his death.[4]

The productivity of a household's labor declines throughout his lifetime, with productivity $\Phi_{a,t} = \Phi_a$ of age group a given by $\Phi_a = \kappa\chi^a$, where $\chi < 1$. Household pre-tax nominal labor income is therefore $W_t\Phi_{a,t}\ell_{a,t}^{OLG}$. Dividends are received in a lump-sum fashion from all firms in the nontradables (N) and tradables (T) manufacturing sectors, the distribution (D), retail (R) and import agent (M) sectors, from the domestic (X) and foreign (F) copper sectors, and from all unions (U) in the labor market, with after-tax nominal dividends received from firm/union i denoted by $D_{a,t}^j(i)$, $j = N, T, D, R, U, M, X, F$. OLG households pay lump-sum transfers $\tau_{T_{a,t}}^{OLG}$ to the government; these transfers are special in that they are earmarked for redistribution to the relatively less well off LIQ agents. Household labor income is taxed at the rate $\tau_{L,t}$, consumption is taxed at the rate $\tau_{c,t}$, and in addition there is a general lump-sum tax $\tau_{ls,t}^{OLG}$. The consumption tax $\tau_{c,t}$ is assumed to be payable on the final goods price P_t, which is the price at which retailers purchase consumption goods from distributors. We choose P_t as our numeraire, and write relative prices for all goods x as $p_t^x = P_t^x/P_t$ and gross inflation rates as $\pi_t^x = P_t^x/P_{t-1}^x$. Gross nominal exchange rate depreciation is denoted by $\varepsilon_t = \mathcal{E}_t/\mathcal{E}_{t-1}$, the real exchange rate is $e_t = (\mathcal{E}_t P_t^*)/P_t$, and the real interest rate is $r_t = E_t\,(i_t/\pi_{t+1})$. The household's budget constraint in nominal terms is

$$P_t^R c_{a,t}^{OLG} + P_t c_{a,t}^{OLG}\tau_{c,t} + B_{a,t} + \mathcal{E}_t F_{a,t} = \frac{1}{\theta}\left[i_{t-1}B_{a-1,t-1} + i_{t-1}^*\mathcal{E}_t F_{a-1,t-1}(1+\xi_{t-1}^f)\right] \tag{2}$$

$$+W_t\Phi_{a,t}\ell_{a,t}^{OLG}(1-\tau_{L,t}) + \sum_{j=N,T,D,R,U,M,X,F}\int_0^1 D_{a,t}^j(i)di - P_t\tau_{T_{a,t}}^{OLG} - P_t\tau_{ls,t}^{OLG}\ .$$

The OLG household maximizes (1) subject to (2). Aggregation of the resulting first-order conditions takes account of the size of each age cohort at the time of birth, and of the remaining size of each generation. Several of the optimality conditions that need to be aggregated are nonlinear Euler equations. In such conditions, aggregation requires nonlinear transformations that are only valid under certainty equivalence. This however is no problem for this paper, which uses log-linear approximations. As we find it preferable to present optimality conditions in nonlinear form, we therefore adopt the notation $\tilde{E}_t$ to denote an expectations operator that is understood in this fashion.

[4] The turnover in the population is assumed to be large enough that the income receipts of the insurance companies exactly equal their payouts.

The first-order conditions for goods varieties, the consumption/leisure choice and uncovered interest parity are standard. The optimal aggregate consumption rule of OLG households expresses current aggregate consumption of OLG households as a function of their real aggregate financial wealth fw_t and human wealth hw_t, with the marginal propensity to consume of out of wealth given by $1/\Theta_t$. Human wealth is in turn composed of hw_t^L, the expected present discounted value of households' time endowments evaluated at the after-tax real wage, and hw_t^K, the expected present discounted value of capital or dividend income net of lump-sum transfer payments to the government. After rescaling by technology we have

$$\check{c}_t^{OLG}\Theta_t = \check{f}w_t + \check{h}w_t^L + \check{h}w_t^K \ , \tag{3}$$

where

$$\check{f}w_t = \frac{1}{\pi_t g n}\left[i_{t-1}\check{b}_{t-1} + i_{t-1}^*\varepsilon_t(1+\xi_{t-1}^f)\check{f}_{t-1}e_{t-1}\right] \ , \tag{4}$$

$$\check{h}w_t^L = (N(1-\psi)(\check{w}_t(1-\tau_{L,t}))) + \tilde{E}_t\frac{\theta\chi g}{r_t}\check{h}w_{t+1}^L \ , \tag{5}$$

$$\check{h}w_t^K = \left(\check{d}_t^N + \check{d}_t^T + \check{d}_t^D + \check{d}_t^R + \check{d}_t^U + \check{d}_t^M + \overline{d^X} + d_t^F - \check{\tau}_{T,t} - \check{\tau}_{ls,t}^{OLG}\right) + \tilde{E}_t\frac{\theta g}{r_t}\check{h}w_{t+1}^K \ , \tag{6}$$

$$\Theta_t = \frac{p_t^R + \tau_{c,t}}{\eta^{OLG}} + \tilde{E}_t\frac{\theta j_t}{r_t}\Theta_{t+1} \ , \tag{7}$$

where $\check{b}_{t-1}$ and $\check{f}_{t-1}$ are domestic and foreign currency real bonds, $\check{d}_t^x$ are real dividends for sector x, and j_t is an expression discussed in Kumhof and Laxton (2009a).

The intuition of (3)-(7) is key to GIMF. Financial wealth (4) is equal to the domestic government's and foreign households' *current* financial liabilities. For the government debt portion, the government services these liabilities through different forms of taxation, and these *future* taxes are reflected in the different components of human wealth (5) and (6) as well as (in the case of consumption taxes) in the marginal propensity to consume (7). But unlike the government, which is infinitely lived, an individual household factors in that he might not be around by the time higher future tax payments fall due. Hence *a household discounts future tax liabilities by a rate of at least* r_t/θ*, which is higher than the market rate* r_t, as reflected in the discount factors in (5), (6) and (7). The discount rate for the labor income component of human wealth is even higher at $r_t/\theta\chi$, due to the decline of labor incomes over individuals' lifetimes.

A fiscal consolidation through higher taxes (or lower transfers) represents a tilting of the tax payment profile from the more distant future to the near future, so as to effect a reduction in the debt stock. The government has to respect its intertemporal budget constraint in effecting this tilting, and this means that the expected present discounted value of its future primary surpluses has to remain equal to the current debt $i_{t-1}b_{t-1}/\pi_t$ *when future surpluses are discounted at the market interest rate* r_t. But when individual households discount future taxes at a higher rate than the government, the same tilting of the tax profile represents a decrease in human wealth because it increases the expected value of future taxes for which the household expects to be responsible. For a given marginal propensity to consume, these reductions in human wealth lead to a reduction in consumption.

The marginal propensity to consume $1/\Theta_t$ is, in the simplest case of logarithmic utility and exogenous labor supply, equal to $(1-\beta\theta)$. For the case of endogenous labor supply, household wealth can be used to either enjoy leisure or to generate purchasing power to buy goods, which explains the presence of the parameter η^{OLG} in the marginal propensity to consume. The intertemporal elasticity of substitution $1/\gamma$ is conventionally assumed to be significantly smaller than one. In that case the income effect of an increase in the real interest rate r is stronger than the substitution effect and tends to increase the marginal propensity to consume, thereby partly offsetting the contractionary effects of a higher r on human wealth $\check{hw}_t$. A larger γ is therefore associated with larger interest rate changes in response to savings shocks.

B. Liquidity-Constrained Households

The objective function of liquidity-constrained (LIQ) households is assumed to be identical to that of OLG households. These agents can consume at most their current income, which consists of their after tax wage income plus net government transfers. The aggregated first-order conditions for goods varieties and for the consumption/leisure choice are identical to those of OLG agents. But their consumption is determined by their intra-period budget constraint, which after aggregating and rescaling by technology is given by

$$\check{c}_t^{LIQ}(p_t^R+\tau_{c,t}) = \check{w}_t\ell_t^{LIQ}(1-\tau_{L,t}) + \check{\tau}_{T,t} - \check{\tau}_{ls,t}^{LIQ}\ . \tag{8}$$

To obtain aggregate consumption and labor we simply add the respective quantities for OLG and LIQ households, with $\check{C}_t = \check{c}_t^{OLG} + \check{c}_t^{LIQ}$ and $\check{L}_t = \check{\ell}_t^{OLG} + \check{\ell}_t^{LIQ}$.

C. Manufacturers

The technology of each manufacturing firm in sectors $J \in \{N, T\}$ is given by a nested CES production function. This first combines copper inputs X_t^J with a capital-labor composite M_t^J, with elasticity of substitution ξ_{XJ} and copper share parameter α_t^X. M_t^J is in turn a CES aggregate in capital K_t^J and union labor U_t^J, with elasticity of substitution ξ_{ZJ}, labor share parameter α^U and labor-augmenting productivity T_t. The only shock we will consider in this paper, due to its great importance for Chile's fiscal policy, is to copper demand via the copper share parameter in Foreign manufacturing $\alpha_t^{X^*}$, and therefore by implication to world copper prices:

$$\alpha_t^{X^*} = \left(1 - \rho^{X^*}\right) \overline{\alpha^{X^*}} + \rho^{X^*} \alpha_{t-1}^{X^*} + \mathbf{e}^{X^*} \ . \tag{9}$$

Manufacturing firms are subject to quadratic inflation adjustment costs. Following Ireland (2001) and Laxton and Pesenti (2003), they are quadratic in changes in the rate of inflation rather than in price levels, which is essential in order to generate realistic inflation dynamics. All other instances of nominal rigidities in the firm and union sectors assume this type of adjustment cost. Investment is subject to another quadratic adjustment cost. Letting δ represent the depreciation rate, the aggregated and rescaled law of motion of capital is described by

$$\check{K}_{t+1}^J gn = (1 - \delta) \check{K}_t^J + \check{I}_t^J \ . \tag{10}$$

It is assumed that each firm maximizes the expected present discounted value of dividends or cash flows. The discount rate it applies in this maximization includes the parameter θ so as to equate the discount factor of firms θ / r_t with the pricing kernel for nonfinancial income streams of their owners, myopic households, which equals $\beta\theta E_t \left(\lambda_{a+1,t+1}/\lambda_{a,t}\right)$. This equality follows directly from an individual OLG household's first-order condition for government debt holdings $\lambda_{a,t} = \beta E_t \left(\lambda_{a+1,t+1} \frac{i_t}{\pi_{t+1}}\right)$. Dividends equal revenue minus cash outflows. The latter include the wage bill, spending on copper $p_t^X X_t^J$ (where p_t^X is the relative domestic currency price of copper), investment, a fixed cost and adjustment costs. The fixed resource cost arises as long as the firm chooses to produce positive output, and is calibrated to make the steady-state income shares of labor and capital in GDP consistent with the data. The first-order conditions for the manufacturer's problem are standard, and include a New Keynesian Phillips curve for sectorial inflation, demand functions for the three inputs, and conditions for optimal investment and capital.

D. Copper Producers

Copper supply or output in each country is specified, for simplicity, as an exogenous endowment X_t^{sup}, and demand is denoted by X_t^{dem}. In this paper we will treat the endowment as a constant. The world copper market is subject to perfect worldwide price arbitrage. Total copper price revenues are paid out to three recipients. We denote the payments to foreigners as f_t^X, the payments to the domestic government as g_t^X, and the payments to domestic factors of production as d_t^X. Furthermore, we assume that the payments to domestic factors do not change with the business cycle, $d_t^X = \overline{d^X}$. All cyclical excess revenue therefore goes to either foreigners or the domestic government, and we assume that they share this revenue in a fixed proportion. To summarize, we have

$$p_t^X \check{X}_t^{sup} = \overline{d^X} + \check{f}_t^X + \check{g}_t^X \quad , \tag{11}$$

$$\overline{d^X} = s_d^x \bar{p}^X \bar{X}^{sup} \quad , \tag{12}$$

$$\check{f}_t^X = s_f^x \left(p_t^X \check{X}_t^{sup} - \overline{d^X} \right) \quad , \tag{13}$$

$$\check{g}_t^X = p_t^X \check{X}_t^{sup} - \bar{d}^X - \check{f}_t^X \quad , \tag{14}$$

where s_d^x and s_f^x are calibrated constants. Net copper exports are given by

$$X_t^x = p_t^X \left(X_t^{sup} - X_t^{dem} \right) \quad . \tag{15}$$

E. Unions

Unions buy labor from households at the household wage and sell labor to manufacturers at the producer wage, with aggregate real household and producer wages denoted by $\check{w}_t$ and $\check{v}_t$. Unions' wage setting is subject to nominal rigidities, and their optimality condition is therefore a New Keynesian Phillips Curve for wage inflation.

F. Import Agents

Each country owns import agents in its export destination markets. The first-order condition for an import agent's problem is another New Keynesian Phillips curve, this time for import price inflation in the destination country.

G. Distributors

This sector produces final output in four stages. In the first stage a tradables composite Y_t^T is produced by combining foreign produced tradables Y_t^{TF} with domestically produced tradables Y_t^{TH}, in a CES technology with elasticity of substitution ξ_T, subject to adjustment costs that make it costly to rapidly vary the share of Foreign produced tradables in total tradables production. In the second stage a tradables-nontradables composite Y_t^A is produced by combining tradables Y_t^T with nontradables Y_t^N, in a CES technology with elasticity of substitution ξ_A. In the third stage a private-public composite is produced by combining Y_t^A with the stock of public infrastructure K_t^G, which enters externally, in an analogous manner to exogenous technology, but with decreasing returns. In the fourth stage final output Y_t is produced by combining foreign produced final output Y_t^{DF} with the domestically produced private-public composite Y_t^{DH}, in a CES technology with elasticity of substitution ξ_D, and subject to import adjustment costs as in the first stage. Profit maximization consists of maximizing the expected present discounted value of nominal revenue minus nominal costs of production, a fixed cost and inflation adjustment costs. Optimality conditions include a New Keynesian Phillips curve for final goods inflation and a number of input demands.

H. Retailers

Retailers buy final output from distributors and sell it to households. Their price setting is subject to real rigidities in that they find it costly to rapidly adjust their sales volume to changing demand conditions. Their optimality condition contains adjustment cost terms whereby consumption goods sales adjust to shocks with a lag.

I. Government

Fiscal policy consists of a specification of public investment spending G_t^{inv}, public consumption spending G_t^{cons}, transfers $\tau_{T,t}$, and of four different taxes $\tau_{L,t}$, $\tau_{c,t}$, $\tau_{k,t}$ and $\tau_{ls,t}$. Government investment and consumption spending $G_t^{inv} + G_t^{cons}$ represents a demand for final output. Government investment spending augments the stock of publicly provided infrastructure capital K_t^G, the evolution of which is, after rescaling by technology, given by

$$\check{K}_{t+1}^G gn = (1-\delta)\,\check{K}_t^G + \check{G}_t^{inv} \ . \tag{16}$$

Government consumption spending on the other hand is unproductive. Both types of government spending are exogenous unless the fiscal rule specifies government spending as the fiscal tool. The government's policy rule for transfers partly compensates for the lack of asset ownership of LIQ agents by redistributing a small fraction of OLG agents's dividend income receipts to LIQ agents. The sources of tax revenue are labor income taxes $\tau_{L,t}w_tL_t$, consumption taxes $\tau_{c,t}C_t$, taxes on the return to capital $\tau_{k,t}\Sigma_{j=N,T}\left[r_{k,t}^J-\delta q_t^J\right]K_t^J$ (where $r_{k,t}^J$ is the rental rate of capital and q_t^J is the shadow value of capital), and lump-sum taxes $\tau_{ls,t}$. We assume that the latter is apportioned between OLG and LIQ agents in proportion to their consumption shares. We define the rescaled aggregate real tax variable as

$$\check{\tau}_t = \tau_{L,t}\check{w}_t\check{L}_t + \tau_{c,t}\check{C}_t + \tau_{k,t}\Sigma_{j=N,T}\left[r_{k,t}^J-\delta q_t^J\right]\check{K}_t^J + \check{\tau}_{ls,t} \ \ .$$

Furthermore, the government issues nominally non-contingent one-period nominal debt B_t at the gross nominal interest rate i_t. The rescaled real government budget constraint therefore takes the form

$$\check{b}_t = \frac{i_{t-1}}{\pi_t gn}\check{b}_{t-1} + \check{G}_t^{inv} + \check{G}_t^{cons} - \check{\tau}_t - \check{g}_t^X \ . \tag{17}$$

A key assumption of the model is that fiscal policy is conducted in accordance with a structural fiscal surplus rule of the following form:

$$gs_t^{rat} = \overline{gs}_t^{rat} + d^{tax}\left(\frac{\check{\tau}_t-\check{\tau}_t^{pot}}{g\check{d}p_t}\right) + d^{cop}\left(\frac{\check{g}_t^X-\check{g}_t^{pot}}{g\check{d}p_t}\right) \ , \tag{18}$$

where gs_t^{rat} is the overall, interest inclusive government-surplus-to-GDP ratio, given by

$$gs_t^{rat} = -\frac{B_t-B_{t-1}}{GDP_t} = -\frac{\check{b}_t-\frac{\check{b}_{t-1}}{\pi_t gn}}{g\check{d}p_t} = \frac{\check{\tau}_t+\check{g}_t^X-\check{G}_t^{inv}-\check{G}_t^{cons}-\frac{i_{t-1}-1}{\pi_t gn}\check{b}_{t-1}}{g\check{d}p_t} \ , \tag{19}$$

$\check{\tau}_t^{pot}$ is tax revenue at potential, that is at current tax rates multiplied by the tax base in steady state,

$$\check{\tau}_t^{pot} = \tau_{L,t}\bar{w}\bar{L} + \tau_{c,t}\bar{C} + \tau_{k,t}\Sigma_{j=N,T}\left[\bar{r}_k^J-\delta\right]\bar{K}^J + \bar{\tau}_{ls} \ , \tag{20}$$

and $\check{g}_{X_t}^{pot}$ is government copper revenue evaluated at a reference or long-run value for world copper prices $\bar{p}^{X^*}$,

$$g_{X_t}^{pot} = \left(e_t\bar{p}^{X^*}\bar{X}^s-\bar{d}^X\right)(1-s_f^x) \ \ . \tag{21}$$

Chile's 2006 Fiscal Responsibility Law specifies that savings are to be accumulated in an Economic and Social Stabilization Fund. As of the end of 2008 this fund had accumulated over 20 billion U.S. dollars (about 14 percent of GDP), principally from excess copper revenues. Chile's January 2009 fiscal stimulus plan, which amounts to 4 billion U.S. dollars, is being funded from this source. This plan includes a significant component of increased transfers as well as tax reductions. In terms of the rule it is being presented as a temporary reduction of the structural-surplus target $\overline{gs}^{rat}$ from 0.5 to 0.

The rule (18) makes two key assumptions about fiscal policy. The first concerns dynamic stability, and the second stabilization of the business cycle.

With respect to *dynamic stability*, fiscal policy ensures a non-explosive government-assets-to-GDP ratio by adjusting one of the tax rates to generate sufficient revenue, or by reducing one of the expenditure items. The rule accomplishes this by stabilizing gs_t^{rat} at a long-run level $\overline{gs}_t^{rat}$, given that on average it must be true that $\check{\tau}_t = \check{\tau}_t^{pot}$ and $\check{g}_t^X = \check{g}_t^{pot}$. Denoting the long-run government-assets-to-GDP ratio by $\overline{gassets}^{rat}$, and the central bank's inflation target by $\bar{\pi}$, we obtain the following relationship between government-surplus-to-GDP and government-assets-to-GDP ratios:

$$\overline{gs}^{rat} = \frac{\bar{\pi}gn - 1}{\bar{\pi}gn}\overline{gassets}^{rat} \ . \tag{22}$$

In other words, choosing a surplus target $\overline{gs}^{rat}$ implies an assets target $\overline{gassets}^{rat}$ and therefore keeps assets (or liabilities) from exploding.

With respect to *business cycle stabilization*, fiscal policy ensures that the government-surplus-to-GDP ratio, while satisfying its long-run target of $\overline{gs}^{rat}$, can also flexibly respond to the business cycle. A structural fiscal surplus rule chooses $d^{tax} = d^{cop} = 1$. Under this rule the realized fiscal surplus is allowed to rise with cyclical excess tax revenue and cyclical excess copper revenue. The implication is that during a boom, when tax revenue exceeds its long-run value, the government uses the extra funds to pay off government debt (or to accumulate government assets) by increasing the surplus above its long-run value. The main effect of this rule is to minimize the variability of fiscal instruments, but of course it also reduces the variability of output and inflation relative to a balanced-budget rule, which would set $d^{tax} = 0$. On the other hand, a more explicitly counter-cyclical rule would set $d^{tax} > 1$. As we will show, this would imply more volatile fiscal instruments but less volatile output.[5]

[5] In this more general form of the rule, Chile's recent stimulus package could be reinterpreted in terms of

The rule (18) is not an instrument rule but rather a targeting rule. Any of the available tax and spending instruments can be used to make sure the rule holds. Our default setting in Section IV is that this instrument is the labor tax rate $\tau_{L,t}$, but we also consider the alternative of government consumption spending, and in Section V we will use lump-sum taxes as the instrument.

Monetary policy uses an interest rate rule to stabilize inflation. We posit a rule that responds to deviations of one year ahead year-on-year inflation $\pi_{4,t+4}$ from the inflation target $\bar{\pi}$, and to year-on-year output growth:

$$i_t = (\bar{r}\pi_{4,t+4})\left(\frac{\pi_{4,t+4}}{\bar{\pi}}\right)^{\mu_\pi}\left(\frac{g\check{d}p_t}{g\check{d}p_{t-4}}\right)^{\mu_y} \quad , \tag{23}$$

$$\pi_{4,t} = \left(\pi_t\pi_{t-1}\pi_{t-2}\pi_{t-3}\right)^{\frac{1}{4}} \quad . \tag{24}$$

J. Equilibrium and Balance of Payments

In equilibrium households maximize utility, firms and unions maximize the present discounted value of cash flows, and the markets for labor, nontradables, tradables, final output, international bonds and copper clear. The copper market clearing condition is worldwide and given by

$$\check{X}_t^N + \check{X}_t^T + \check{X}_t^{N*} + \check{X}_t^{T*} = \check{X}_t^{sup} + \check{X}_t^{sup^*} \ , \tag{25}$$

and, denoting import agents' dividends by $\check{d}_t^{TM}$ and $\check{d}_t^{DM}$, the current account is

$$\begin{aligned} e_t\check{f}_t \quad &= \quad \frac{i_{t-1}^*\varepsilon_t\left(1+\xi_{t-1}^f\right)}{\pi_t gn}e_{t-1}\check{f}_{t-1} + \check{X}_t^x - \check{f}_t^X \\ &+p_t^{TH}\check{Y}_t^{TX} + \check{d}_t^{TM} - p_t^{TF}\check{Y}_t^{TF} + \check{Y}_t^{DX} + \check{d}_t^{DM} - p_t^{DF}\check{Y}_t^{DF} \ . \end{aligned} \tag{26}$$

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the rule as a more aggressive countercyclical behavior $d^{tax} > 1$, rather than as a temporary reduction in the structural surplus target $\overline{gs}^{rat}$.

III. Calibration

The model is quarterly, and the denomination of international bonds is in the currency of Foreign. Chile represents one third of one percent of the world economy, both in terms of GDP and in terms of population. It faces a long-run world real interest rate of 3% per annum. The foreign exchange risk premium function ξ_t^f is calibrated to produce a 50 to 60 basis points premium over international interest rates at the steady-state net-foreign-liabilities-to-GDP ratio of 20 percent, in line with recent values for Chile. The baseline government-debt-to-GDP ratio is zero in Chile and 50 percent in Foreign. The real world growth rate is assumed to equal 2% per annum, and the population growth rate 1% per annum. The long-run inflation rate in Chile, equal to the central bank's inflation target, is assumed to equal 3% per annum, and 2% per annum in the rest of the world.

The assumed share ψ of liquidity-constrained agents in the population is 50 percent for Chile and 40 percent in Foreign. The share of these agents in dividend income is assumed to be half of their share in the population. The wage elasticity of labor supply depends on the steady-state value of labor supply among both OLG and LIQ households, which is in turn determined by the leisure share parameters η^{OLG} and η^{LIQ}. We adjust these parameters to obtain a wage elasticity of 0.5. Pencavel (1986) reports that most microeconomic estimates of this elasticity are between 0 and 0.45, and our calibration is at the upper end of that range, in line with much of the business cycle literature. Household preferences are further characterized by habit persistence $v = 0.7$, and by an intertemporal elasticity of substitution of 0.2, or $\gamma = 5$. We emphasize that the choice of this parameter is highly model specific, and common calibrations for infinite-horizon models can therefore not be used as benchmarks for a finite-horizon model, where as discussed above the choice of γ affects the sensitivity of interest rates to changes in the debt ratio, and therefore interacts with the choice of θ and χ. Both θ and χ are set to 0.98125, which corresponds to a 15 year planning horizon or average life expectancy $1/(1-\theta)$ in the case of θ, and to a 15 year remaining working life for χ. We have found that in U.S. calibrations of the model this parameter choice produces an elasticity of the real interest rate with respect to a 1 percentage point increase in the government-debt-to-GDP ratio of around 4 basis points, which is in the middle of the range of estimates produced by Engen and Hubbard (2004), Gale and Orszag (2004) and Laubach (2003).

The elasticities of substitution between capital, labor and copper in both tradables and nontradables are assumed to be equal to one. The elasticities of substitution between domestic and foreign traded intermediates and final goods are assumed to equal 1.5 as in Erceg, Guerrieri and Gust (2005). The elasticity of substitution between tradables and nontradables is assumed to equal 0.8, based on the evidence cited in Mendoza (2005). We assume that the markup of price over marginal cost is equal to 10 percent in the two manufacturing sectors and in the labor market. This is a typical assumption in the monetary business cycle literature. For the distribution and retail sectors we assume smaller markups of 5 percent, and for import agents of 2.5 percent. The real and nominal adjustment cost parameters are chosen to yield reasonable aggregate dynamics.

A number of share and other parameters is calibrated by reference to long-run values for the shares of different expenditure and income categories in GDP. The manufacturing labor share parameters are set to ensure a labor income share of 55 percent in Chile and 64 percent in the rest of the world, while the nontradables labor shares are assumed to equal 64 percent in both Chile and Foreign. This reflects the low labor share in the Chilean tradable goods sector. The nontradables share parameter is adjusted to ensure a nontradables share in GDP of 50 percent. The steady-state shares of government spending in GDP are 12 percent in Chile and 18 percent in Foreign, with government investment shares of 2 percent and 3 percent. Ratios of transfers to GDP are set to 10 percent in both countries. On the revenue side we have calibrated the shares of different tax revenues in overall tax revenue based on Chilean data as 50 percent for consumption tax revenue, 14 percent for capital income tax revenue, 15 percent for labor income tax revenue, and 21 percent for all other tax revenue, classified as lump-sum taxes. The corresponding shares for Foreign are 30, 10, 30 and 30.

As for private capital accumulation and utilization, we are able to calibrate not only the two capital income shares (through the share parameters, see above) and the depreciation rate (directly, at 10 percent per annum) but also the investment-to-GDP ratio. This is because our model features a fourth free parameter, the steady-state markup profits that remain after deducting fixed costs, which are part of capital income. The steady-state shares of investment spending in GDP are then calibrated at 20 percent in both countries. For public capital accumulation, we choose a depreciation rate of four percent per annum and a production function coefficient such that the elasticity of GDP with respect to public capital equals 0.14. See Kumhof and Laxton (2007) for details.

The copper endowments and demand share parameters are calibrated in order to approximately reproduce Chile's historic ratios of copper output and copper exports to GDP, which we set to 12.38 percent and 12.3 percent. The copper demand shock is assumed to be highly persistent, as in the data. We calibrate the trade share parameters to produce Chilean ratios to GDP of intermediate and final goods exports of 8.7 percent and 14 percent, and of final goods imports of 5 percent. Taken together with net copper exports the current account equation then determines the intermediate goods imports ratio as a residual given the net foreign-liabilities-to-GDP ratio.

As for the division of copper revenue between the different parties, we assume that in steady state domestic factors of production receive 65 percent, with the remainder split evenly between the domestic government and the foreign private sector. The net excess revenue following a shock is shared evenly between the domestic government and the foreign private sector.

For the monetary policy rules in each country we assume a small coefficient on output growth $\mu_y = 0.1$. For each fiscal rule that we consider we will analyze two alternatives for the monetary authority's response to inflation, a baseline policy with $\mu_\pi = 0.5$ and a more aggressive policy with $\mu_\pi = 1.5$. Note that, given the form in which the rules are written, this amounts to overall inflation coefficients of 1.5 and 2.5, respectively. Our main focus is of course on the fiscal rules, where we will investigate the consequences of a number of rule calibrations.

IV. Choice of Countercyclical Coefficients

The parameters of the fiscal rule (18) are critical for its effect on the business cycle. In this section we focus on the coefficients d^{tax} and d^{cop}, which determine the countercyclicality of fiscal policy in response to shocks, and which can therefore be used to represent a variety of different policy rules. Setting both equal to zero corresponds to a balanced-budget rule, which requires lower taxes (or higher spending) in response to a boom in demand. This is highly procyclical and therefore undesirable. Setting both equal to one corresponds to Chile's structural-surplus rule. It implies minimal short-run changes in fiscal instruments in response to shocks, and it implies a countercyclical overall deficit. This has somewhat countercyclical effects on the business cycle and is far superior to a balanced-budget rule.

Finally, setting both coefficients at values greater than one is even more countercyclical, because it implies not only a countercyclical overall deficit but also countercyclical fiscal instruments, such as higher tax rates (or lower spending) in response to a boom in demand. Investigating this possibility is a key part of our analysis.

To quantify the performance of different choices of the coefficients d^{tax} and d^{cop} we adopt the following conventional loss function

$$Loss = sd(\pi) + \lambda * sd(gdp) \ , \tag{27}$$

where sd stands for standard deviation. This function penalizes a weighted sum of the standard deviations of inflation and output. To trace out an inflation-output efficiency frontier we vary λ. For each λ we choose the weights d^{tax} and d^{cop} in the fiscal policy rule that minimize the loss function. The resulting efficiency frontier represents the best available combinations of output and inflation volatility, given the model and the shock distribution. We focus only on shocks to copper prices, calibrated to reproduce the unconditional variance and autocorrelation of international copper prices. We choose either the labor income tax rate $\tau_{L,t}$ or government consumption spending $\check{G}_t^{cons}$ as the fiscal instruments that adjust endogenously to satisfy the structural-surplus rule. In practice however there are two very important caveats to this procedure.

First, the volatilities of consumption and employment would generally be better indicators of how policies affect household welfare. While loss functions in inflation and output volatilities have been shown to be reasonable approximations to household welfare in certain highly stylized economies with infinitely-lived agents, this is not a general result. And it certainly does not hold in economies with finitely-lived agents, especially with liquidity-constrained agents. In fact, as shown in Kumhof and Laxton (2009b), in such economies the policymaker should concentrate on stabilizing the income of liquidity-constrained agents in order to help them smooth their consumption, and one way of doing so is by setting the copper coefficient d^{cop} fairly close to one. Portions of efficiency frontiers with copper coefficients very different from one should therefore be interpreted with this caveat in mind. More generally, and even more so than for more conventional models, an analysis based on efficiency frontiers, while informative, should ultimately be supported by a welfare-based analysis.

Second, for policymakers the implied volatility of the fiscal instruments used to satisfy the fiscal rule is also of great practical concern, as certain points on the frontier may involve far too volatile taxes or spending. In this paper, instead of introducing for example the volatility of deficits as a third argument in the objective function (27), we simply augment our presentation of efficiency frontier plots with tables that show the associated volatilities of the underlying fiscal instruments.

Figure 2 and Tables 1-6 show the results. The blue and red frontiers in Figure 2 represent a combination of the labor income tax rate as the fiscal instrument with a baseline or a more aggressive monetary policy. The green and blue dotted frontiers represent a combination of government spending as the fiscal instrument with a baseline or a more aggressive monetary policy. Because the use of this instrument entails a very high fiscal volatility, we also consider the case where the coefficient d^{tax} in the fiscal rule is restricted to a maximum of 3. This is shown as the solid green and blue lines in Figure 2. Apart from the frontiers, Figure 2 also shows the results achieved by balanced-budget rules (0,0) and structural-surplus rules (1,1) for each fiscal-monetary policy combination.

Tables 1-6 accompany Figure 2 and show more details. In each case the columns show the outcomes associated with, in this order, a balanced-budget rule, a rule with a close to zero output weight in the loss function, a structural-surplus rule, a rule located on the frontier and closest to the structural-surplus rule (only for two cases), and finally a rule with the maximum output weight in the loss function. The additional standard deviations shown in the tables are of the fiscal deficit and debt, and of the chosen fiscal instrument.

We now discuss the results. On monetary policy we find, unsurprisingly, that a more aggressive monetary policy leads to a very substantial reduction in inflation volatility for each fiscal instrument, but possibly also a slight increase in output volatility, as seen for example by a comparison of structural-surplus rules across monetary regimes.

On fiscal policy, the most striking result is the extremely high output volatility associated with the procyclical balanced-budget rules, under any fiscal-monetary policy combination. Structural-surplus rules perform much better in terms of output volatility, at the expense of a relatively smaller increase in inflation volatility. But greater reductions in output volatility are generally available by adopting a more aggressively countercyclical fiscal stance and moving to the left end of the frontiers. The associated increases in inflation volatility are modest but not always insignificant.

The frontiers for labor income taxes as the fiscal instrument are generally flatter than those for government spending. The reason is that higher labor income taxes in a boom reduce not only demand but also supply, which means that inflation volatility does not have to change as much for any given reduction in output volatility. Government spending affects almost exclusively demand.

For labor income taxes as the fiscal instrument, the outcome of Chile's structural-surplus rule is very close to the efficiency frontier and implies relative weights on output volatility in the policymaker's objective function of around 0.8. A rule aimed at more aggressively stabilizing output, by increasing the weight on output in the loss function to greater than one, and consequently increasing the fiscal rule coefficient on excess copper revenue to just over two and the coefficient on excess taxes to 1.3, results in significantly less output volatility (0.36 versus 0.54), but at the cost of significantly higher inflation volatility (0.74 versus 0.54).

More importantly however, as shown in Tables 1 and 2, it results in much higher volatility in tax rates, fiscal deficits, and government debt. In fact the volatility of the fiscal instrument is of the same order of magnitude as under a balanced-budget rule, but of course the changes in the instrument in this case are counter- rather than procyclical. The volatility of fiscal instruments is minimized by the structural-surplus rule. The reason is that this rule instructs the policymaker to exactly save excess tax and copper revenue, and to only start changing fiscal instruments gradually as these savings start to be reflected in the net interest earnings on the government's assets.

For government spending as the fiscal instrument, the unrestricted efficiency frontiers (dotted green and blue lines) show far lower volatility of both output and inflation than the structural-surplus rule, and they are also significantly better than the frontiers for labor income taxes as the fiscal instrument. But this is subject to two very important caveats. Both are associated with the fact that the optimal coefficient on tax revenue for these rules exceeds 10. The first caveat is that, by Tables 3 and 4, the standard deviation of the government-spending-to-GDP ratio (roughly 1 to 2) is two to three times larger than under a structural-surplus rule, and is large even relative to a balanced-budget rule. The implied standard deviation of the level of government spending is, given comparatively low steady-state spending in Chile, extremely large at around 15. To be able to compare these volatilities to those obtained under labor income taxes as the fiscal instruments we have to turn to the implied deficit-to-GDP ratios. Again, the standard deviation under government spending (around 2.3 to 4.4) is very much larger than under labor income taxes (around 1.4 to 2.2). These unrestricted versions of the rule are therefore not realistic, first because in practice the government's objective, as argued above, is likely to put a premium on avoiding excessive volatility in fiscal instruments, and second because the difficulties are especially pronounced for government spending, which is hard to adjust by large amounts in response to information about the state of the economy. The recent experiences with spending-based fiscal stimulus in various parts of the world have underscored this concern. The second caveat relates to the fact that in this paper we only consider shocks to copper demand but no conventional demand and supply shocks. For a model with only copper demand shocks, the optimal copper coefficient d^{cop} should be reasonably close to that of a more complete model. But the optimal tax coefficient d^{tax} will generally depend far more on other shocks. This is shown in Kumhof and Laxton (2009b), which performs welfare analysis on a model of the Chilean fiscal rule that contains several additional shocks. The model and optimization procedure are not directly comparable, but the conclusion regarding the tax coefficient is likely to be robust. The analysis points to significantly smaller optimal tax coefficients than those on our unrestricted frontiers, and to significantly lower instrument volatility.

We therefore repeat the analysis for government spending by deriving efficiency frontiers with an upper bound of 3 on the tax coefficient. These are reported as the solid green and blue lines, and as Tables 5 and 6. The implied volatility of the government-spending-to-GDP ratios is now similar to that of tax rates in Tables 1 and 2, and the volatility of the deficit is even somewhat lower, especially under tighter monetary policy. For tighter monetary policy the frontier is now much closer to the outcome of a structural-surplus rule, but significantly worse in output volatility space than a labor tax rate-based rule. The latter result would be modified depending on the extent to which the fiscal authority was willing to live with a similar deficit volatility as under a labor tax rate-based rule. However, we repeat the concern that volatile spending may be much more difficult to implement.

To understand the macroeconomic dynamics, and especially the fiscal dynamics, underlying the frontiers in Figure 2, we now turn to impulse responses (40 quarters) in Figures 3-8. We concentrate on the case of labor tax rates as the fiscal instrument, and an intermediate parameterization of monetary policy with $\mu_\pi = 1$.

Figures 3 and 4 show the performance of the structural-surplus rule following a one standard deviation copper price shock. We observe an expansion of GDP accompanied by a reduction in inflation, the latter driven primarily by a contraction of net exports of non-copper goods and services following a real appreciation. Lower inflation causes an accommodative response of monetary policy, which boosts investment. On the fiscal side, the surge in copper related revenue accruing to the government is allowed to reduce deficits and debt. Tax rates change very little in the short run, but as debt and interest charges on debt decline tax rates start to fall, thereby providing a stimulus to consumption for an extended period of time. The boom in GDP is much more short-lived than that in consumption, as the monetary stimulus disappears quickly and the effect of the real appreciation on net exports dominates over the medium term.

These results are broadly comparable with the theoretical impulse responses shown in Medina and Soto (2007) and García and Restrepo (2007), including the moderate drop in inflation. But the empirical evidence is not unambiguous on this latter point. For example, Tena and Salazar (2008) show, using a structural VAR approach for Chile, that over the 1984-2006 period the response of inflation to the copper price in Chile was small but positive. Of course this is likely to be highly sensitive to their sample period, over most of which Chile did not have an operational fiscal rule. But more importantly, a slight modification of the model would also generate a less negative, or a positive, inflation response. Specifically, we have assumed that Chilean households do not directly receive higher incomes following a copper price shock ($\overline{d^X}$ is a constant), as this appears more reasonable than the polar opposite assumption that households share equally in the benefits of higher copper prices. But an intermediate assumption would be possible, and this would lead to a much stronger domestic demand response and therefore higher inflation.[6]

Figures 5 and 6 show impulse responses for a balanced-budget rule. The main difference to the previous case is that the surge in copper revenue is not allowed to affect deficits and instead leads to an immediate reduction in labor tax rates of initially close to one percent. The result is a strong amplification of the short-run boom in GDP.

Figures 7 and 8 show impulse responses for a strongly countercyclical rule at the left end of the efficiency frontier. The main difference to the structural-surplus rule is that the surge

[6] Note that the balanced budget rule impulse responses below, which imply that the benefits of copper price shocks are immediately passed on to households, are nevertheless not useful to help us understand the effect of a variable d_t^X. This is because under that rule an increase in copper prices leads to lower labor income taxes, which increases not only demand but also supply, and the latter tends to reduce inflation.

in copper prices is now accompanied by an immediate *increase* in taxes that causes much higher fiscal surpluses. The short-run effect on GDP is now slightly contractionary rather than expansionary. The amplitude of GDP fluctuations is lower than under a structural-surplus rule, but that of inflation is slightly higher.

V. Choice of Surplus Target

Chile's government-surplus-to-GDP target ratio before May 2007 was 1%, and its government-assets-to-GDP ratio was around 8%-9%. The simple manipulation of the government budget constraint shown in equation (22) shows that, given the assumed nominal growth rate for Chile, a 1% surplus target implied a long-run government-assets-to-GDP ratio of 17.4%, which would have represented a substantial asset accumulation beyond the 2007 level. The 0.5% surplus target adopted in May 2007 (and effective 2008) was however consistent with the then current assets-to-GDP ratio and implied no significant changes in assets in the long run. This has advantages for business cycle stabilization, because further asset accumulation would require higher taxes and/or lower spending today relative to the future, which would induce intertemporal effects in consumption and investment, even in the complete absence of shocks.

Figures 9 and 10 illustrate the consequences of choosing a surplus target that is inconsistent with the current asset stock. The thought experiment is as follows. Assume a steady state where the government has been pursuing a 0.5% government surplus target, and has reached the corresponding 8.7% assets-to-GDP ratio, which is very close to Chile's 2007 assets-to-GDP ratio. Next assume that the target is permanently raised to 1%. In this case we choose lump-sum transfers (negative lump-sum taxes) as our fiscal instrument.

The change in the target deficit immediately causes macroeconomic volatility. Transfers have to be temporarily reduced to allow the government to accumulate the desired assets, and this temporarily but very persistently crowds out consumption and crowds in investment and net exports. We emphasize that this consideration is of course only one of many in evaluating the merits of different levels of the surplus target.

VI. Summary

This paper analyzes the performance of Chile's structural fiscal surplus rule in the face of world copper price shocks originating in foreign copper demand, which have been a major factor for Chilean fiscal dynamics in recent years. The objective of the paper is to explore whether the performance of this rule could be improved by making it more countercyclical and/or by making its target government-surplus-to-GDP ratio more consistent with pre-existing government debt stocks. We have obtained two sets of results.

First, Chile's current structural-surplus rule performs well if the policymaker values low volatility of fiscal variables, and if he puts a relatively small weight on output volatility relative to inflation volatility in his/her objective function. By contrast, a balanced-budget rule implies extremely high output volatility, given that it requires highly procyclical changes in fiscal instruments. A more aggressively countercyclical fiscal rule can attain lower output volatility than a structural-surplus rule, but there is a trade-off with (somewhat) higher inflation volatility and (much) higher volatility of fiscal variables. If labor income taxes are used as the fiscal instrument, a reduction in output volatility can be achieved at a lower cost in terms of inflation volatility than if government spending is used. The reason is that labor income taxes affect both demand and supply in the same direction. If government spending is instead used as the fiscal instrument, fiscal policy could obtain even lower output and inflation volatility, but only by generating volatilities of government spending that may be so high as to be unrealistic in practice. Finally, a more aggressive monetary rule, for any given fiscal rule, mainly affects inflation volatility rather than output volatility.

Second, given its 2007 stock of government assets, Chile's adoption of a 0.5% surplus target starting in 2008 was desirable from a business cycle perspective. This is because the earlier 1% target would have required significant further asset accumulation that could only have been accomplished at the expense of greater volatility in fiscal instruments, consumption, investment and net exports.

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$\mathbf{d}^{cop}$	0	0.19	1	*Frontier*	2.18
$\mathbf{d}^{tax}$	0	4.74	1	*close to* $(1,1)$	1.27
Real GDP std.	0.98	0.72	0.56	0.54	0.36
Inflation std.	0.51	0.43	0.57	0.54	0.74
Deficit std.	0	1.44	1.06	1.58	1.96
Debt std.	0	18.5	10.4	18.3	18.7
Δ Tax std.	0.65	0.40	0.03	0.06	0.71
Output Weight in Loss Fct.	-	0.04	-	0.80	>1

Table 1: Fiscal Instrument = Labor Income Tax, $\mu_\pi = 0.5$

$\mathbf{d}^{cop}$	0	1.53	1	2.32
$\mathbf{d}^{tax}$	0	1.94	1	1.46
Real GDP std.	1.03	0.46	0.60	0.36
Inflation std.	1.19	0.22	0.21	0.27
Deficit std.	0.00	1.64	1.08	2.17
Debt std.	0.00	17.1	10.5	20.9
Δ Tax std.	0.66	0.30	0.04	0.85
Output Weight in Loss Fct.	-	0.13	-	>1

Table 2: Fiscal Instrument = Labor Income Tax, $\mu_\pi = 1.5$

$\mathbf{d}^{cop}$	0	0.22	1	2.05
$\mathbf{d}^{tax}$	0	9.10	1	12.5
Real GDP std.	0.96	0.52	0.69	0.33
Inflation std.	0.45	0.26	0.60	0.65
Deficit std.	0.00	2.29	1.03	3.93
Debt std.	0.00	28.6	9.57	50.1
Gov. Spending std.	1.04	0.99	0.60	1.93
Output Weight in Loss Fct.	-	0.6	-	>1

Table 3: Fiscal Instrument = Government Spending, $\mu_\pi = 0.5$

$\mathbf{d}^{cop}$	0	0.63	1	2.19
$\mathbf{d}^{tax}$	0	12.3	1	14.8
Real GDP std.	0.97	0.44	0.73	0.34
Inflation std.	0.17	0.13	0.22	0.23
Deficit std.	0.00	3.15	1.04	4.44
Debt std.	0.00	40.7	9.64	58.2
Gov. Spending std.	1.04	1.42	0.61	2.17
Output Weight in Loss Fct.	-	0.15	-	>1

Table 4: Fiscal Instrument = Government Spending, $\mu_\pi = 1.5$

$\mathbf{d}^{cop}$	0	1.88	1	*Frontier*	1.23
$\mathbf{d}^{tax}$	0	3.00	1	*close to* $(1,1)$	3.00
Real GDP std.	0.96	0.73	0.69	0.60	0.57
Inflation std.	0.45	0.30	0.60	0.47	0.65
Deficit std.	0.00	0.84	1.03	1.33	1.68
Debt std.	0.00	9.60	9.57	14.3	17.6
Gov. Spending std.	1.04	0.61	0.60	0.58	0.77
Output Weight in Loss Fct.	-	0.28	-	2.00	>1

Table 5: Fiscal Instrument = Restricted Government Spending, $\mu_\pi = 0.5$

$\mathbf{d}^{cop}$	0	0.40	1	1.21
$\mathbf{d}^{tax}$	0	3.00	1	3.00
Real GDP std.	0.97	0.68	0.73	0.62
Inflation std.	0.17	0.14	0.22	0.22
Deficit std.	0.00	1.07	1.04	1.62
Debt std.	0.00	11.8	9.64	17.0
Gov. Spending std.	1.04	0.55	0.61	0.74
Output Weight in Loss Fct.	-	0.13	-	>1

Table 6: Fiscal Instrument = Restricted Government Spending, $\mu_\pi = 1.5$

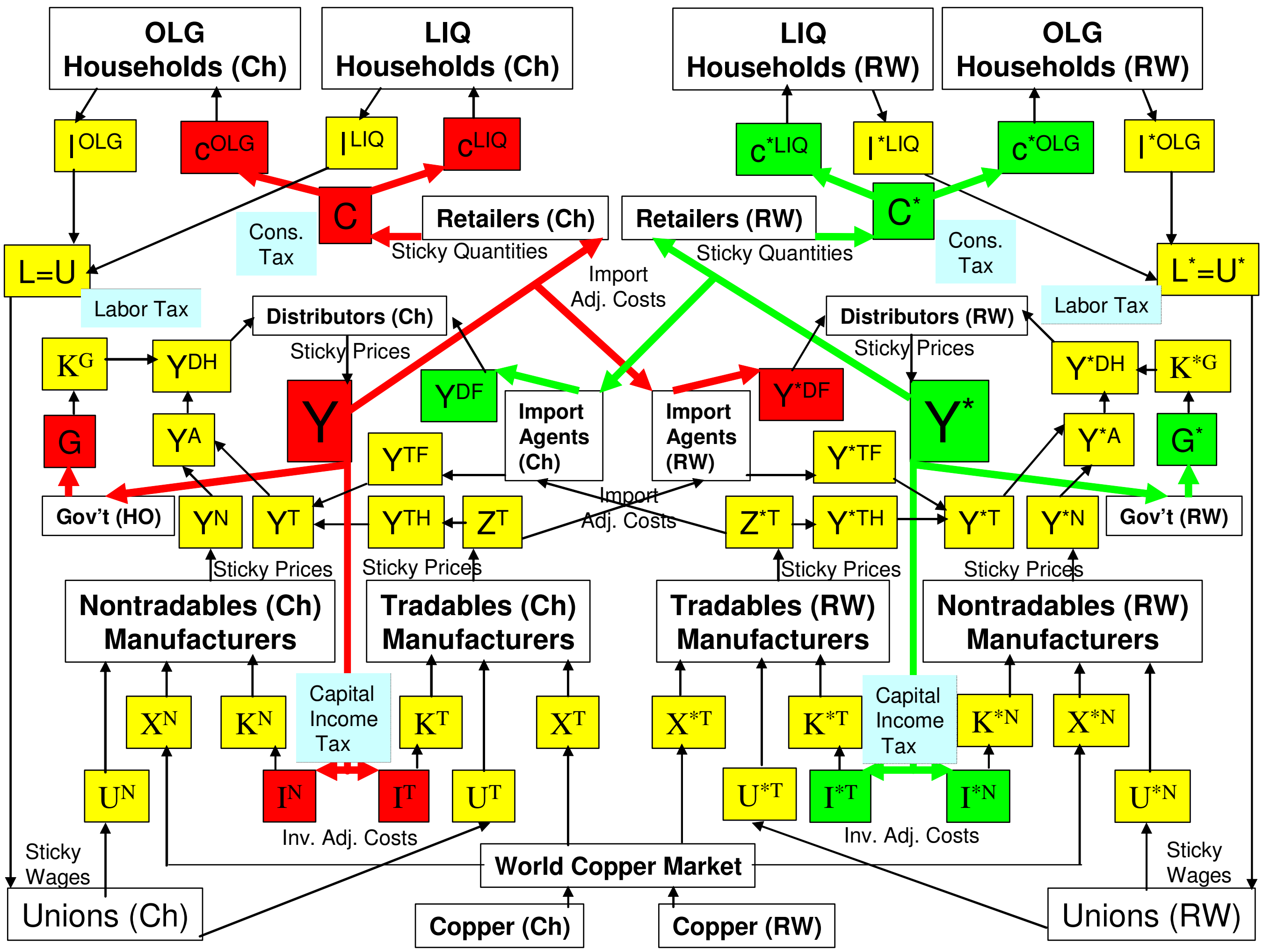

Figure 1: Goods and Factor Flows in GIMF

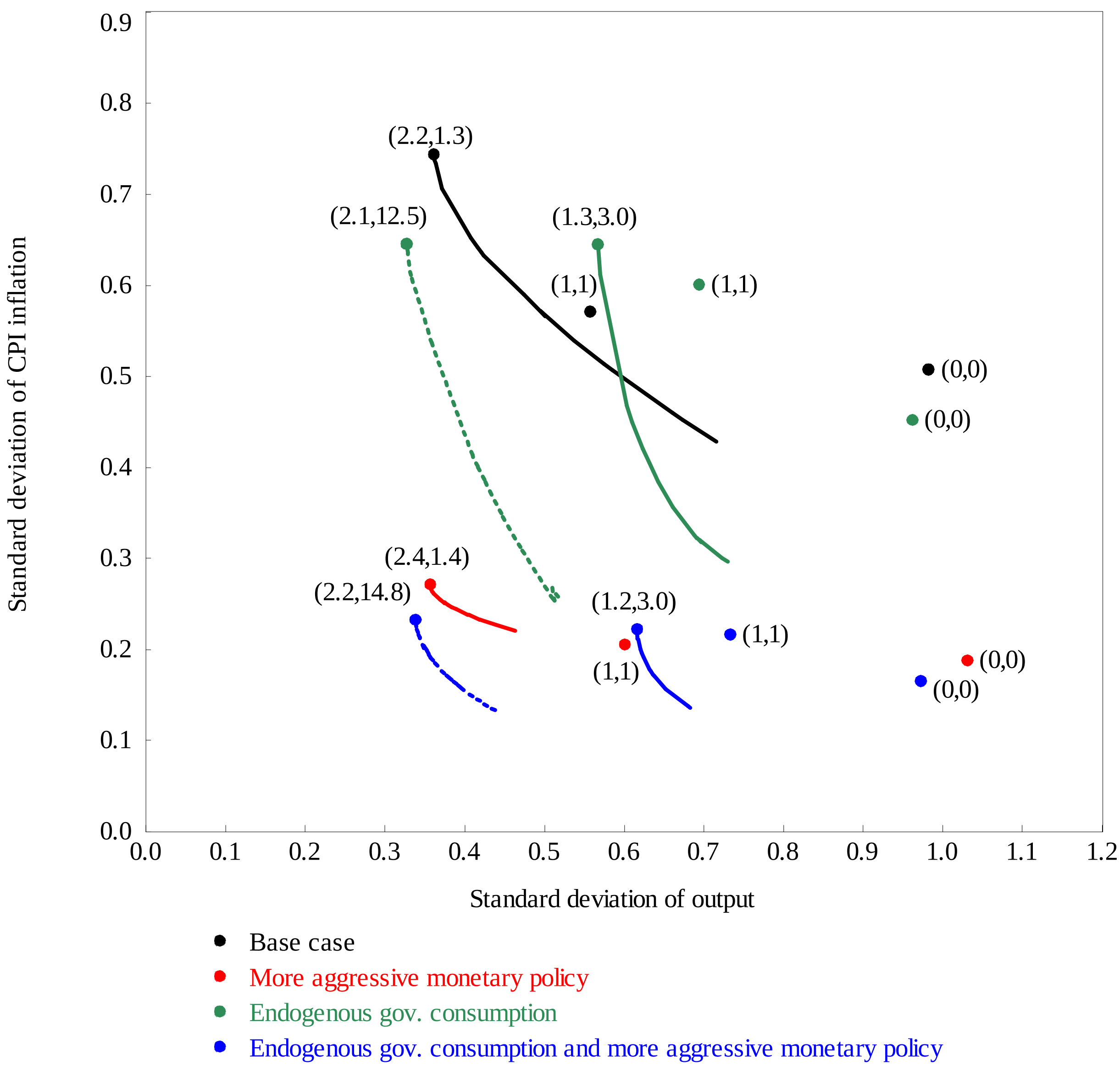

Figure 2: Inflation-Output Efficiency Frontiers under Different Fiscal and Monetary Rules (items in brackets show (d^{cop}, d^{tax}))

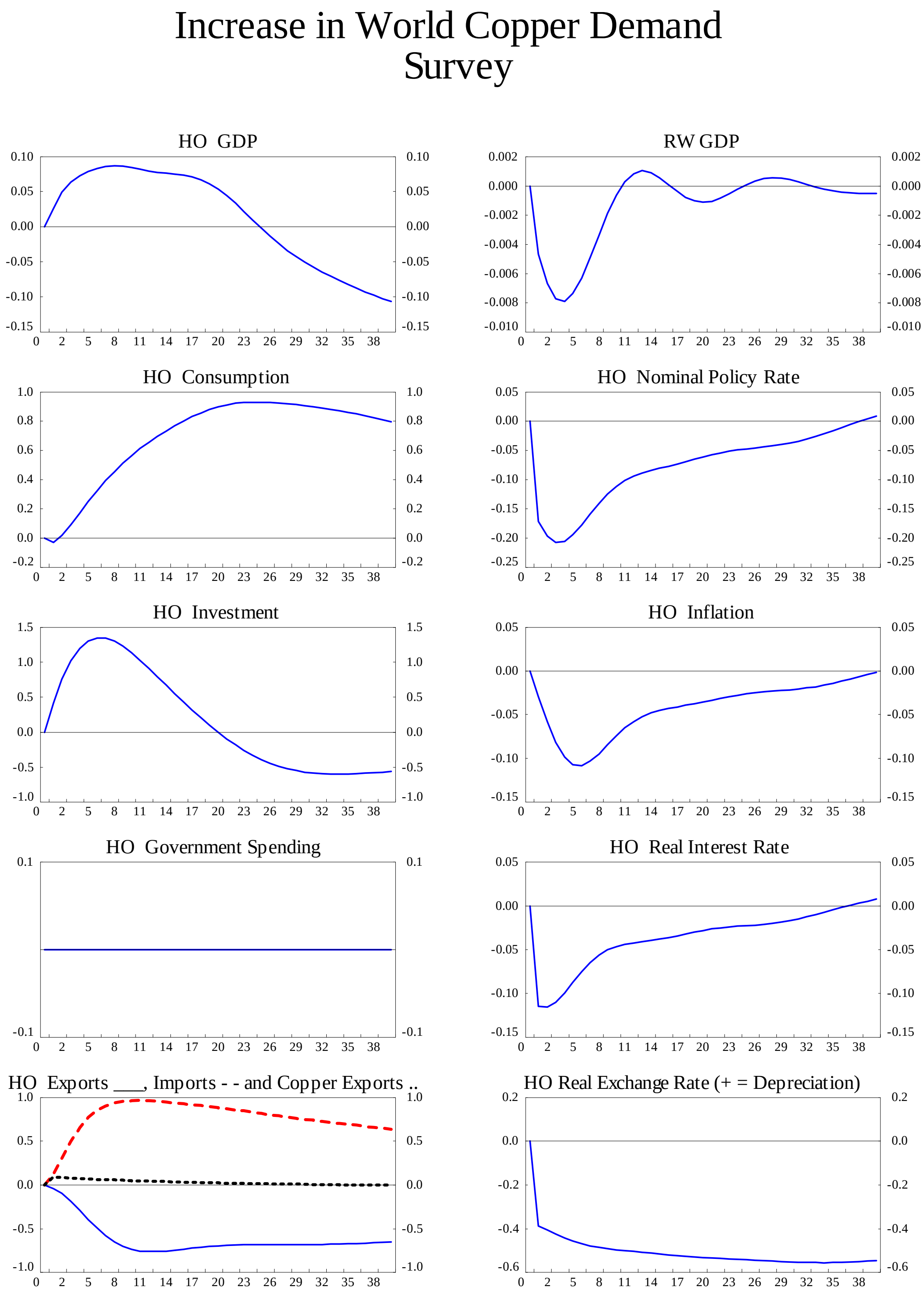

Figure 3: Structural Surplus Rule - Survey

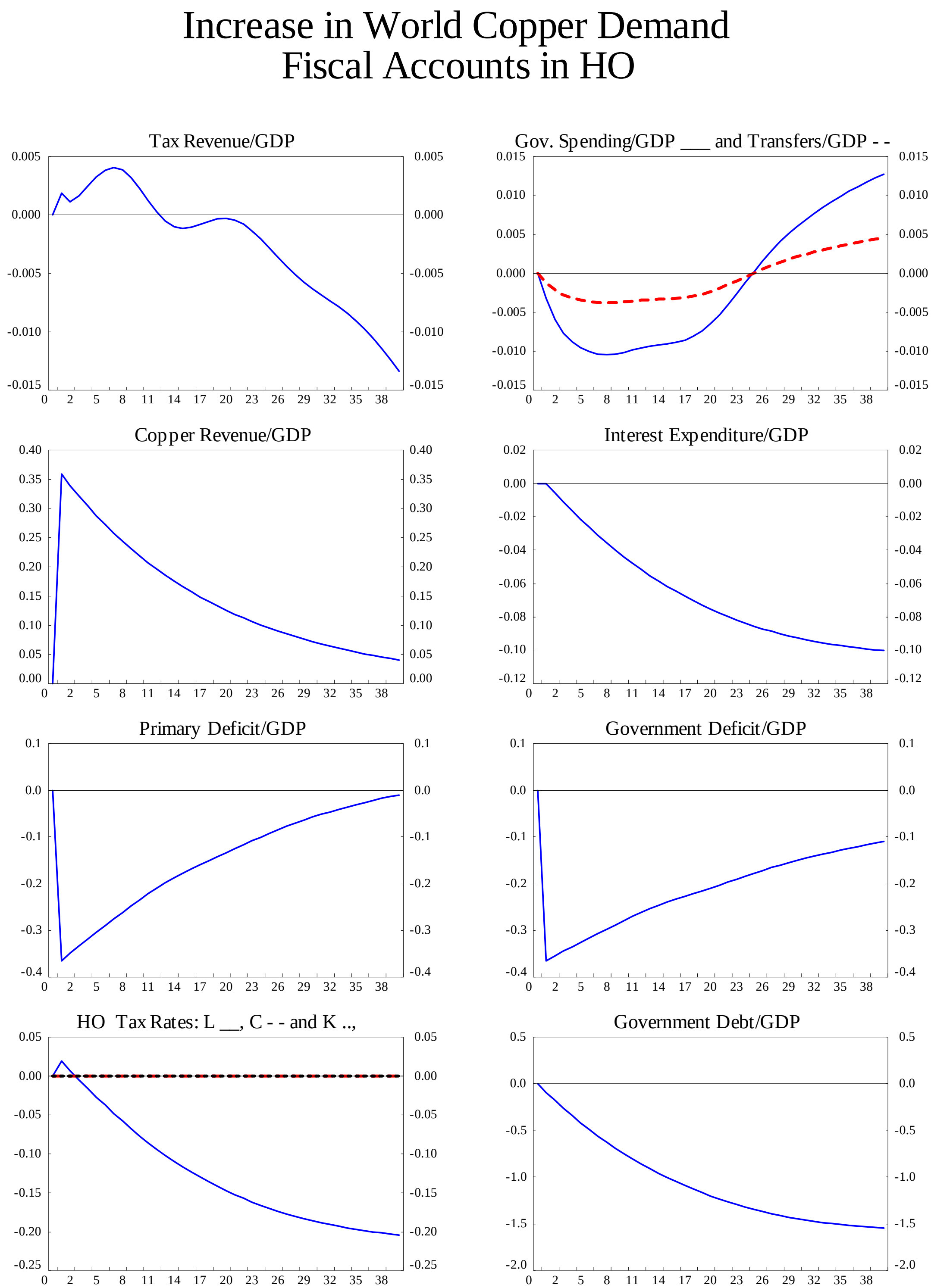

Figure 4: Structural Surplus Rule - Fiscal Accounts

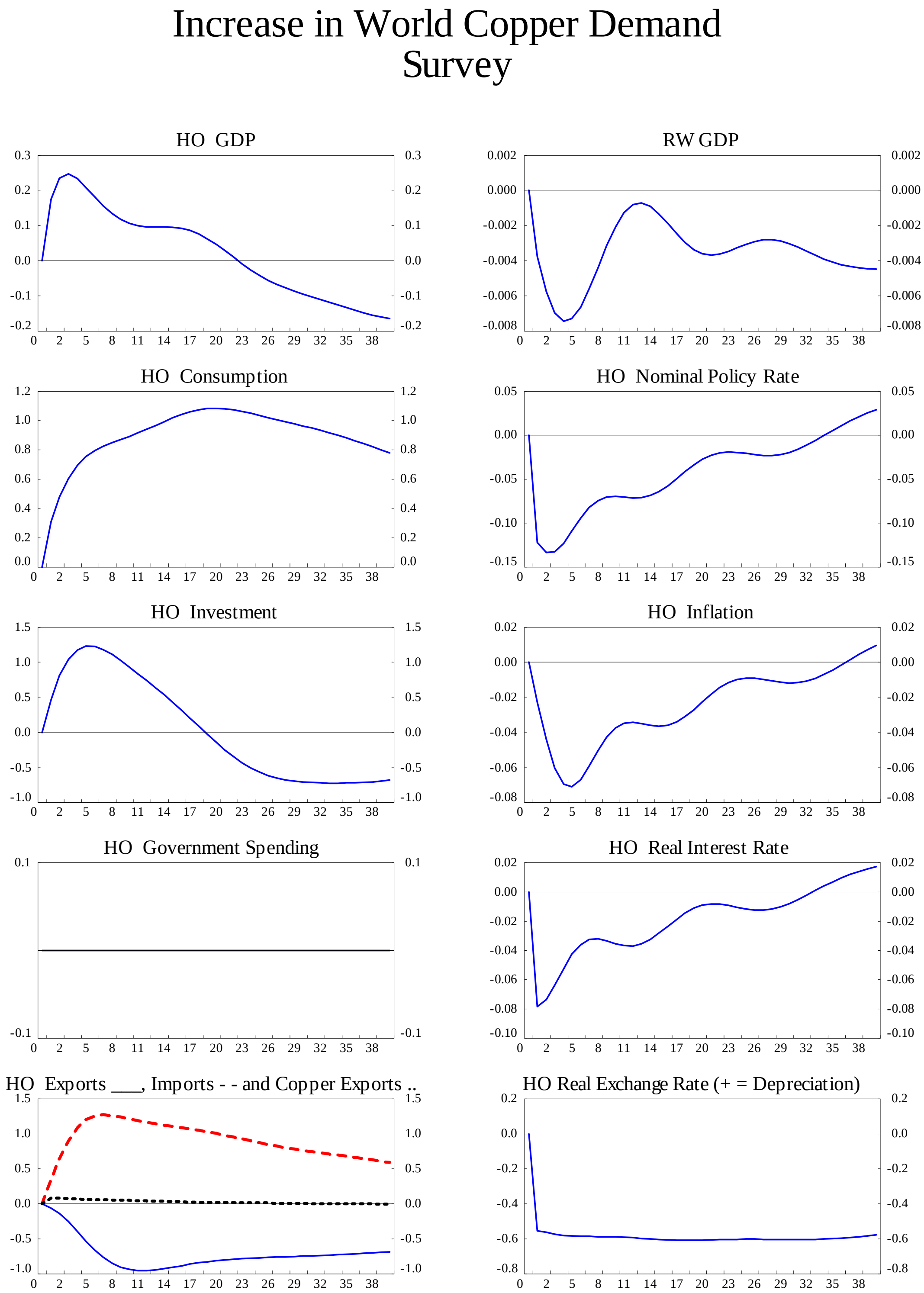

Figure 5: Balanced Budget Rule - Survey

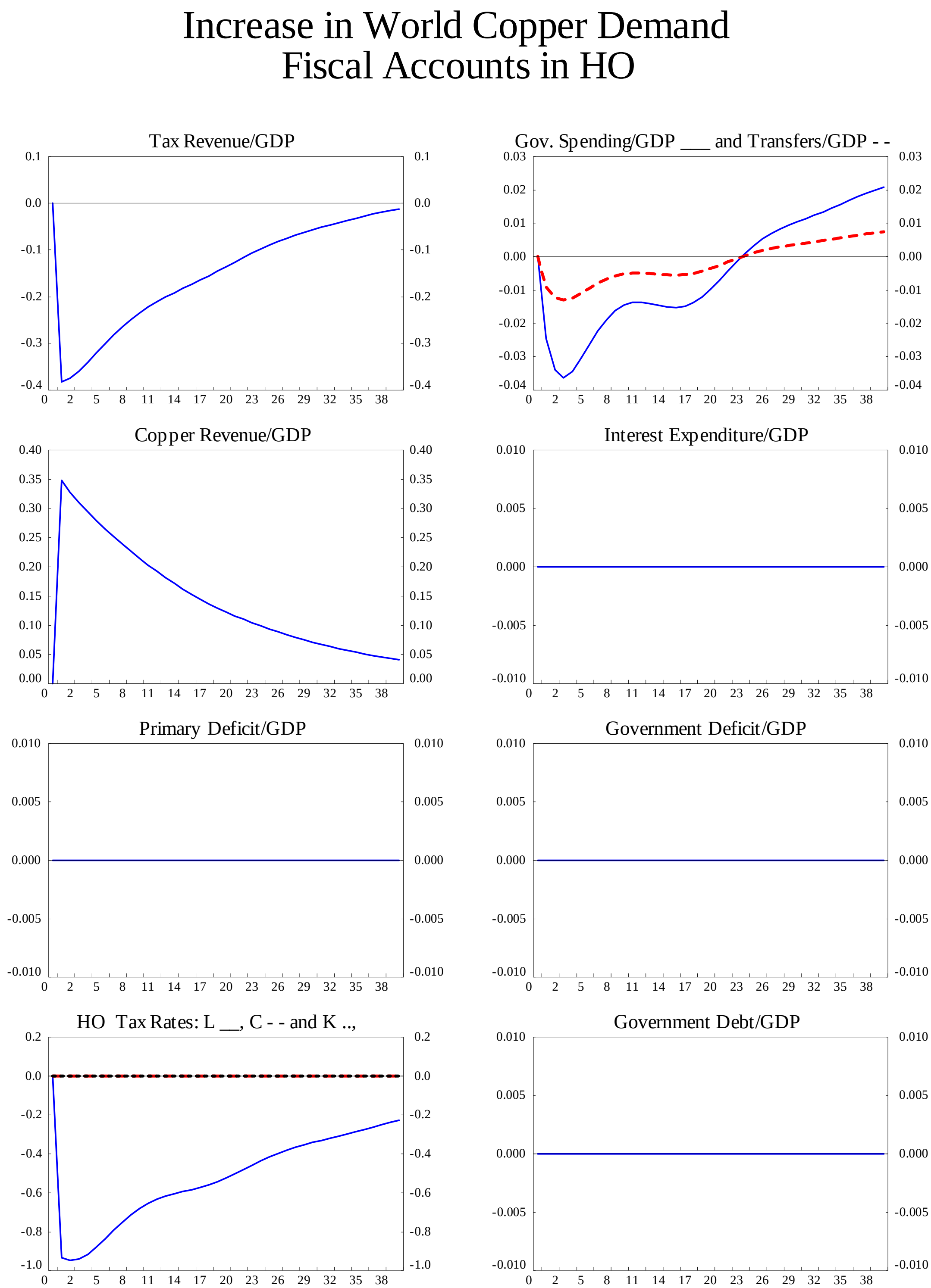

Figure 6: Balanced Budget Rule - Fiscal Accounts

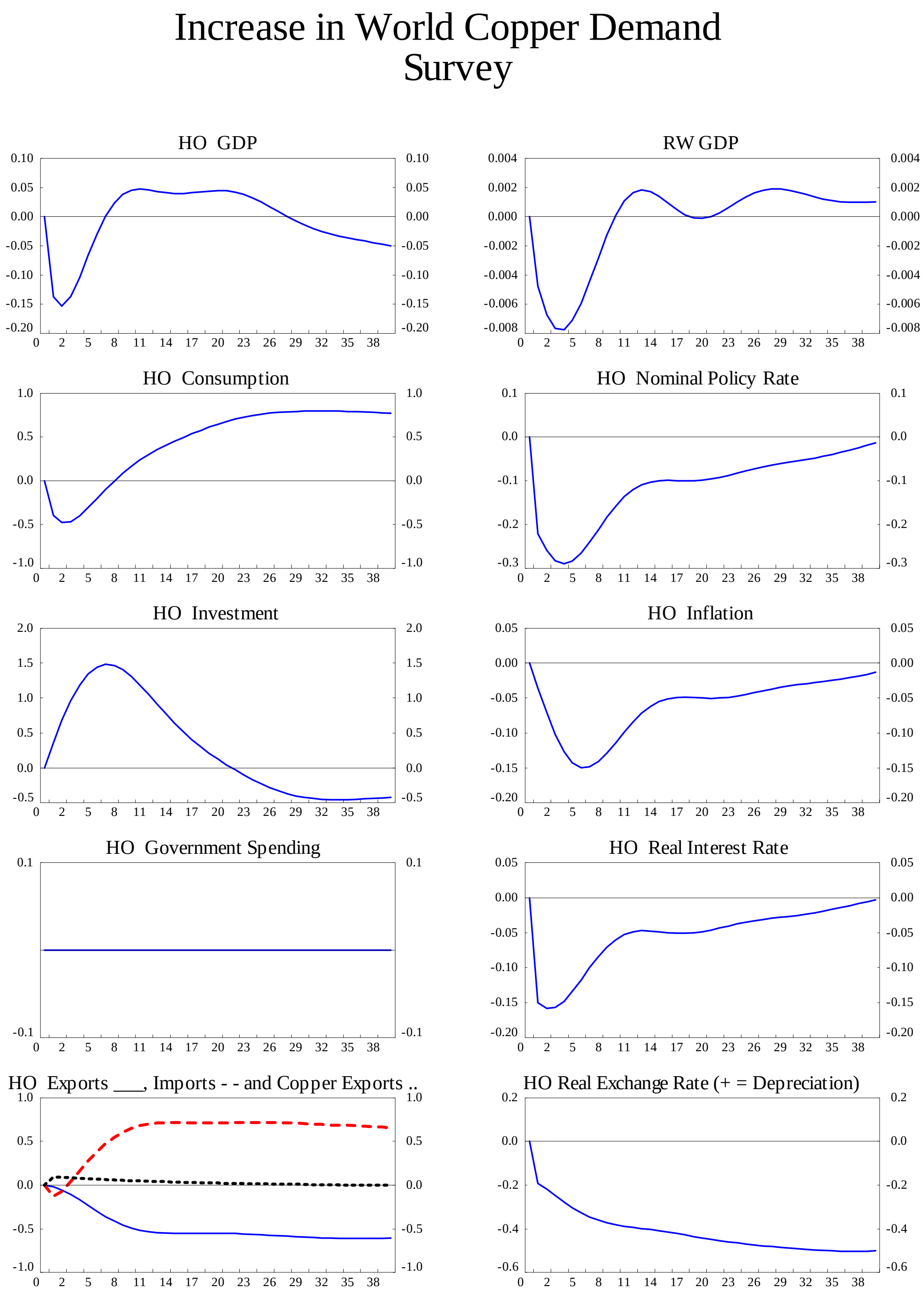

Figure 7: Aggressive Countercyclical Rule - Survey

Increase in World Copper Demand
Fiscal Accounts in HO

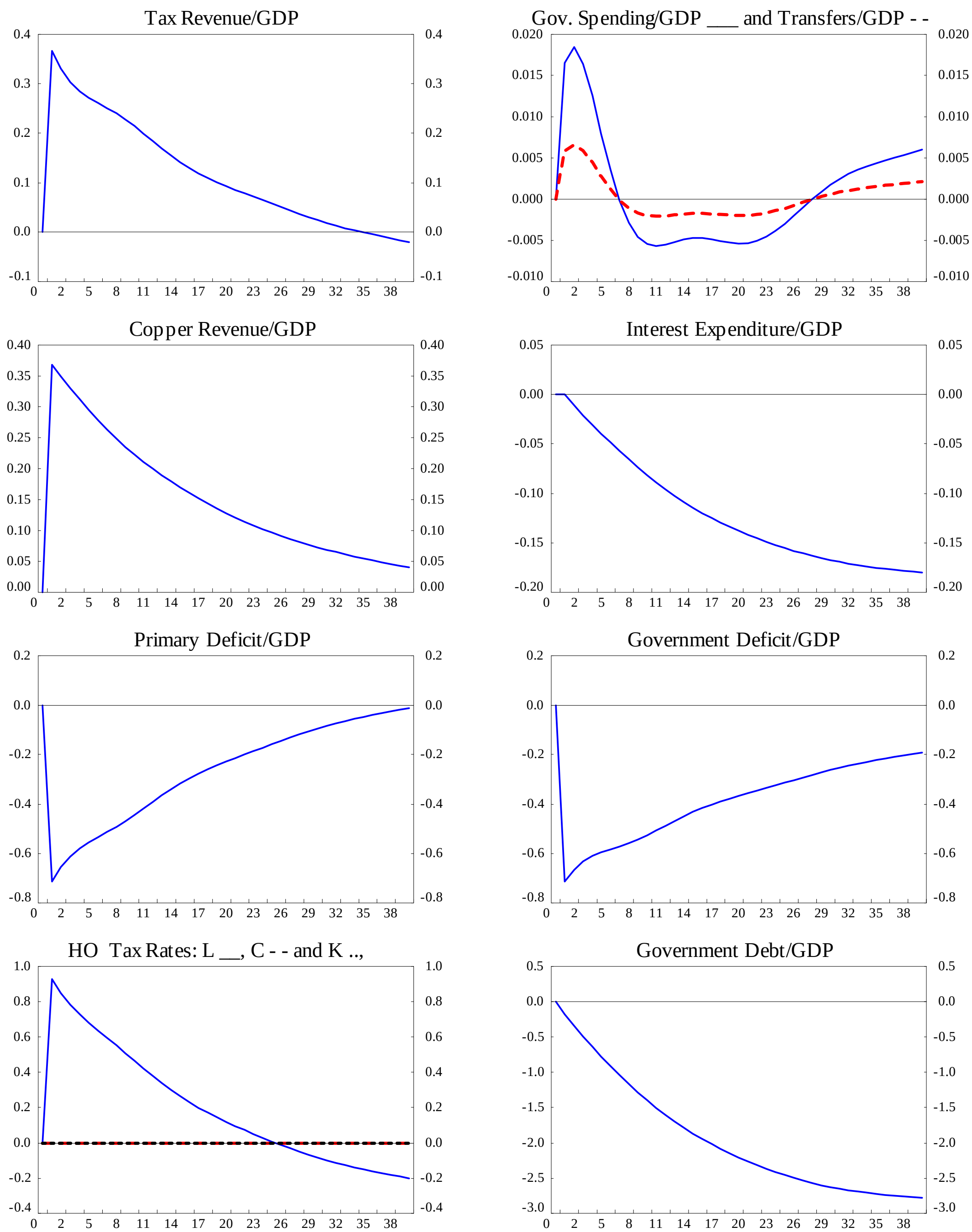

Figure 8: Aggressive Countercyclical Rule - Fiscal Accounts

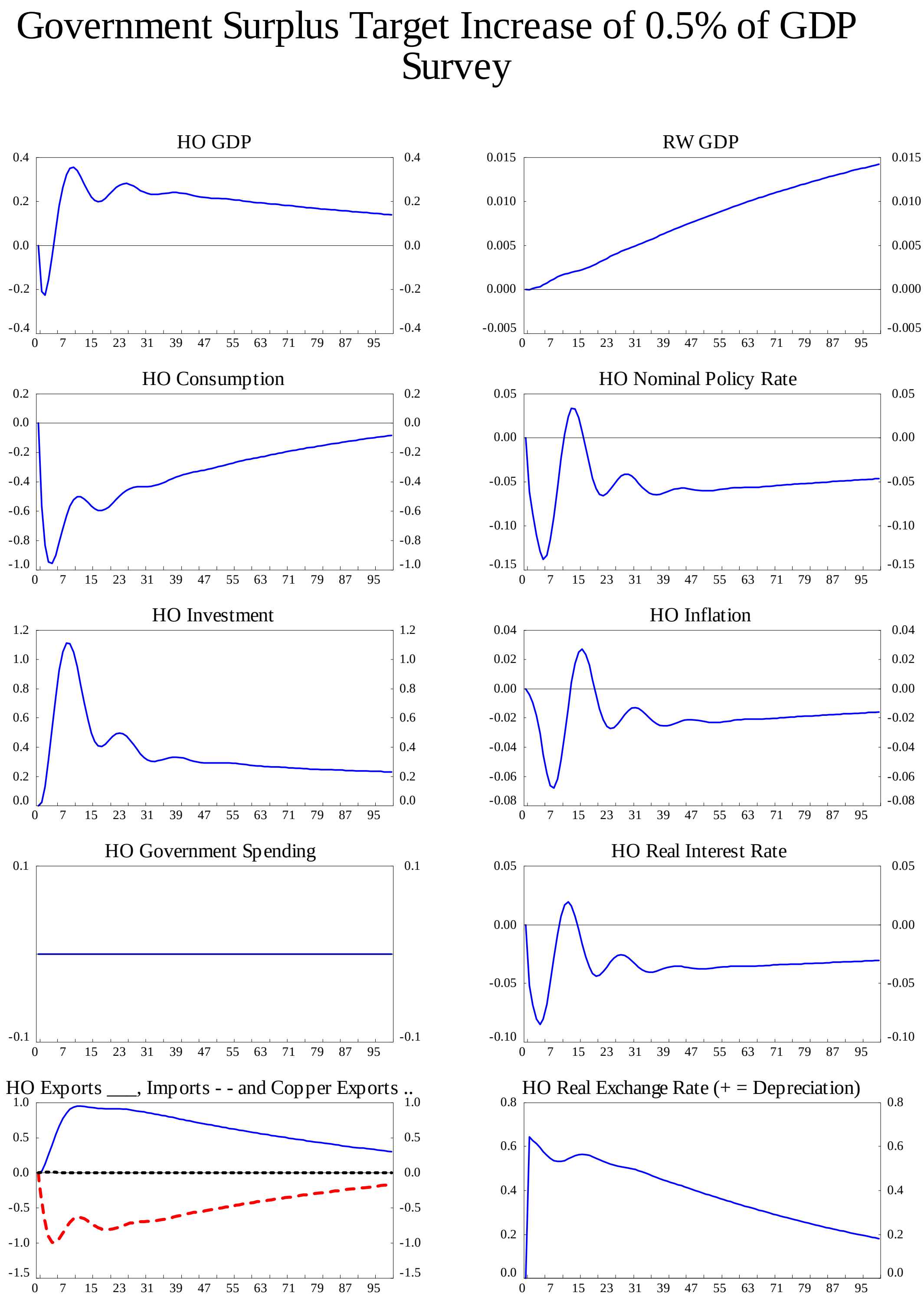

Figure 9: Surplus Target Shock - Survey

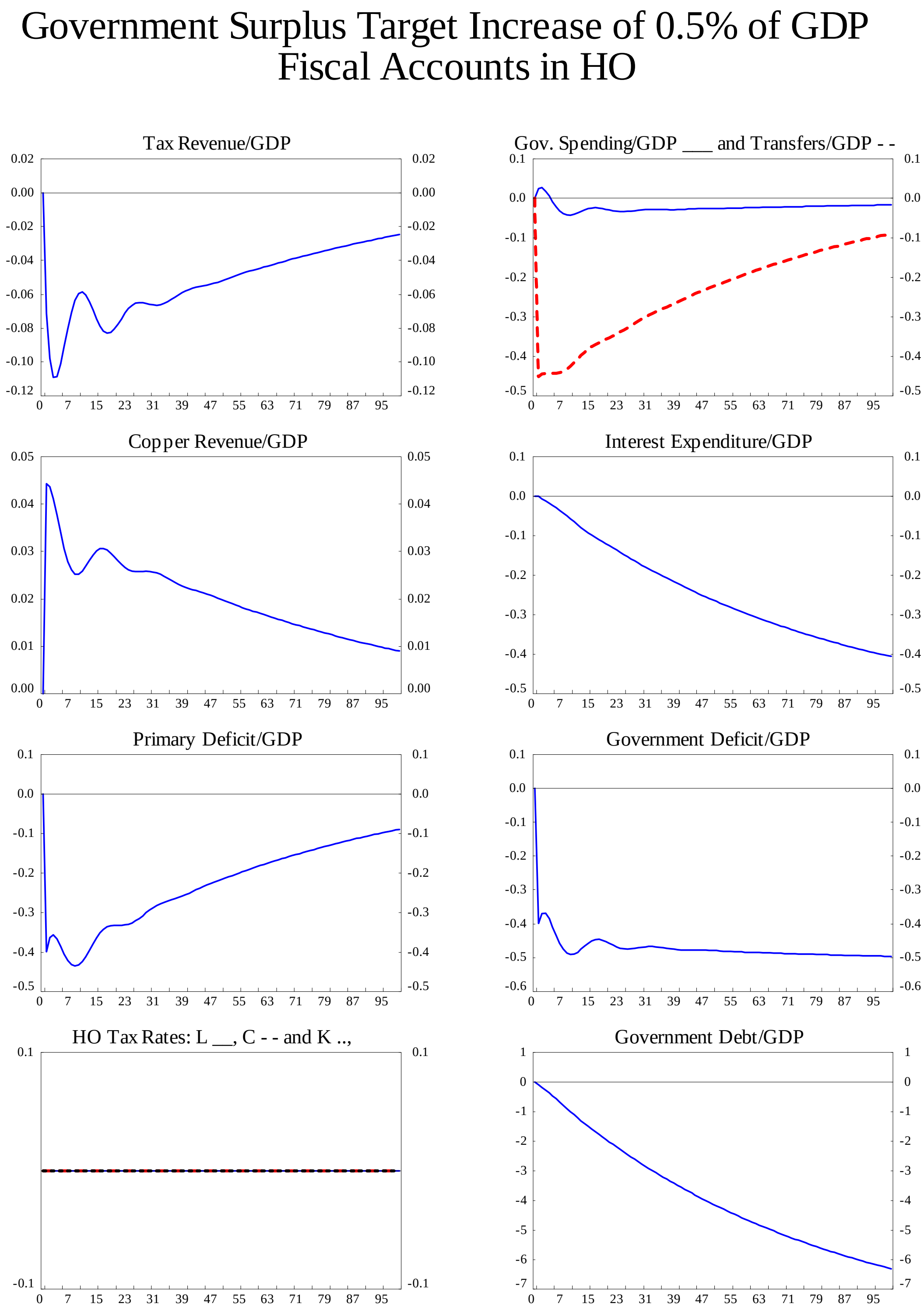

Figure 10: Surplus Target Shock - Fiscal Accounts

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