WP/09/286

IMF Working Paper

Jointly Optimal Monetary and Fiscal Policy Rules under Borrowing Constraints

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INTERNATIONAL MONETARY FUND

 WP/09/286

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Research Department

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Authorized for Distribution by Douglas Laxton

December 2009

Abstract

We study the welfare properties of an economy where both monetary and fiscal policy follow simple rules, and where a subset of agents is borrowing constrained. The optimized fiscal rule is far more aggressive than automatic stabilizers, and stabilizes the income of borrowing-constrained agents, rather than output. The optimized monetary rule features super-inertia and a very low coefficient on inflation, which minimizes real wage volatility. The welfare gains of optimizing the fiscal rule are far larger than the welfare gains of optimizing the monetary rule. The preferred fiscal instruments are government spending and transfers targeted to borrowing-constrained agents.

JEL Classification Numbers: E43, E63, H30.

Keywords: Optimal simple rules; monetary policy rules; fiscal policy rules; welfare analysis; borrowing constraints.

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I. Introduction

Fiscal policy has, in the wake of the recent financial crisis, become the center of attention in macroeconomics. Given the perceived urgency of preventing a very deep recession, the initial attention was almost exclusively focused on the pros and cons of fiscal stimulus measures[2], but some attention is now shifting to the need for longer run sustainability.[3] Remarkably though, the economics profession entered this period of turmoil with an almost non-existent set of analytical tools to think about the systematic use of fiscal policy in response to the business cycle. In other words, and completely unlike the monetary policy literature since Taylor (1993), there was almost no work on systematic rules-based fiscal policy. This should be of significant concern, because one of the main lessons of the monetary policy literature following the Lucas critique has been that we cannot expect the public to respond in the intended fashion to systematic policies unless such policies have first been clearly communicated and incorporated into agents' expectations.

Furthermore, if such communication is the goal, it makes little sense for such policies to be formulated, as is sometimes found in the academic literature, as feedback rules that have fiscal instruments respond to a host of variables that are, in the real world, not observable by economic agents, or even worse, to have them respond directly to "shocks". In the monetary policy literature this problem is overcome in a very simple and effective manner: One clearly observable variable, the nominal interest rate, responds to another clearly observable variable, inflation. We propose something similar for fiscal policy, by having the interest inclusive deficit to GDP ratio, a closely watched economic aggregate, respond to an appropriate measure of tax collection. The reason for the latter is that tax collection moves closely with a measure of budget tightness of borrowing-constrained agents that is key for aggregate welfare. The reason for choosing the interest inclusive deficit to GDP ratio is that stabilizing this variable automatically stabilizes the debt to GDP ratio, but with a near unit root in debt. The latter has been found to be optimal in the theoretical literature[4], and will again be found to be optimal here.

There is however one key difference between monetary and fiscal policy that even the best designed rule cannot overcome. In monetary policy there is, except for the possibility of exchange rate targeting in open economies, no serious alternative to the one main candidate for the policy instrument, the nominal interest rate. Fiscal policy on the other hand exhibits a great multiplicity of possible instruments. We argue that there is no serious alternative to examining these one at a time, and do so in this paper. Specifically, we consider three different distortionary taxes and three different categories of government spending, and compare their potential for raising welfare if combined with the appropriate rule.

[2]There is a large empirical literature on this topic, with fairly inconclusive results. In the theoretical literature, for a skeptical view on the effects of stimulus through government spending see Taylor and Wieland (2008) and Cogan et al. (2009) and for a more positive view see Christiano et al. (2009). Freedman et al. (2009) considers a much larger range of fiscal instruments and monetary responses, and obtains a broad range of possible multipliers.

[3]Freedman et al. (2009) analyze long-run crowding-out effects.

[4]For a very prominent example see Aiyagari et al. (2002).

Taylor (2000) is one of the very few recent examples that analyze a feasible, practical fiscal policy rule. In his case the budget surplus depends on the output gap. But Taylor argues that such a rule is unnecessary, and in fact undesirable, because the Fed has been very successful at stabilizing the business cycle and would only suffer from having to forecast the fiscal stance. He therefore argues, along with many other commentators at that time, that the role of fiscal policy should be limited to minimizing distortions and to "letting automatic stabilizers work". Automatic stabilizers describes channels through which policy can be mildly countercyclical even if spending and the transfer and tax systems are held constant. In an upturn this reduces the spending and transfers to GDP ratios, and it increases the tax revenues to GDP ratio.

Taylor (2000) makes two exceptions to his assessment. The first is fixed exchange rate regimes, where monetary policy deliberately gives up its stabilizing role. The second is a situation where nominal interest rates approach their zero lower bound, so that discretionary monetary policy becomes much more difficult. A fixed exchange rate regime such as EMU is indeed the main case for which countercyclical fiscal policy has so far been analyzed by the theoretical literature.[5] The zero lower bound problem is what the world's economies face today, and is a major reason for the renewed interest in fiscal policy even under flexible exchange rates. As shown in a number of recent papers, it does in fact mean that fiscal policy becomes far more effective at stimulating the economy.[6]

There is however a third exception that has so far been largely neglected by the literature[7], and on which we focus here. This is the much greater power of fiscal policy in an economy where a large share of agents is unable to smooth consumption intertemporally. In such an environment fiscal activism may be desirable even under flexible exchange rates and away from the zero bound. Such an environment has always characterized developing countries, and furthermore, in the light of the worldwide financial crisis, it is likely to characterize a significant share of households in industrialized countries in the future.

Optimality of a fiscal rule can mean many different things to different people. Clearly in a model the appropriate measure for optimality vis-a-vis households is welfare, and we will analyze this here. But in practice policymakers will also worry about excessive volatility of their fiscal instruments as a result of rules that are too aggressive. An analysis of fiscal volatility will therefore accompany our welfare analysis. For welfare analysis, we perform a full second-order approximation of the model and utility function, and we numerically optimize the coefficients of the policy reaction function. Results are presented by way of grid searches over those coefficients.

As explained above, we find that the preferred type of simple rule targets a tax revenue gap rather than an output gap. Choosing the right measure of the tax revenue gap closely proxies the budget tightness of borrowing-constrained agents, so that the government, by responding to this gap, can help relieve that tightness by substituting its access to capital markets for that of the constrained agents. Tax revenue gap rules can be used to represent a continuum of rules that includes the balanced budget rule, the structural surplus rule,

[5] The contributions on fiscal policy under fixed exchange rates include Beetsma and Jensen (2005) and Gali and Monacelli (2008). Muscatelli, Tirelli and Trecroci (2004) examine the closed economy case. All of these papers assume that households face no constraints on smoothing consumption intertemporally.

[6] See Christiano et al. (2009) and Freedman et al. (2009).

[7] For recent exceptions see Kumhof and Laxton (2009) and Stehn (2009).

and highly countercyclical rules. We find that the welfare improvements available by moving from balanced budget rules to more aggressive rules are very large compared to what is typically found in the monetary policy literature. The optimal rule is far more aggressive and responds to a different tax aggregate than simple structural surplus rules or automatic stabilizers. Furthermore, these increases in welfare have only modest costs in terms of additional fiscal instrument volatility.

Among our different fiscal instruments, we find that the best choices are government spending and transfers targeted to borrowing-constrained agents. We will however argue that the former is not a realistic choice in practice, making targeted transfers the instrument of choice. The recent literature often considers only one gap variable in fiscal rules, namely the debt gap.[8] We find the debt gap to be of only second-order importance once the tax revenue gap is present.

For monetary policy, we find that the optimal rule exhibits super-inertia and a very small coefficient on inflation. The reason for the former has to do with complex interactions between the monetary and fiscal policy rules. The reason for the latter is that a more aggressive real interest rate response causes a more volatile real wage. This increases the volatility of borrowing-constrained agents' income in a way that cannot be fully offset by fiscal policy, thereby lowering welfare. This part of our results is similar to Stehn (2009), who uses a linear-quadratic model without capital.

An analysis of fiscal and monetary rules must be part of an appropriate overall modeling framework that makes both fiscal and monetary interventions non-neutral. Pure monetary business cycle models with nominal rigidities are well known to not adequately replicate the dynamic short-run effects of fiscal policy.[9] The solution is to combine non-Ricardian household savings behavior with nominal rigidities. This can then also account for the critical interactions between monetary and fiscal policy rules.

The main non-Ricardian models known from the literature are overlapping generations models following Blanchard (1985) and Weil (1989) and infinite horizon models with a subset of borrowing-constrained agents following Gali, López-Salido and Vallés (2007). In this paper we use the latter model class, for three reasons. First, the consumption optimality condition of an overlapping generations model can typically only be derived under certainty equivalence, which rules out welfare analysis. Second, the assumption that a share of households are constrained to consume at most their current income in every period seems intuitively very plausible and is supported by recent empirical evidence. Third, as we will see, the presence of borrowing-constrained agents is what really gives power to fiscal policy and therefore makes the analysis interesting. This is because a borrowing constraint is a market failure that the government is extremely well placed to correct. Overlapping generations models, while they do generate a role for active fiscal policy[10], remain much closer to infinite horizon models because they do not feature borrowing constraints.

[8] For a well-known recent example see Schmitt-Grohe and Uribe (2007).

[9] See Fatas and Mihov (2001), Blanchard and Perotti (2002), Ganelli and Lane (2002) and Gali, López-Salido and Vallés (2007).

[10] See Chadha and Nolan (2007).

The rest of the model contains the minimum features necessary to, first, permit us to study a comprehensive range of fiscal tools, and second, to allow for a realistic calibration of the model that matches key moments of the U.S. data. The model therefore features endogenous labor supply and capital accumulation, productive government investment in infrastructure, habit persistence, investment adjustment costs, and sticky nominal goods prices.

The remainder of the paper is organized as follows. Section 2 describes the model, Section 3 discusses calibration, Section 4 presents our results, and Section 5 concludes.

II. The Model

We consider a closed economy that is populated by two types of households, both of which consume output and supply labor. Infinitely-lived households, identified by the superscript INF, have full access to financial markets, while borrowing-constrained households, identified by BC, are limited to consuming their after tax income, augmented by government net transfers, in every period. The share of BC agents in the population equals ψ. Households of both types are subject to uniform taxes on labor income and consumption. They also pay/receive lump-sum taxes/transfers that can be targeted to each household group separately.

Manufacturers operate a Cobb-Douglas technology in capital and labor, both of which are obtained from households. The technology's productivity is augmented by a publicly provided, tax-financed capital stock (infrastructure). Final output is sold to households and the government, subject to nominal rigidities in price setting.

Asset markets are incomplete. Government debt takes the form of nominally non-contingent one-period bonds, while firm dividends are distributed to households in a lump-sum fashion.

Technology grows at the constant rate $g = A_t/A_{t-1}$, where A_t is the level of labor augmenting technology. The model's real variables, say x_t, therefore have to be rescaled by A_t, where we will use the notation $\check{x}_t = x_t/A_t$. The steady state of $\check{x}_t$ is denoted by $\bar{x}$. Time units represent quarters.

A. Infinitely-Lived Households

The utility of a representative INF household at time t depends on consumption c_t^{INF} and labor supply ℓ_t^{INF}. Lifetime expected utility has the form

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\left(1 - \frac{v}{g}\right) \epsilon_t^c \ln(c_t^{INF} - v\bar{c}_{t-1}^{INF}) - \frac{\kappa}{1+\frac{1}{\gamma}} (\ell_t^{INF})^{1+\frac{1}{\gamma}} \right) , \tag{1}$$

where β is the discount factor, v indexes the degree of (external) habit persistence, γ is the labor supply elasticity, ϵ_t^c is a shock to the marginal utility of consumption, and the factor $(1 - v/g)$ ensures that the marginal utility of consumption is independent of the degree of habit persistence. Consumption c_t^{INF}, which is taxed at the rate $\tau_{c,t}$, is given by a CES aggregate over consumption goods varieties $c_t^{INF}(i)$, with elasticity of substitution σ. Lagged consumption $\bar{c}_{t-1}^{INF}$ is in average per capita terms and is external to the INF household.

A household can hold nominal domestic government bonds B_t^{INF}, with real debt given by $b_t^{INF} = B_t^{INF}/P_t$, where P_t is the consumer price index. The time subscript t denotes financial claims held from period t to period $t+1$. The gross nominal interest rate on government debt held from t to $t+1$ is i_t. We denote gross inflation by $\pi_t = P_t/P_{t-1}$, and the gross real interest rate by $r_t = i_t/\pi_{t+1}$.

In addition to interest income INF households receive after tax labor income, capital income and dividends. Real after-tax labor income equals $w_t \ell_t^{INF}(1-\tau_{L,t})$, where $w_t = W_t/P_t$ is the real wage rate and $\tau_{L,t}$ is the labor income tax rate. Real after-tax capital income equals $r_t^k k_{t-1}^{INF} - \tau_t^k k_{t-1}^{INF}\left(r_t^k - \delta_k q_t\right)$, where $r_t^k = R_t^k/P_t$ is the real rental rate of capital, τ_t^k is the capital income tax rate, δ_k is the depreciation rate of capital and q_t is the market value of installed capital (Tobin's q). Real after-tax dividends equal $d_t^{INF}(1-\tau_t^k)$, where $d_t^{INF} = D_t^{INF}/P_t$. Note that we assume that all of the return to capital, including pure economic profits due to market power, are taxed at the rate τ_t^k. Per capita investment spending is given by I_t^{INF}. Finally, INF households pay lump-sum taxes τ_t^{ls} to the government. The INF household's budget constraint in real terms is

$$\begin{aligned}(1+\tau_t^c)c_t^{INF} + I_t^{INF} + b_t^{INF} &= r_{t-1}b_{t-1}^{INF} + w_t\ell_t^{INF}(1-\tau_t^L) + (r_t^k k_{t-1}^{INF} + d_t^{INF})(1-\tau_t^k) \\ &+ \tau_t^k \delta_k q_t k_{t-1}^{INF} - \tau_{ls,t}^{INF} \; . \end{aligned} \tag{2}$$

Capital accumulation is given by

$$k_t^{INF} = (1-\delta_k)k_{t-1}^{INF} + I_t^{INF} - \frac{\phi_I}{2}\left(\frac{\epsilon_t^I}{g}\frac{I_t^{INF}}{I_{t-1}^{INF}} - 1\right)^2 \bar{I}_t^{INF} \; , \tag{3}$$

where the final term gives rise to inertia in investment, $\bar{I}_t^{INF}$ average per capita investment and taken as given by the household, and ϵ_t^I is a shock to investment demand.

The household maximizes (1) subject to the budget constraint (2) and the capital accumulation equation (3). We denote the multiplier of (2) by λ_t, and the multiplier of (3) by $\lambda_t q_t$. Then the first-order conditions of the INF household's optimization problem with respect to consumption c_t^{INF}, labor ℓ_t^{INF}, government bonds b_t^{INF}, capital k_t^{INF} and investment I_t^{INF} are, after normalizing by technology, given by

$$\frac{\left(1-\frac{v}{g}\right)\epsilon_t^c}{\check{c}_t^{INF} - \frac{v}{g}\check{c}_{t-1}^{INF}} = \check{\lambda}_t(1+\tau_t^c) \; , \tag{4}$$

$$\kappa(\ell_t^{INF})^{\frac{1}{\gamma}} = \check{\lambda}_t \check{w}_t(1-\tau_t^L) \; , \tag{5}$$

$$\check{\lambda}_t = \frac{\beta}{g}E_t\left(\check{\lambda}_{t+1}\frac{i_t}{\pi_{t+1}}\right) \; , \tag{6}$$

$$\check{\lambda}_t q_t = \frac{\beta}{g}E_t\left(\check{\lambda}_{t+1}\left(q_{t+1} + (r_{t+1}^k - \delta_k q_{t+1})(1-\tau_{t+1}^k)\right)\right) \; , \tag{7}$$

$$q_t \left(1 - \phi_I \epsilon_t^I \frac{\check{I}_t^{INF}}{\check{I}_{t-1}^{INF}} \left(\epsilon_t^I \frac{\check{I}_t^{INF}}{\check{I}_{t-1}^{INF}} - 1 \right) \right) \tag{8}$$

$$= 1 - \beta E_t q_{t+1} \frac{\check{\lambda}_{t+1}}{\check{\lambda}_t} \phi_I \epsilon_{t+1}^I \left(\frac{\check{I}_{t+1}^{INF}}{\check{I}_t^{INF}} \right)^2 \left(\epsilon_{t+1}^I \frac{\check{I}_{t+1}^{INF}}{\check{I}_t^{INF}} - 1 \right) .$$

B. Borrowing-Constrained Households

The objective function of BC households differs from that of INF households in two ways. First, BC households do not exhibit habit persistence. And second, they are assumed to not be subject to consumption demand shocks:

$$\max \quad E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln(c_t^{BC}) - \frac{\kappa}{1 + \frac{1}{\gamma}} (\ell_t^{BC})^{1+\frac{1}{\gamma}} \right) . \tag{9}$$

The budget constraint of BC households differs in that these agents cannot engage in intertemporal substitution, and are instead limited to consuming at most their current income in each period. The latter consists of their after tax wage income $w_t \ell_t^{BC}(1 - \tau_t^L)$ minus lump-sum taxes $\tau_{ls,t}^{BC}$ plus lump-sum transfers targeted specifically to this group of households Υ_t/ψ, where Υ_t are the aggregate targeted transfers that appear in the government's budget constraint and Υ_t/ψ is their per capita equivalent:

$$(1 + \tau_t^c) c_t^{BC} \leq w_t \ell_t^{BC} (1 - \tau_t^L) - \tau_{ls,t}^{BC} + \frac{\Upsilon_t}{\psi} . \tag{10}$$

The BC household maximizes (9) subject to the budget constraint (10), where the multiplier of the latter is given by η_t. Then the first-order conditions of the BC household's optimization problem with respect to consumption c_t^{BC} and labor ℓ_t^{BC} are, after normalization by technology, given by

$$\frac{1}{\check{c}_t^{BC}} = \check{\eta}_t (1 + \tau_t^c) , \tag{11}$$

$$\kappa (\ell_t^{BC})^{\frac{1}{\gamma}} = \check{\eta}_t \check{w}_t (1 - \tau_t^L) , \tag{12}$$

together with (10) holding with equality. Aggregate consumption is given by $\check{c}_t = (1-\psi)\check{c}_t^{INF} + \psi \check{c}_t^{BC}$, and similarly for aggregate labor L_t and real lump-sum taxes $\check{\tau}_{ls,t}$. Aggregate government debt is $b_t = (1-\psi) b_t^{INF}$, and similarly for dividends d_t, capital k_t and investment I_t. When we consider for comparison purposes a more canonical model with only infinitely-lived households we set $\psi = 0$.

C. Firms

There is a continuum of firms indexed by $j \in [0, 1]$. Firms are perfectly competitive in their input markets and monopolistically competitive in their output market. They pay out each period's net cash flow as dividends to INF households and maximize the present discounted value of these dividends. Their price setting is subject to nominal rigidities.

The technology of a representative firm is given by a Cobb-Douglas production function in aggregate private capital k_{t-1}, labor L_t and aggregate public infrastructure k^g_{t-1}:

$$y_t(j) = \mathcal{A}\left(k_{t-1}(j)\right)^{\alpha_k}\left(A_t\epsilon^a_t\ell_t(j)\right)^{1-\alpha_k}\left(\frac{k^g_{t-1}}{A_{t-1}}\right)^{\alpha_g} . \tag{13}$$

Here the scaling factor equals $\mathcal{A} = (\alpha_k)^{-\alpha_k}(1-\alpha_k)^{-(1-\alpha_k)}$, and ϵ^a_t is a shock to labor augmenting productivity. The stock of public infrastructure k^G_{t-1} is external to the firm's decision, and is identical for all firms. It is provided free of charge to the end user (but not of course to the taxpayer), and enters in a similar fashion to the level of technology, but with decreasing returns to public capital as long as $\alpha_g < 1$. The advantage of this formulation is that it retains constant returns to scale at the level of each firm.

Cost minimization yields standard conditions, which we report here after dropping the firm specific index j because in equilibrium all firms behave identically, and also after normalizing by technology:

$$r^k_t = \alpha_k\frac{\check{y}_t}{\check{k}_{t-1}/g} , \tag{14}$$

$$\check{w}_t = (1-\alpha_k)\frac{\check{y}_t}{\ell_t} , \tag{15}$$

The definition of marginal cost mc_t is

$$mc_t = \frac{\check{w}_t^{1-\alpha_k}(r^k_t)^{\alpha_k}}{(\epsilon^a_t)^{1-\alpha_k}\left(\check{k}^g_{t-1}\right)^{\alpha_g}} . \tag{16}$$

Firms' profit maximization problem consists of maximizing the present discounted value of dividends $d_t(i)$, where the latter equal real revenue $P_t(i)y_t(j)/P_t$ minus real marginal costs $mc_ty_t(j)$, price adjustment costs $G^p_t(j)$, and a fixed cost $A_t\Psi$. The latter arises as long as the firm chooses to produce positive output, and grows at the constant growth rate of technological progress. Net output is therefore equal to $\max(0, y_t(j) - A_t\Psi)$. This cost term will be useful for calibrating the model's steady state. Price adjustment costs $G^p_t(j)$ follow Rotemberg (1982), but allowing for a nonzero steady state rate of inflation $\bar{\pi}$, which equals the inflation target of the central bank, and with costs scaled by the aggregate level of output y_t:

$$G^p_t(j) = \frac{\phi_p}{2}y_t\left(\frac{P_t(j)}{P_{t-1}(j)} - \bar{\pi}\right)^2 . \tag{17}$$

Firms discount future nominal cash flows using the intertemporal marginal rate of substitution of their owners, INF households, which equals $\beta\left(\lambda_{t+1}/\lambda_t\right)\left(P_t/P_{t+1}\right)$. The optimization problem is therefore

$$\max \quad E_0\sum_{t=0}^{\infty}\beta^t\frac{\lambda_t}{P_t}\left(P_t(j)y_t(j) - P_tmc_ty_t(j) - P_tG^p_t(j) - P_tA_t\Psi\right) . \tag{18}$$

The first-order condition for price setting is, after normalization, given by

$$\mu mc_t - 1 = \phi_p\left(\mu-1\right)\left(\pi_t - \bar{\pi}\right)\pi_t - \beta E_t\phi_p\left(\mu-1\right)\frac{\check{\lambda}_{t+1}}{\check{\lambda}_t}\frac{\check{y}_{t+1}}{\check{y}_t}\left(\pi_{t+1} - \bar{\pi}\right)\pi_{t+1} , \tag{19}$$

where $\mu = \sigma/(\sigma-1)$ is the steady state gross markup of price over marginal cost. Finally, after taking account of the fact that all firms act identically in equilibrium, aggregate real dividends are given by

$$\check{d}_t = \check{y}_t - mc_t\check{y}_t - \check{G}_t^p - \Psi \ . \tag{20}$$

D. Government

Monetary policy follows a conventional inflation forecast-based rule for the nominal interest rate. Fiscal policy follows a rule that depends on a real activity gap, whose nature will be discussed in more detail below. Policymakers jointly optimize the coefficients of both rules.

1. Monetary Policy

The interest rate rule allows for smoothing of the nominal interest rate, and for responses to both an inflation and output gap term. It is given by

$$\ln\frac{i_t}{\bar{\imath}} = \delta^i \ln\frac{i_{t-1}}{\bar{\imath}} + \delta^\pi\left(\iota\ln\frac{\pi_t}{\bar{\pi}} + (1-\iota)\ln\frac{\pi_{t+1}}{\bar{\pi}}\right) + \delta^y\left(\ln\frac{\check{y}_t}{\bar{y}}\right) \ ,$$

where $\bar{\imath}$ is the product of the long-run or target real interest rate $\bar{r}$ and the inflation target $\bar{\pi}$. We have dropped the output gap from this rule because it turns out to have negligible effects on our results. The parameter ι determines the weight on contemporaneous and one-period-ahead inflation in the inflation gap. This weight will turn out to be different from one in our calibration of the model, but for optimal policy, given our remaining assumptions, it ends up being optimal to set $\iota = 1$.

2. Budget Constraint

Government consumption spending c_t^g is wasteful, while government investment spending I_t^g augments the stock of publicly provided infrastructure capital k_t^g, the evolution of which is given by

$$k_t^g = (1-\delta^g)k_{t-1}^g + I_t^g \ . \tag{21}$$

The government budget constraint, in nominal terms, takes the form

$$B_t = i_{t-1}B_{t-1} - P_t s_t^p \ , \tag{22}$$

where s_t^p is the primary surplus

$$s_t^p = \tau_t - c_t^g - I_t^g - \Upsilon_t \ , \tag{23}$$

and where τ_t is aggregate tax revenue

$$\tau_t = \tau_t^L w_t \ell_t + \tau_t^c c_t + \tau_t^k (r_t^k - \delta_k q_t)k_{t-1} + \tau_t^k d_t + \tau_{ls,t} \ . \tag{24}$$

The final component of fiscal policy is the policy rule, which is presented separately in the following subsection. This rule is expressed in terms of the overall, interest-inclusive fiscal surplus, which is defined as

$$\begin{aligned} s_t^f &= \frac{B_{t-1} - B_t}{P_t} = s_t^p - \frac{(i_{t-1} - 1)B_{t-1}}{P_t} \\ &= \frac{b_{t-1}}{\pi_t} - b_t = s_t^p - \frac{i_{t-1} - 1}{\pi_t} b_{t-1} \ . \end{aligned} \tag{25}$$

3. Fiscal Policy

Structural Surplus Rules

Structural surplus rules (henceforth SSR) are becoming more popular, with Germany recently joining Chile, Switzerland and Sweden in adopting such a rule. In terms of our model it can be represented as

$$\frac{\check{s}_t^f}{\check{y}_t} - \overline{s^{rat}} = \frac{\check{\tau}_t}{\check{y}_t} - \frac{\check{\tau}_t^{pot,SSR}}{\bar{y}} \ . \tag{26}$$

The structural surplus target $\overline{s^{rat}}$ is exogenous. The right-hand side represents a cyclical adjustment term whereby the government saves, in the form of reduced debt or increased assets, excess tax revenue. Potential output $\bar{y}$ is the steady output of the model. Potential tax revenue $\check{\tau}_t^{pot,SSR}$ is given by the same formula as actual tax revenue $\check{\tau}_t$ in equation (24), at current tax rates, but with the actual tax bases replaced by potential tax bases, which in our model will simply equal their steady state values:

$$\check{\tau}_t^{pot,SSR} = \tau_t^L \bar{w}\bar{\ell} + \tau_t^c \bar{c} + \tau_t^k (\bar{r}^k - \delta_k) \left(\bar{k}/g\right) + \tau_t^k \bar{d} + \check{\tau}_{ls,t} \ . \tag{27}$$

It is important to emphasize that a structural surplus rule does not require a debt feedback term in order to stabilize government debt. Equation (25) shows that the rule (26) anchors the long-run debt to GDP ratio $\overline{b^{rat}}$ at

$$\overline{b^{rat}} = -\frac{1}{4}\overline{s^{rat}}\frac{\bar{\pi}g}{\bar{\pi}g - 1} \ . \tag{28}$$

Our calibrated economy features a 5% annual nominal growth rate $\bar{\pi}g$. This implies a quarterly autoregressive coefficient on debt in equation (25) of 0.988, so that debt takes a very long time to return to its long-run value following a shock. If this speed of debt stabilization should be deemed insufficient, then a debt feedback term can be included in the rule. Equation (26) is a targeting rule, and it leaves open which instrument is to be used to move the government surplus in the desired direction. We will look at six possible instruments, three tax rates ($\tau_{c,t}$, $\tau_{L,t}$, $\tau_{k,t}$) and three spending items (Υ_t, g_t^{cons}, g_t^{inv}). The default instrument for our baseline results reported below is targeted transfers Υ_t.

The rule (26) states that when the economy is hit with a shock that produces additional tax revenue at given tax rates, all of that excess revenue should go towards repaying debt, while only the interest savings on debt that accrue over time should be used to gradually lower tax rates or increase spending. This is a natural rules-based way to formalize automatic stabilizers. Such a rule however does not have business cycle stabilization or welfare-type objectives as its prime concern. We therefore now turn to alternatives that are however built directly on the logic of (26).

Countercyclical Rules

The attempt to develop a more general class of rules is based on two key insights. First, the coefficient multiplying the tax revenue gap in (26), which we will denote by d^{τ}, can be varied continuously rather than being limited to a value of 1. For example, $d^{\tau} = 0$ corresponds to a balanced budget rule, and $d^{\tau} > 1$ corresponds to more highly countercyclical rules, where the cycle being referred to does not necessarily represent GDP but other measures of activity more closely associated with household welfare. This leads us to the second key insight, which is that the definition of the tax revenue gap itself in (26) may need to be changed to achieve higher welfare. As we will demonstrate, the critical role of fiscal policy is to stabilize the income of BC households, and in that case the preferred tax revenue gap excludes capital income tax revenue, which exclusively affects INF households. After a quantitative search over a number of alternatives, we have therefore concluded that the following alternative tax revenue and potential tax revenue variables offer the best performance:

$$\check{\tau}_t^{rule} = \tau_t^L \check{w}_t \ell_t + \tau_t^c \check{c}_t \ , \tag{29}$$

$$\check{\tau}_t^{pot} = \tau_t^L \bar{w} \bar{\ell} + \tau_t^c \bar{c} \ . \tag{30}$$

Finally, we add to the rule an additional debt gap variable with coefficient d^b, but it turns out that this is of comparatively minor significance. The rule then becomes

$$\frac{\check{s}_t^f}{\check{y}_t} - \overline{s^{rat}} = d^{\tau} \left(\frac{\check{\tau}_t^{rule}}{\check{y}_t} - \frac{\check{\tau}^{pot}}{\bar{y}} \right) + d^b \left(\frac{\check{b}_t}{\check{y}_t} - \overline{b^{rat}} \right) \ . \tag{31}$$

The case of $d^{\tau} = d^b = 0$ corresponds to a strict balanced budget rule (henceforth BBR). This is highly procyclical because in a boom it calls for lower tax rates or higher spending, depending on which fiscal instrument is being endogenized by the rule. A choice of $d^{\tau} > 1$ corresponds to a countercyclical rule (henceforth CCR) that generally calls for a higher tax rate (or lower spending) in a boom.

We will also need to specify a fiscal rule when calibrating the key dynamic coefficients of our model based on U.S. data. But here it is important that the U.S. has not in fact been following a rule such as (31), because that rule only represents a proposal of this paper. Instead, the best approximation of what the actual rule may have looked like is provided by the OECD estimates of Girouard and André (2005), who estimate an output gap rule similar to Taylor (2000). In terms of our model this can be represented as

$$\frac{\check{s}_t^f}{\check{y}_t} - \overline{s^{rat}} = d^y \ln \left(\frac{\check{y}_t}{\bar{y}} \right) \ . \tag{32}$$

In the context of our model $d^{\tau} > 1$ represents systematic changes in fiscal instruments. It can also be interpreted more broadly to represent automatic stabilizers in an economy where, unlike in our model, the tax system is progressive or where transfers, such as unemployment insurance, are countercyclical. But it is highly unlikely that such automatic stabilizers would be as countercyclical as the best rules selected by our welfare analysis.

E. Competitive Equilibrium

In equilibrium INF and BC households maximize utility and firms maximize the present discounted value of their cash flows, taking as given the government's policy rules, and the following market clearing condition holds for the final goods market:

$$\check{y}_t = \check{c}_t + \check{c}_t^g + \check{I}_t + \check{I}_t^g - \Psi \ . \tag{33}$$

The three shocks of the model are given by

$$z_t = (1 - \rho_z)\, \bar{z} + \rho_z z_{t-1} + \bar{z} u_t^z \ \ , \tag{34}$$

where $z_t \in \left\{\epsilon_t^c, \epsilon_t^I, \epsilon_t^a\right\}$.

F. Aggregate Welfare

The period utility of a representative INF household in equilibrium at time t is, letting $\zeta = \left(1 - \frac{v}{g}\right)$, given by

$$u_t^{INF} = \zeta \epsilon_t^c \ln\left(c_t^{INF} - v c_{t-1}^{INF}\right) - \frac{\kappa}{1 + \frac{1}{\gamma}} \left(\ell_t^{INF}\right)^{1+\frac{1}{\gamma}} \ .$$

The expectation of welfare is

$$\mathcal{W}_t^{INF} = u_t^{INF} + \beta E_t \mathcal{W}_{t+1}^{INF} \ . \tag{35}$$

We define the Lucas (1987) compensating consumption variation η^{INF} (in percent) of a given suboptimal combination of fiscal and monetary rule parameters as the percentage reduction of average consumption under the optimal combination of rule parameters that agents would be willing to tolerate while remaining indifferent between the expectations of welfare under the two combinations, say $E\mathcal{W}^{INF,sub}$ and $E\mathcal{W}^{INF,opt}$. Then η^{INF} is given by

$$\eta^{INF} = 100 \left(1 - \exp\left(\frac{(\beta - 1)}{\zeta}\left(E\mathcal{W}^{INF,sub} - E\mathcal{W}^{INF,opt}\right)\right)\right) \ . \tag{36}$$

The formula for η^{BC} is identical. We will analyze these group specific welfare measures but also aggregate welfare, which we quantify by way of the population-weighted average of compensating variations:

$$\eta = (1 - \psi)\, \eta^{INF} + \psi \eta^{BC} \ . \tag{37}$$

The paper uses DYNARE++ second order approximations of the model to compute unconditional welfare, and then uses the foregoing formulas to compute compensating consumption variations.

We perform a multi-dimensional grid search over all fiscal and monetary rule coefficients. We find that the output gap term in the monetary rule does not have significant effects (and neither does an output growth term), and we therefore set $\delta^y = 0$. We also find that welfare is always strictly increasing in ι, and we therefore set $\iota = 1$. Given this, we are left with a four dimensional grid search over δ^τ, δ^b, δ^i and δ^π. That grid search produces an overall optimum, and as mentioned above we will express all welfare results as compensating variation differences between that overall optimum and other points on the grid.

III. Calibration

The model is calibrated for the quarterly frequency. We use U.S. data for the period 1984Q1 - 2007Q4, detrended by removing a log-linear trend, to calibrate key national accounts ratios and the dynamics of the shock processes, and we rely on the literature for a number of other parameters. The real growth rate is calibrated at 2% per annum ($g = 1.005$) and the real interest rate at 3% per annum ($\beta = 0.9975$). The steady-state inflation rate is fixed at 3% per annum ($\bar{\pi} = 1.0075$). As for the share of borrowing-constrained agents ψ, important recent theoretical studies such as Galí et al. (2007) and Erceg et al. (2005) have assumed $\psi = 0.5$. The empirical literature has not yet converged on a consensus estimate, but $\psi = 0.5$ is generally held to be at the high end, with some studies having found quite low estimates of around $\psi = 0.1$. We adopt an intermediate value of $\psi = 0.3$, which is supported by several recent studies using Bayesian estimation in developed countries. For the Euro area Coenen and Straub (2005) obtain an estimate of 0.37, and Forni, Monteforte and Sessa (2007) obtain 0.34. Iwata (2009) estimates the share to be 0.248 in Japan.

The habit parameter v is set to 0.7, following Smets and Wouters (2003), and the labor supply elasticity is fixed at 1 ($\gamma = 1$). The depreciation rate of private capital is standard at 10% per annum ($\delta_k = 0.025$), and the investment adjustment cost parameter, at $\phi_I = 2.5$, follows Christiano, Eichenbaum and Evans (2005). The price adjustment cost parameter is set to $\phi_p = 100$. Together with the assumption that the gross markup equals $\mu = 1.2$, this is equivalent to assuming, in a model with Calvo (1983) pricing, that the average duration of price contracts equals roughly 4 quarters. The cost share of private capital, α^k, is calibrated to obtain a labor income share of 64%, and he private investment to GDP ratio is calibrated at 17%.

As for the public capital stock, in the U.S. infrastructure investment represents one sixth of all government spending. This may however be too low as it assumes a zero productivity of public education and health spending. We therefore raise that share, but only slightly, to one fifth. Given an overall government spending to GDP ratio of 20%, we therefore fix the government consumption to GDP ratio at 16% and the government investment to GDP ratio at 4%. Also, steady state lump-sum transfers equal 10% of GDP. Following the method in Jones (2002), the steady state labor income, capital income and consumption tax rates are computed as 19.18%, 39.49% and 8.6% respectively. We follow Kamps' (2006) evidence for the depreciation rate of public capital at 4% per annum ($\delta_g = 0.01$). The productivity of public capital is determined by the parameter α_g. Ligthart and Suárez (2005) present a meta analysis that finds an elasticity of aggregate output with respect to public capital of 0.14, which we can replicate by setting $\alpha_g = 0.1$.[11]

On the basis of recent historical data, we set the steady state government debt to GDP ratio $\overline{b^{rat}}$ to 50 percent, with the corresponding deficit $\overline{s^{rat}}$ determined by the nominal growth rate. We calibrate the fiscal policy rule (32) according to the empirical estimates estimates of Girouard and André (2005), which for the U.S. equal $d^y = 0.34$.

[11] As summarized in Leeper, Walker and Yang (2009), the empirical literature has a wide range of values for this elasticity. At one extreme, Holtz-Eakin (1994) and Evans and Karras (1994) use state-level data and find that public-sector capital has negative or no effect on private sector productivity. At the other extreme, Aschauer (1989) and Pereira and de Frutos (1999) obtain significant productive effects from public capital, with elasticities in the range of 0.24 and 0.39. In this paper.

The autocorrelation coefficients and standard deviations of the model's three shocks are calibrated, together with the coefficients of the monetary rule, to reproduce the standard deviations and correlations of U.S. investment, consumption and inflation. Table 1 shows the moments of the data and the model.[12] We will show that our main results on welfare and policy instrument volatility are not very sensitive to changes in the relative sizes of the shock processes, by decomposing our results into the contributions of the shocks.

The model's one significant shortcoming is that the correlation between consumption and investment, while significant and of the right sign, is smaller than in the data. As is well known from the recent literature such as Christiano et al. (2009), this is due to the extreme simplicity of the model on the production and financing side, and could be remedied by introducing financial accelerator-type features. However, given that our focus is on a thorough understanding of the determinants of optimal monetary and fiscal policy rules, we feel that at this stage there is a payoff to maintaining a simpler model whose transmission mechanisms can be more readily understood.

IV. Results

A. Impulse Responses

To build intuition for our welfare results, we begin by comparing the impulse responses for one standard deviation shocks under different assumptions for one of the four coefficients of our rules, holding the three other coefficients at their overall optimum on the grid. That optimum is given by $\delta^{\tau} = 3$, $\delta^{b} = 0$, $\delta^{i} = 1.2$ and $\delta^{\pi} = 0.2$. For all simulations shown here, the fiscal instrument used to satisfy the fiscal rule (31) is transfers targeted to borrowing-constrained agents Υ.

1. Fiscal Policy Rule Parameters

Technology Shock

Figure 1 shows the impulse responses for a technology shock. A positive technology shock reduces inflation, leading to a drop in nominal and real interest rates and therefore a modest increase in INF households' consumption. It also reduces labor demand and the real wage, thereby significantly reducing labor tax revenue.

Under a BBR $d^{\tau} = 0$ consumption tax revenue does not increase very much because borrowing-constrained agents' consumption cannot increase much given their drop in income. On the other hand, capital income taxes increase sharply. As a result, while the overall targeted tax revenue drops, actual tax revenue collected increases. Under a BBR this requires the government to transfer more resources to BC households, thereby helping them to reduce their labor supply to benefit from the higher productivity.

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[12] The implied shock autocorrelations are $\rho_a = 0.68$, $\rho_c = 0.6$ and $\rho_I = 0.4$, and shock standard deviations are $\sigma_a = 0.018$, $\sigma_c = 0.015$ and $\sigma_I = 0.018$. The monetary rule parameters required to match the data are $\delta_i = 0.7$, $\delta_\pi = 2.0$ and $\iota = 0.5$.

Under a CCR $d^{\tau} > 0$ the fiscal surplus may deviate from its target, depending on the behavior of the targeted tax revenue. Under a positive supply shock, if d^{τ} is larger, more resources are transferred to BC households, allowing them to consume more but also to work less, which reduces the drop in the real wage. Both effects combine to reduce the drop in the targeted tax revenue, but given the stronger response to that revenue transfers nevertheless increase.

BC households benefit from smoother consumption as d^{τ} increases from 0 to around 1. However, beyond that the effect of higher d^{τ} becomes destabilizing because it is procyclical, boosting consumption in a boom, and also making BC labor supply more volatile. INF households on the other hand benefit from a larger d^{τ} almost without limit, as the reduction in BC households' labor supply accommodates the reduction in aggregate labor demand, thereby reducing the volatility of the real wage and thus the volatility of INF labor supply. INF households' consumption is not much affected by d^{τ} as they can intertemporally smooth the consumption effects of the productivity shock.

Investment Shock

Figure 2 shows the impulse responses for a negative investment shock. Monetary policy plays the usual demand supporting role during this shock, by lowering the real interest rate during a contraction and thereby supporting investment and INF consumption. However, this effect is small relative to the effect of fiscal policy on BC agents.

Comparing the effects of fiscal policy with those under a technology shock, the major difference is that a larger d^{τ} stabilizes the consumption of BC household under a demand shock over a much larger range. This is because a demand shock moves output and the targeted tax revenue in the same direction, while a supply shock moves them in opposite directions. When both move in the same direction, an aggressive fiscal policy supports BC agents during periods of low demand. This allows them to reduce their drop in consumption and to reduce the increase in their labor supply, or even to reduce it. The latter, during a period of low demand, helps to stabilize the real wage and therefore the labor supply volatility of INF agents, who therefore always benefit from a higher d^{τ}. On the other hand, beyond $d^{\tau} = 4$, the increase in the volatility of BC agents' labor supply starts to exceed the decrease in their consumption volatility.

Consumption Shock

Figure 3 shows the impulse responses under a positive consumption shock. The logic is almost identical to that of investment shocks: A large d^{τ} can make BC household better off if output and the targeted tax revenue go in the same direction.

2. Monetary Policy Rule Parameters

Figure 4 shows the impulse responses for different δ^{π} under a positive technology shock. A large δ^{π} implies that the central bank cuts the nominal interest rate aggressively in response to lower inflation. This lower the volatility of inflation but increases the volatility of the real interest rate, in this case reducing it and thereby boosting demand. Higher demand raises labor demand and the real wage. BC household consume more, which further raises the demand for goods and the real wage.

From the point of welfare, a large δ^{π} slightly improves the welfare of INF households by reducing the volatility of consumption through the real interest rate. But it makes BC households more significantly worse off by increasing the volatility of consumption through the real wage. Overall, the model calls for the optimal δ^{π} to be at 0.2, close to the minimum compatible with dynamic stability.

The conclusion that a small δ^{π} is optimal stands in sharp contrast to models without borrowing constraints. Schmitt-Grohe and Uribe (2007) use a similar model but allow all households to access the capital market. They find that a large δ^{π} always improves welfare. To facilitate a comparison with this case, we therefore now consider the case of $\psi = 0$, that is an identical model except for the absence of BC households.

Figure 5 illustrates. Under a positive technology shock, a lower demand for labor reduces the real wage by 1 percent immediately after the shock. However, an aggressive response of the central bank to lower inflation lowers the real interest rate, raises the demand for goods and raises the real wage. This helps to stabilize the volatility of labor supply and makes INF household better off. Overall, the results of Figures 4 and 5 for INF households look fairly similar. It is therefore not so much any interaction of INF and BC households that causes results regarding the optimal δ^{π} to be so different in our model, but rather the fact that BC suffer from an aggressive inflation response, and that given their lack of access to capital markets their losses tend to always exceed any corresponding benefits on the part of INF households.

Figure 6 shows the impulse responses for different δ^{i} under a positive technology shock. A large δ^{i} implies a lot of interest rate inertia for both nominal and real rates. Under a positive technology shock, a larger δ^{i} keeps the real interest rate low for a prolonged period and leads to a persistent boom that largely offsets the disinflationary effects of the technology shock. A higher output reduces the fiscal surplus to GDP ratio from the denominator. Therefore, in order to keep the fiscal surplus to GDP ratio consistent with its target, transfers have to be reduced to increase the fiscal surplus. Smoother transfers under higher δ^{i} reduce the consumption and labor supply volatility of BC households, and therefore raise their welfare. This is an example of monetary-fiscal interactions driving some of the welfare results in our model. For INF households, a persistent boom under higher δ^{i} increases their consumption volatility and therefore reduces their welfare. Weighted welfare reflects these opposing effects, exhibiting a hump-shape with respect to δ^{i} that peaks at $\delta^{i} = 1.2$.

The fact that an "explosive" monetary rule ($\delta^{i} > 1$) does not produce explosive equilibria is related to the expectations of the private sector. The real interest rate in our example would fall exponentially unless the price level accommodates. An exponential initial decrease in real rates represents a substantial increase in future prices over the baseline. This stabilizes the path of inflation, leading it to increase after the first period, and thereby causing the real rate to return to neutral following the initial drop. The optimally of super-inertial interest rates is consistent with the results of Rotemberg and Woodford (1998) and Giannoni and Woodford (2002, 2003).

B. Welfare under Different Shocks

Figures 7-10 illustrate the welfare effects of varying one fiscal or monetary parameter at a time around the overall optimum. As any deviations from that optimum are of course associated with welfare losses, the axes for weighted welfare results show negative numbers, with a maximum of zero. The left, middle and right column show welfare results for all agents (weighted), INF households and BC households. The rows show the results of varying the parameters d^{τ}, d^{b}, δ^{i} and δ^{π}. Results reflect our discussion of impulse responses closely.

Figure 7 shows the results for technology shocks. For d^{τ} welfare increases quite steeply until it reaches a hump at around $d^{\tau}=3$. The hump is due to the fact that for BC households fiscal policy becomes too procyclical at d^{τ} rises. Welfare is almost invariant with respect to the debt coefficient, but with an optimum at $d^{b}=0$. For the interest rate smoothing coefficient δ^{i} welfare is increasing, with a hump at $\delta^{i}=1.8$, due to the monetary-fiscal interactions explained above. For δ^{π} welfare is decreasing over almost the entire range, with an optimum at $\delta^{\pi}=0.2$, due to the stronger negative effects of a strong inflation-fighting stance on BC agents, through the real wage, than the positive effect on INF agents, through the real interest rate.

Figure 8 shows the results under investment shocks. There are two main differences. First, the overall size of the welfare effects is significantly smaller. Second, welfare associated with a larger δ^{π} is hump-shaped and peaks around $\delta^{\pi}=0.8$. Figure 9 shows the results under consumption shocks. This is similar to investment shocks, but here welfare is increasing in δ^{π} for both groups of agents. Finally, Figure 10 shows the results under all three shocks combined. They are dominated by the effects of technology shocks. In general, it is very notable that the welfare differences associated with varying the fiscal coefficients are five to ten times larger than the differences due to monetary coefficients.

C. Welfare and Volatility

1. Welfare and Volatility of Policy Instruments

To judge the attractiveness of policy rules to policymakers it is essential to evaluate not only their welfare but also their implied fiscal instrument volatility. Figure 11 addresses both questions by looking at three-dimensional surface plots, with the two fiscal and monetary coefficients on the axes of plots in the left and right column, of welfare and of the standard deviations of policy instruments.

The top left panel shows the weighted welfare surface over the grid of d^τ and d^b, while the top right shows the surface over δ^i and δ^π. These are of course consistent with the 2-dimensional welfare plots in Figure 10. The middle panels illustrate the surfaces of the standard deviations of our two baseline policy instruments, the transfers to GDP ratio and the nominal interest rate, over the parameter grids. The volatility of the fiscal instrument increases with both d^τ and d^b. The figure implies that the surplus target rule should not respond to the debt gap, as doing so both lowers welfare and raises volatility. On the other hand, a response to the tax revenue gap is of course optimal on welfare grounds up to $d^\tau = 3$. This does increase fiscal volatility, but only from around 0.7 to around 1.1, which does not seem excessive. The volatility of the monetary instrument increases with δ^π but decreases with δ^i. Interest rate volatility therefore does not contradict the welfare result, whereby the optimal monetary rule is super-inertial and does not respond to inflation aggressively. The bottom panel conveys a similar message as the middle panel, by looking at the standard deviations of the quarter-on-quarter changes of the two policy instruments.

2. Efficiency Frontiers

Figure 12 depicts the combinations of weighted welfare and of fiscal instrument volatility as the tax coefficient d^τ changes from 0 to 5, holding all other coefficients at their overall optimum values $d^b = 0$, $\delta^i = 1.2$ and $\delta^\pi = 0.2$. We again use the optimal point as our zero welfare gain baseline. The government uses targeted transfers to stabilize the economy. Not surprisingly, the volatility of lump-sum transfers increases as welfare improves. However, a substantial consumption equivalent gain of 0.028 can be achieved by going from the balanced budget rule to the best possible rule. The cost in additional volatility, as previously mentioned, is small, amounting to an increase of roughly 0.45 in the standard deviation of the targeted transfers to GDP ratio. A more aggressive rule might therefore well be judged attractive by policymakers if the other conditions of this model should hold. It might however be misleading to call such a rule countercyclical, as it does in fact not attempt to stabilize GDP, but rather the volatility of consumption and labor supply of households, and predominantly of borrowing-constrained households. In this model those are two very different concepts.

3. Alternative Fiscal Instruments

Transfers targeted to BC households have been our default instrument up to this point. However, our model allows for five other alternatives. Figure 13 considers four of them, consumption taxes, capital income taxes, government consumption, and government investment. Figure 13 shows how welfare changes with respect to $d^\tau$for each of them, again holding d^b, δ^i and δ^π at their overall optimum values. To have a common benchmark, we use the maximum welfare in the case of targeted transfers as the zero welfare benchmark. We find that consumption taxes perform similarly to transfers with respect to d^τ, but with very much lower absolute welfare levels. Capital income taxes and government investments are even less desirable, the former because of their distortionary effects on capital accumulation, and the latter because their effect on output last very much longer than the shock that they are trying to offset. Government consumption spending on the other hand is in theory far superior to targeted transfers. We have simulated this policy instrument because it is the most frequently considered fiscal instrument in the literature, but we feel that taking Figure 13 literally here may be a little naive. Government consumption spending to a very large extent consists of public sector salaries, with a big part of the rest going to arms procurement. It is very unclear that such spending can be ramped up and then down at will, and in a timely manner, in response to economic shocks. Targeted transfers on the other hand can be implemented as automatic stabilizers, for example through well-designed welfare programs.[13]

We note that labor income taxes have been absent from this discussion. The reason is that such taxes are very undesirable here, because they destabilize the economy in the presence of the "tsunami" style technology shocks that play such an important role in our model. For instance, following a positive technology shock the target tax revenue falls. In that case the government would have to cut the labor income tax rate. But that lower tax rate raises the labor supply and reduces the real wage. The combination of a lower labor tax rate and a lower real wage further reduces the target tax revenue and therefore the labor tax rate. This induces instability if d^{τ} exceeds a fairly low upper limit. This problem would not arise if technology shocks were modeled as persistent shocks to the growth rate of technology, as such shocks have effects akin to demand shocks in the short run. We will consider this possibility in future work.

4. Alternative Fiscal Rules

We have selected the rule (31) carefully, in that we have considered a number of alternatives to the specific tax revenue gap (29) used. All of them, and specifically an overall tax revenue gap, were welfare inferior. This is because capital income taxes contain no information about the budget tightness of BC agents.

We have also performed a welfare evaluation of the output gap rule (32), by performing a grid search over d^y, d^b, δ^i and δ^{π}. The maximum welfare available from that rule is between 0.01 and 0.015 lower, in terms of the compensating variation in consumption, than the maximum welfare gain available from the tax revenue gap rule. That is a very large number, almost one half of the welfare difference between the BBR rule and our optimal CCR rule. Output gap rules are clearly inferior, for the reasons given above.

5. Comparison with the Canonical Infinite-Horizon Case

Here we return to the case of $\psi = 0$ that was briefly mentioned in our discussion of Figure 5. Figure 14 shows the welfare surface over the grid of δ^i and δ^{π}, and Figure 15 illustrates how welfare changes with respect to δ^i and δ^{π} separately around the optimal point. Welfare peaks at $\delta^i = 1.2$, but it always increases with a larger δ^{π}.

The most striking aspect of this figure is that welfare losses due to getting monetary policy very wrong, by getting very close to violating the Taylor principle, are of the same order of magnitude as the losses from getting fiscal policy very wrong in our model, by

[13] Of course this abstracts entirely from the question of how this should be done without inviting corruption and work disincentives.

adopting a balanced budget rule. But compare this to the much smaller maximum losses from bad monetary policy in our model, in the top right panel of Figure 11. It is important to recall that this panel holds the fiscal policy rule coefficients fixed at their overall optimal values. Fiscal policy thereby provides an anchor to this system that makes it very much harder for monetary policy to get it really wrong. No such anchor is available in the canonical model, where a fiscal policy implemented through variations in lump-sum transfers is completely irrelevant.

V. Conclusion

We have studied the welfare and macroeconomic properties of an economy where both monetary and fiscal policies follow simple, implementable rules, and where a subset of agents is borrowing-constrained. We have found that the optimized fiscal rule is far more aggressive than automatic stabilizers, and that this aggressive stance comes at a fairly modest cost in terms of fiscal instrument volatility. We have also found that the optimized fiscal rule stabilizes the income of borrowing-constrained agents, rather than output. This is because the optimal course of action for the government is to try to offset, as much as possible, the market imperfection of the missing capital market access of this sizeable group of households. The optimized monetary rule features super-inertia and a very low coefficient on inflation. Again, the main benefit of this rule accrues to borrowing-constrained agents, by minimizing real wage volatility through a less aggressive and more patient monetary stance. Critically, we have found that, in the neighborhood of the overall optimum, the welfare gains of optimizing the fiscal rule are far larger than the welfare gains of optimizing the monetary rule. The preferred fiscal instruments are government spending and transfers targeted to borrowing-constrained agents, but only the latter may be a practical choice.

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Figure 1: Positive Technology Shock, Different dtax

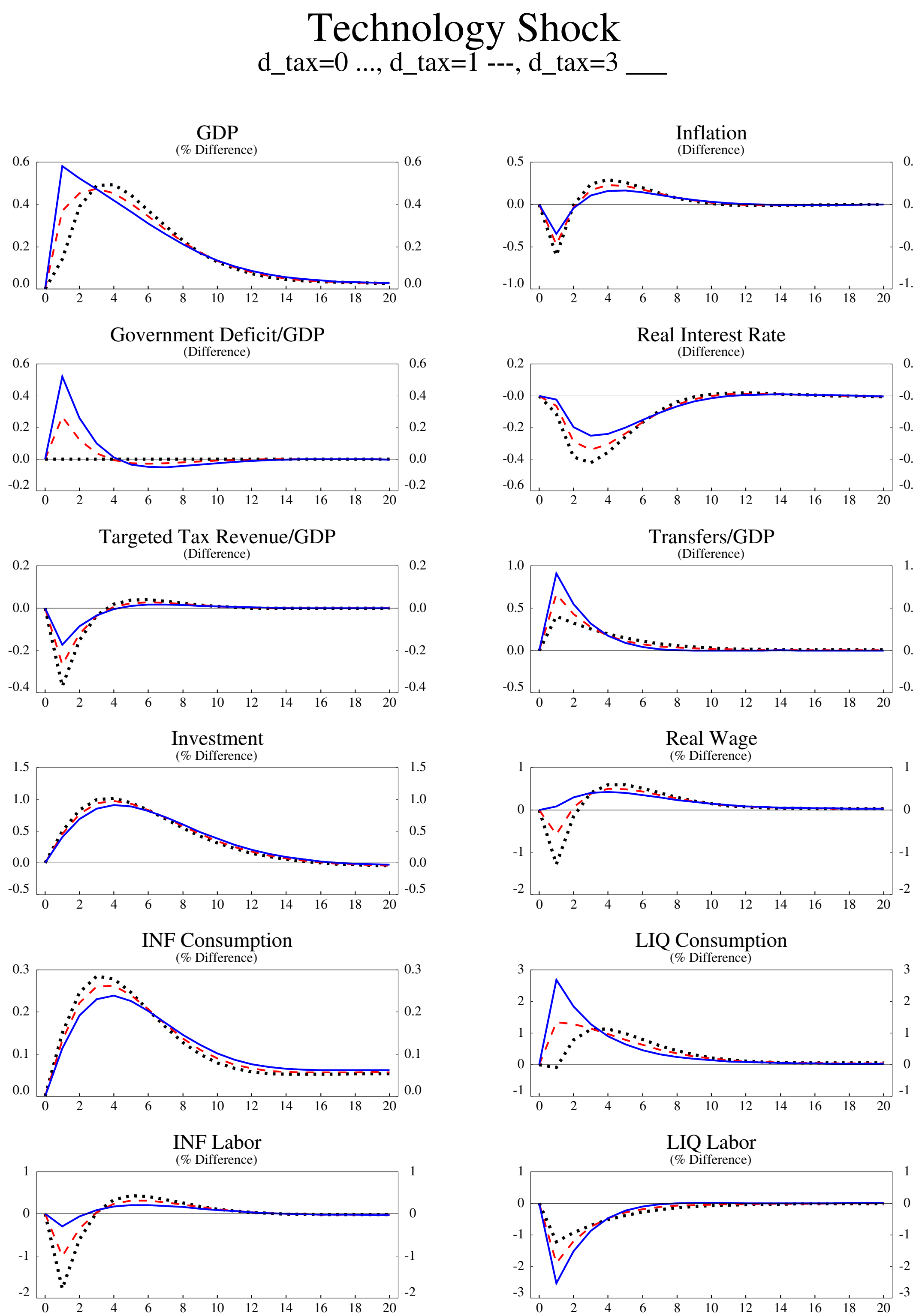

Figure 2: Negative Investment Shock, Different dtax

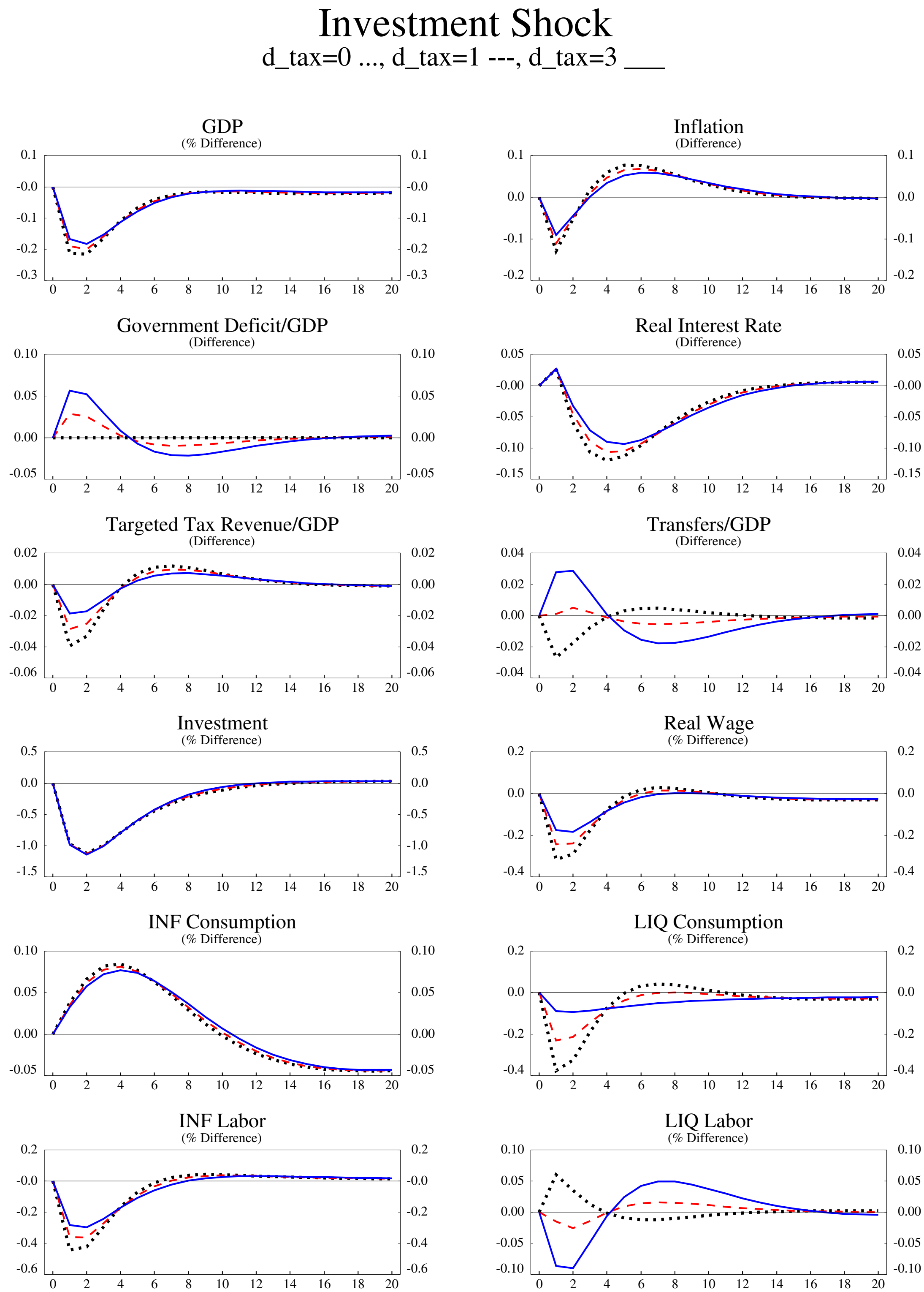

Figure 3: Positive Consumption Shock, Different dtax

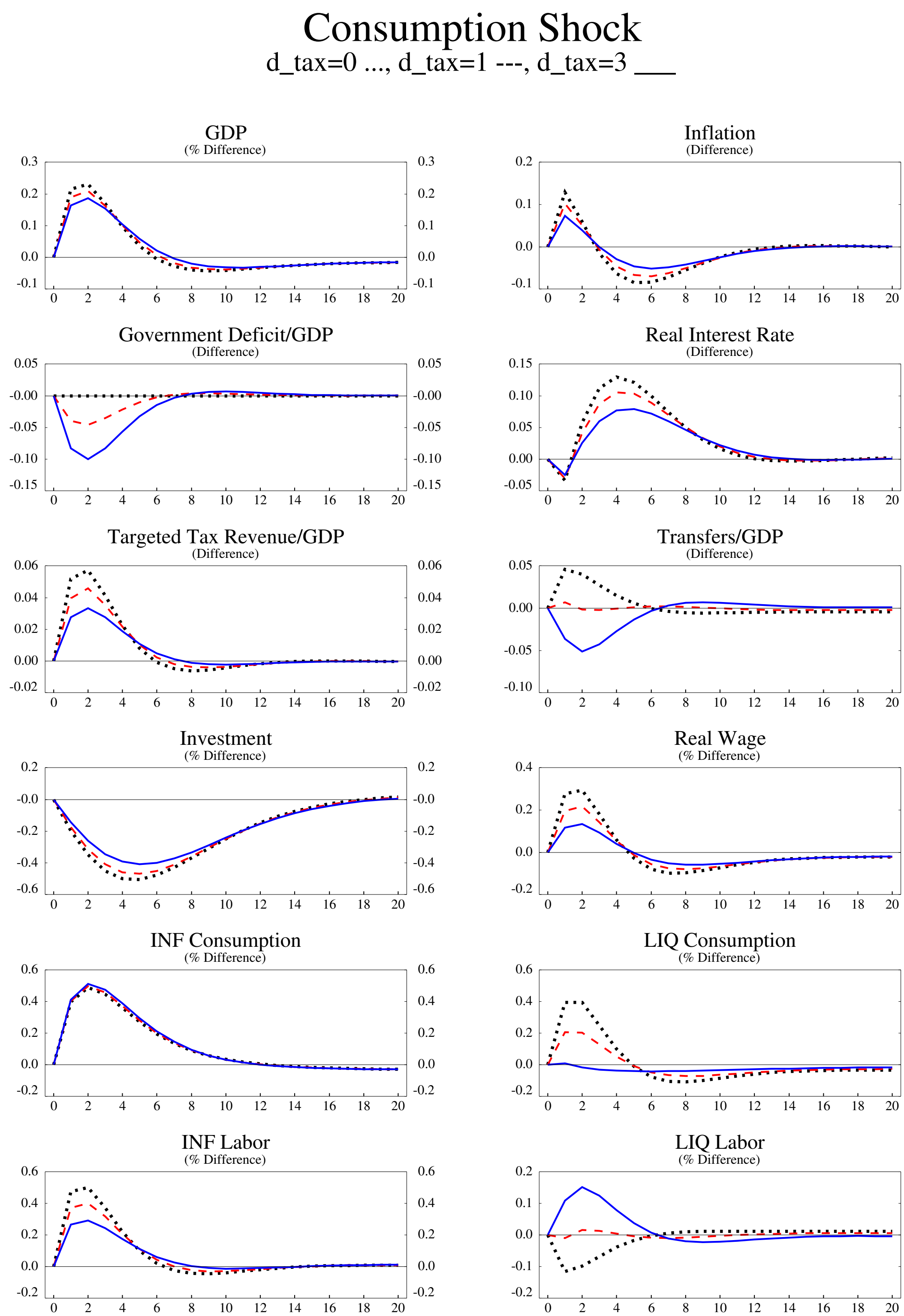

Figure 4: Positive Technology Shock, Different dpie

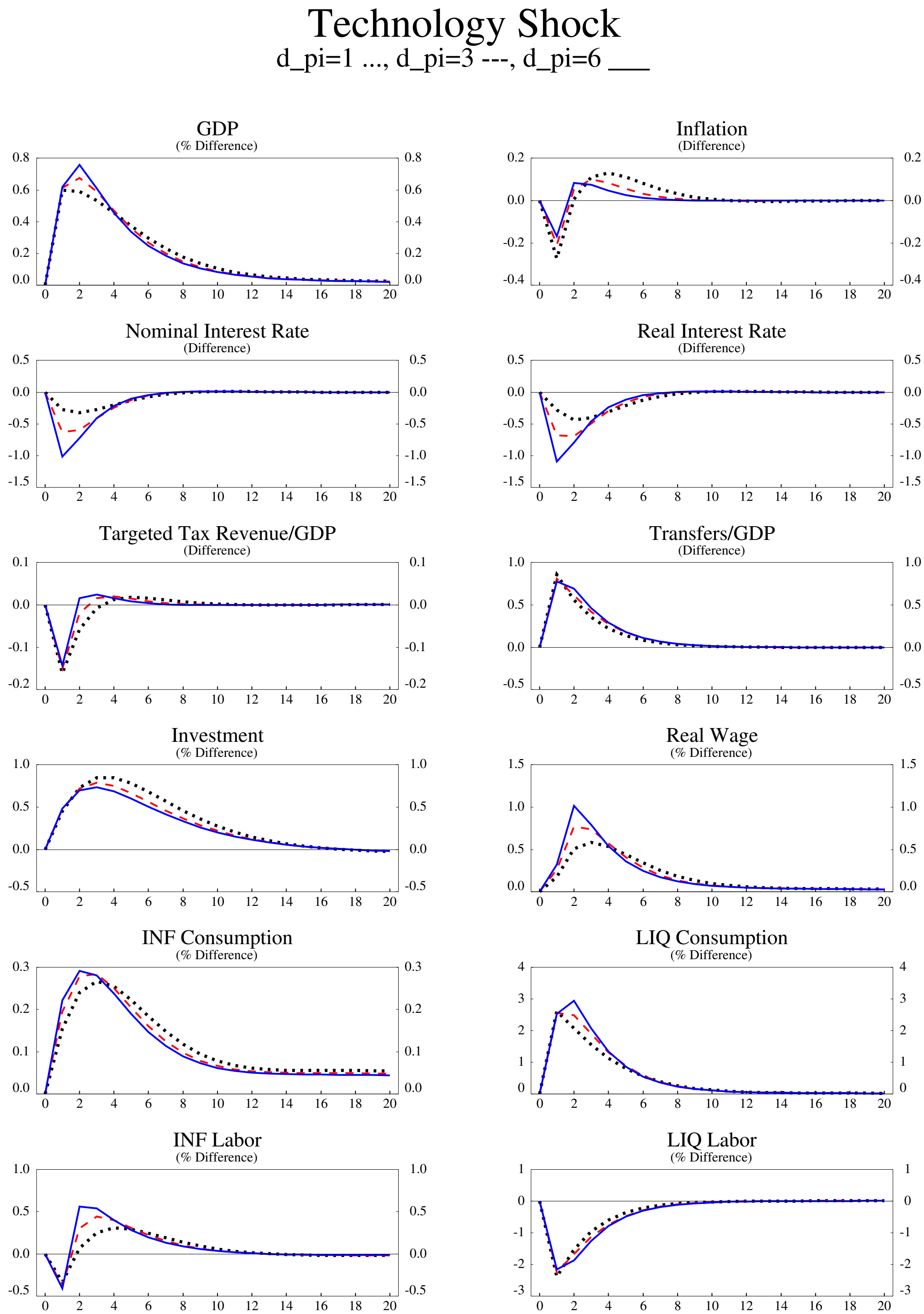

Figure 5: Positive Technology Shock, Different dpie, No Liquidity-Constrained Agents

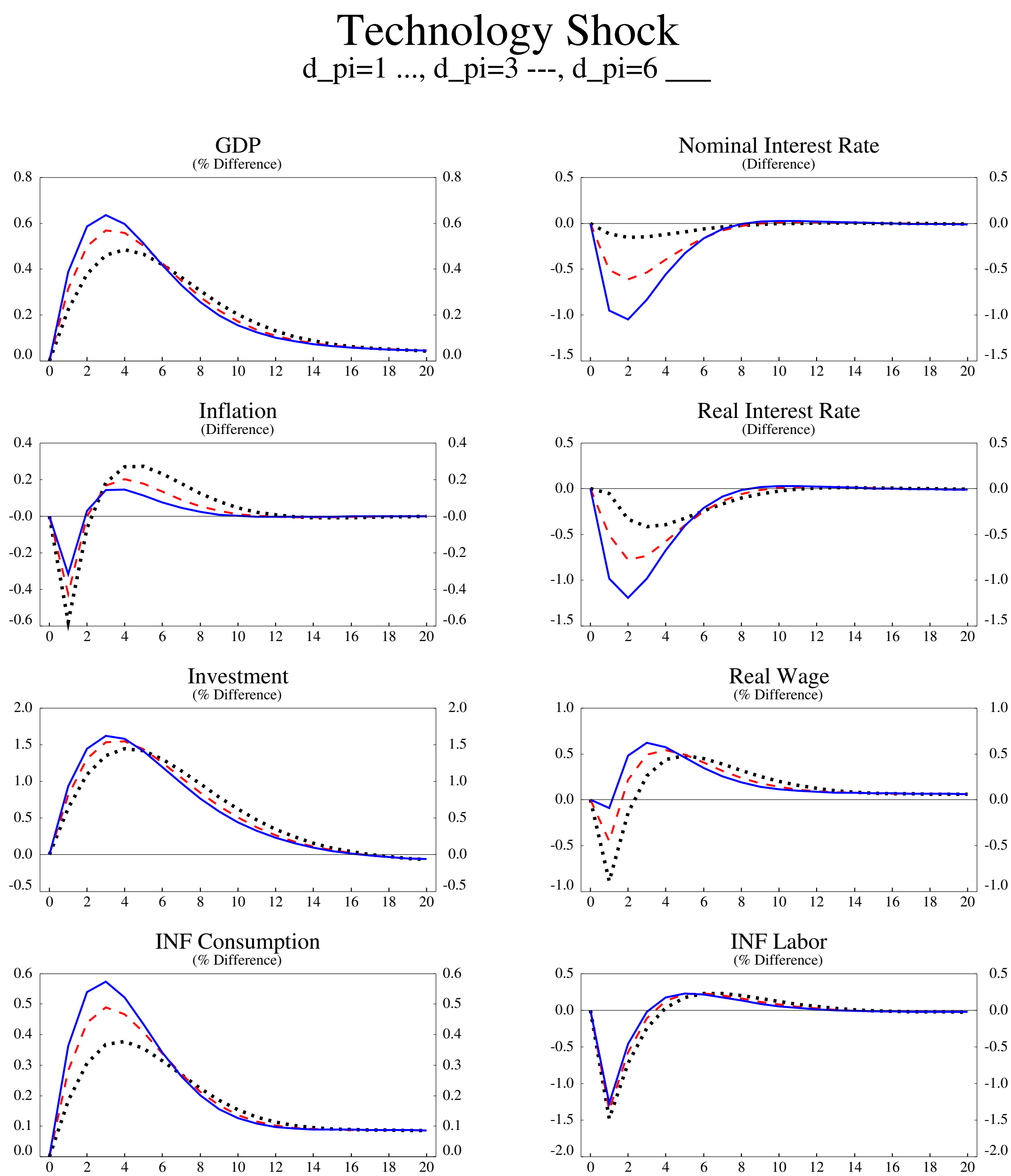

Figure 6: Positive Technology Shock, Different di

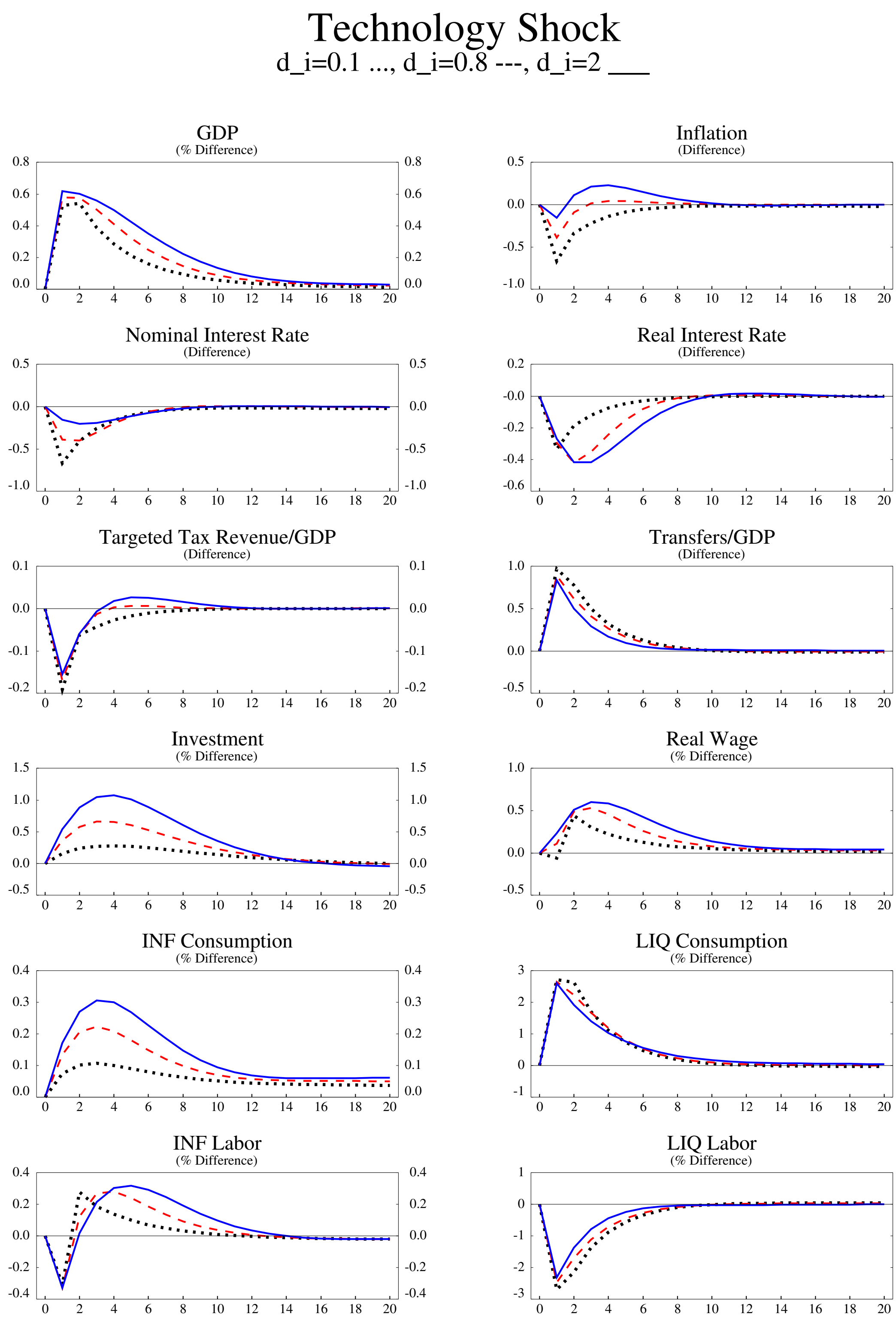

Figure 7: Welfare - Technology Shock

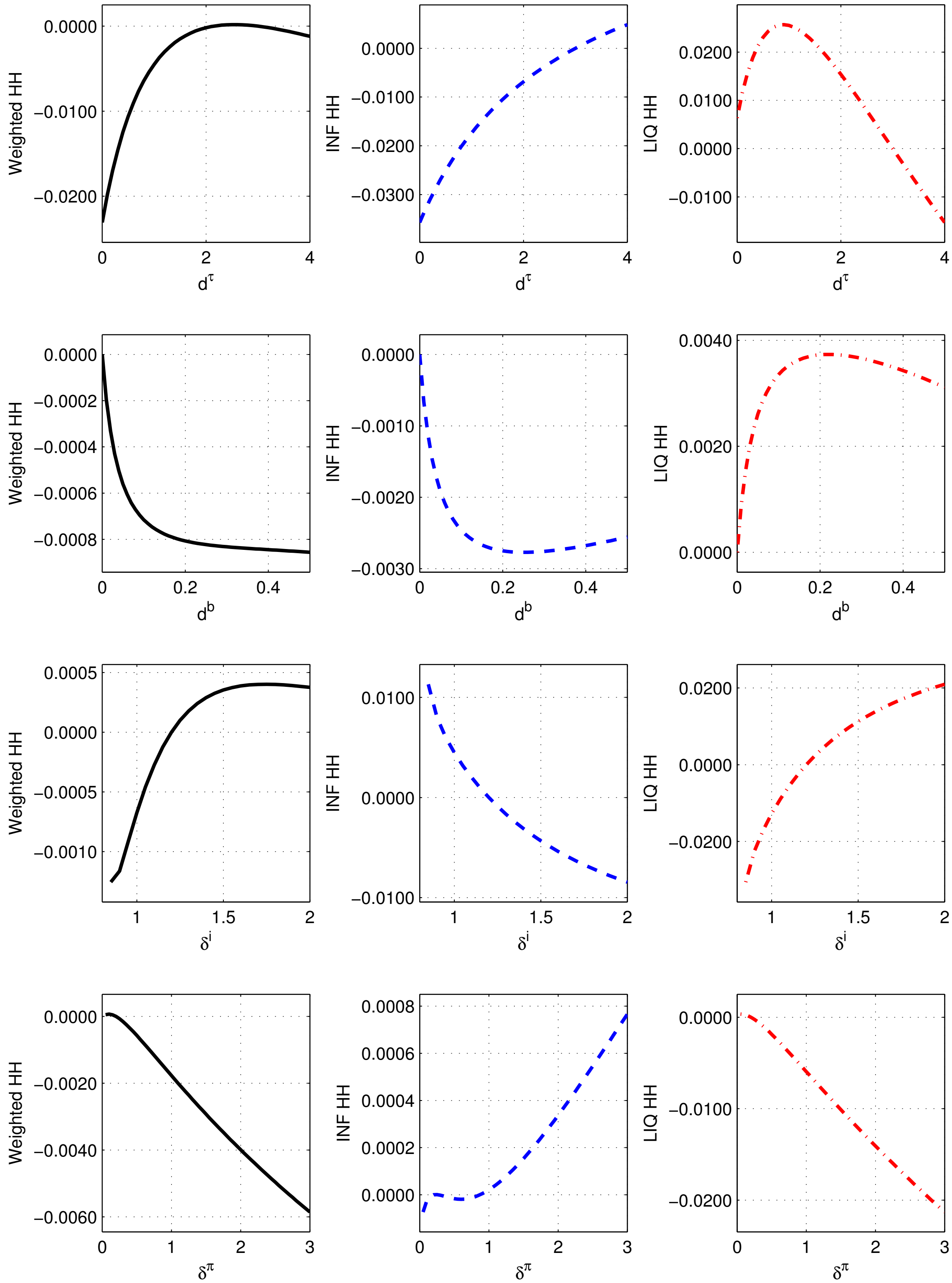

Figure 8: Welfare - Investment Shock

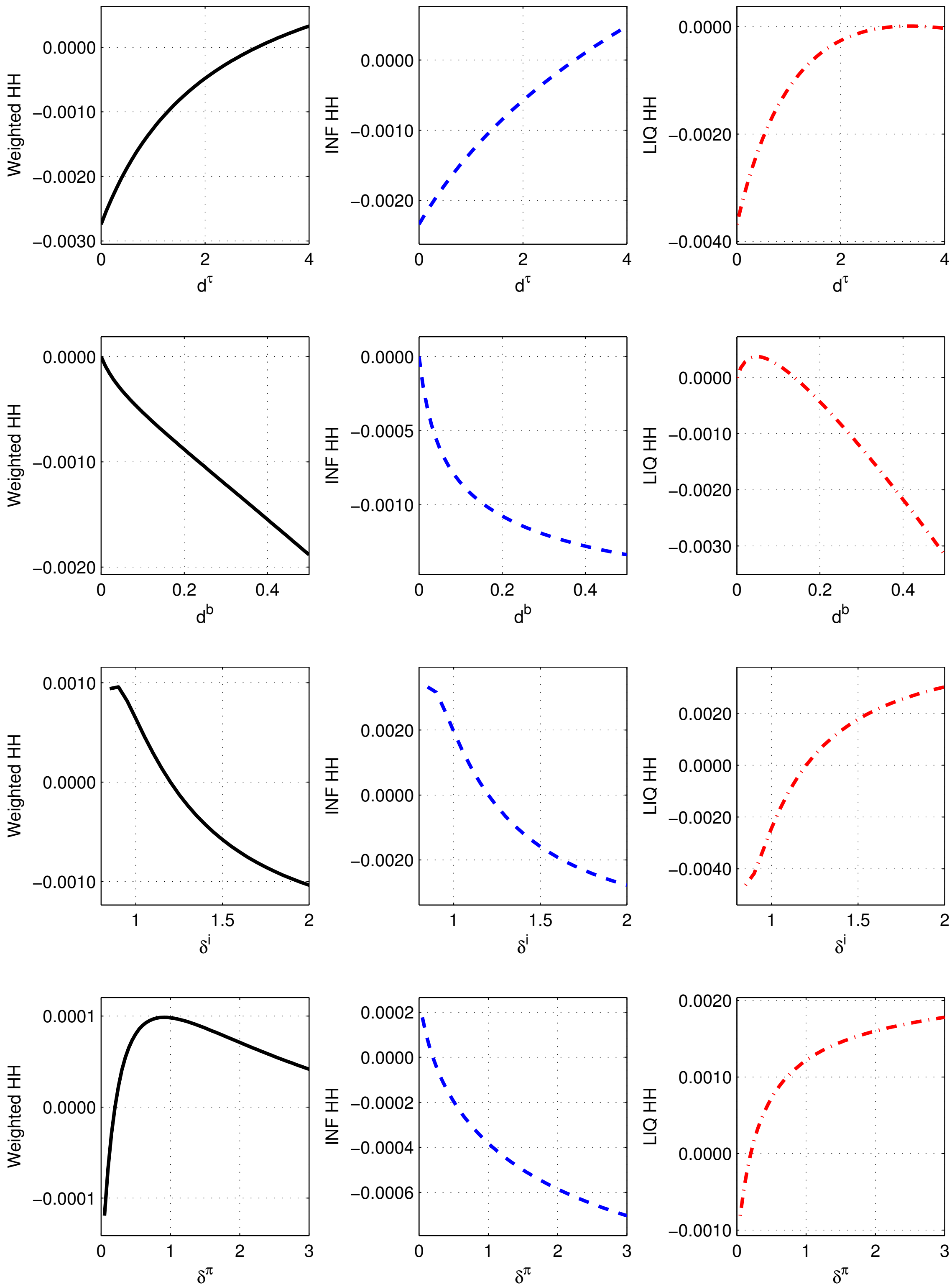

Figure 9: Welfare - Consumption Shock

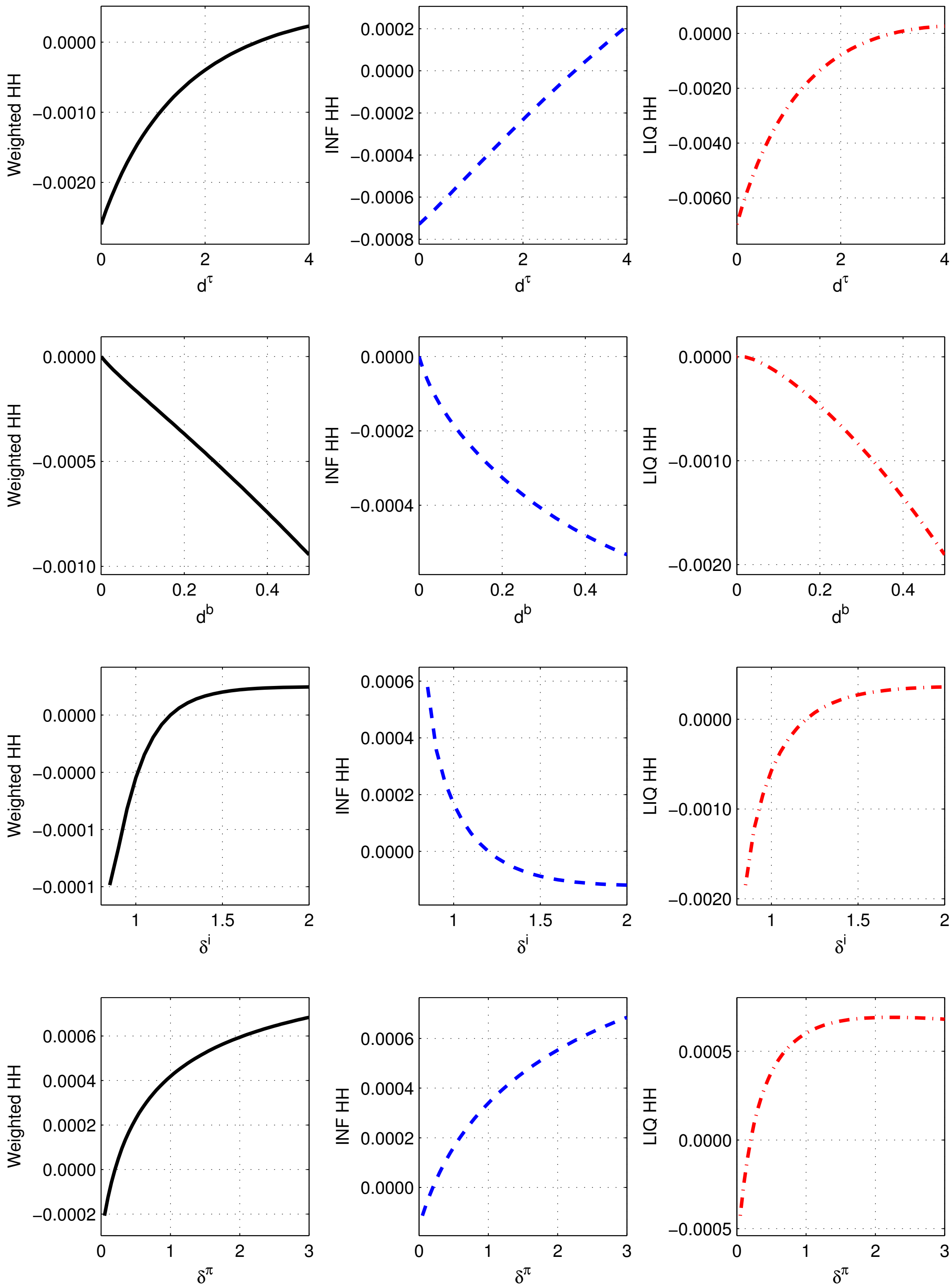

Figure 10: Welfare - All Shocks

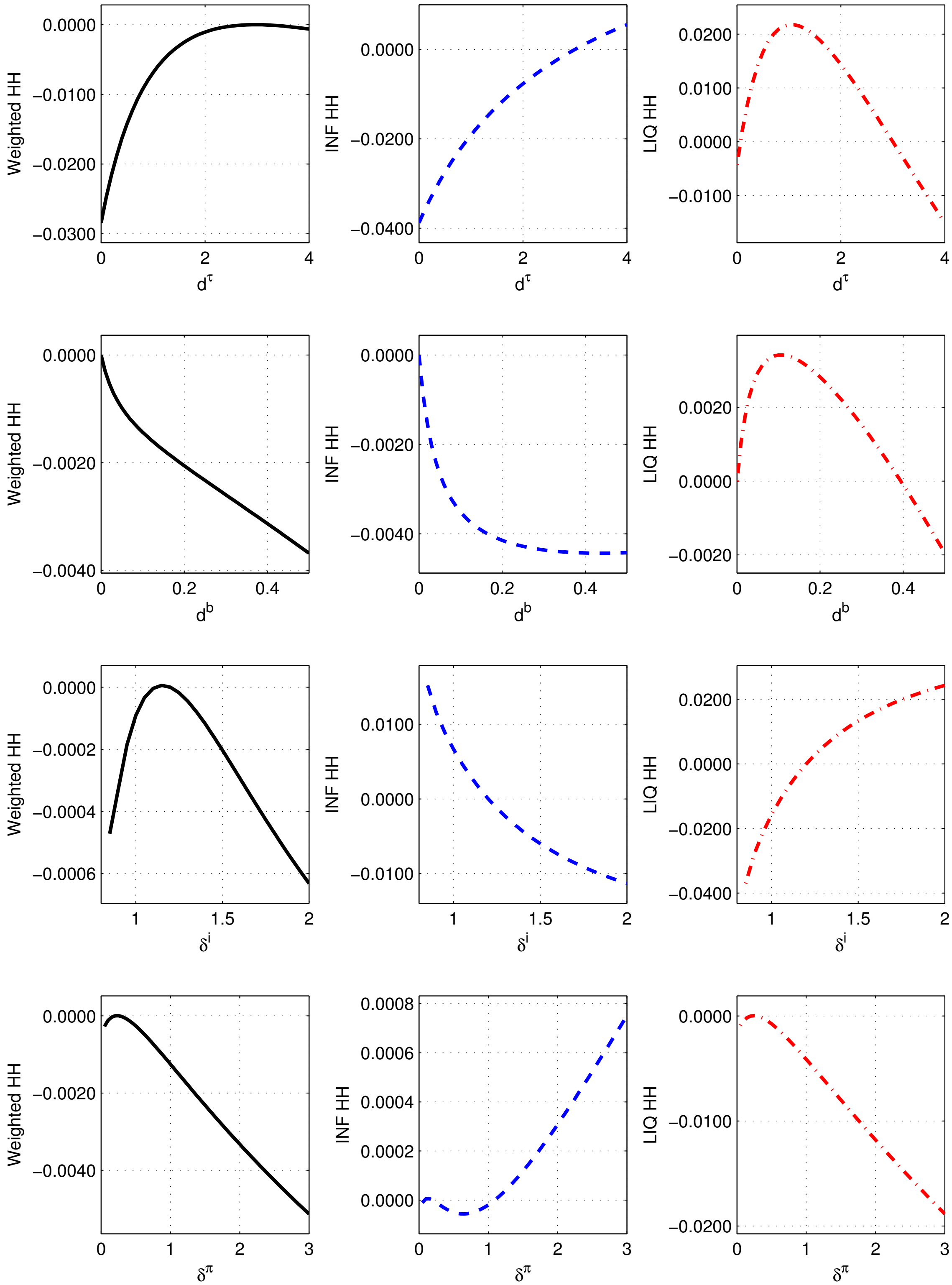

Figure 11: Welfare and Policy Instrument Volatility

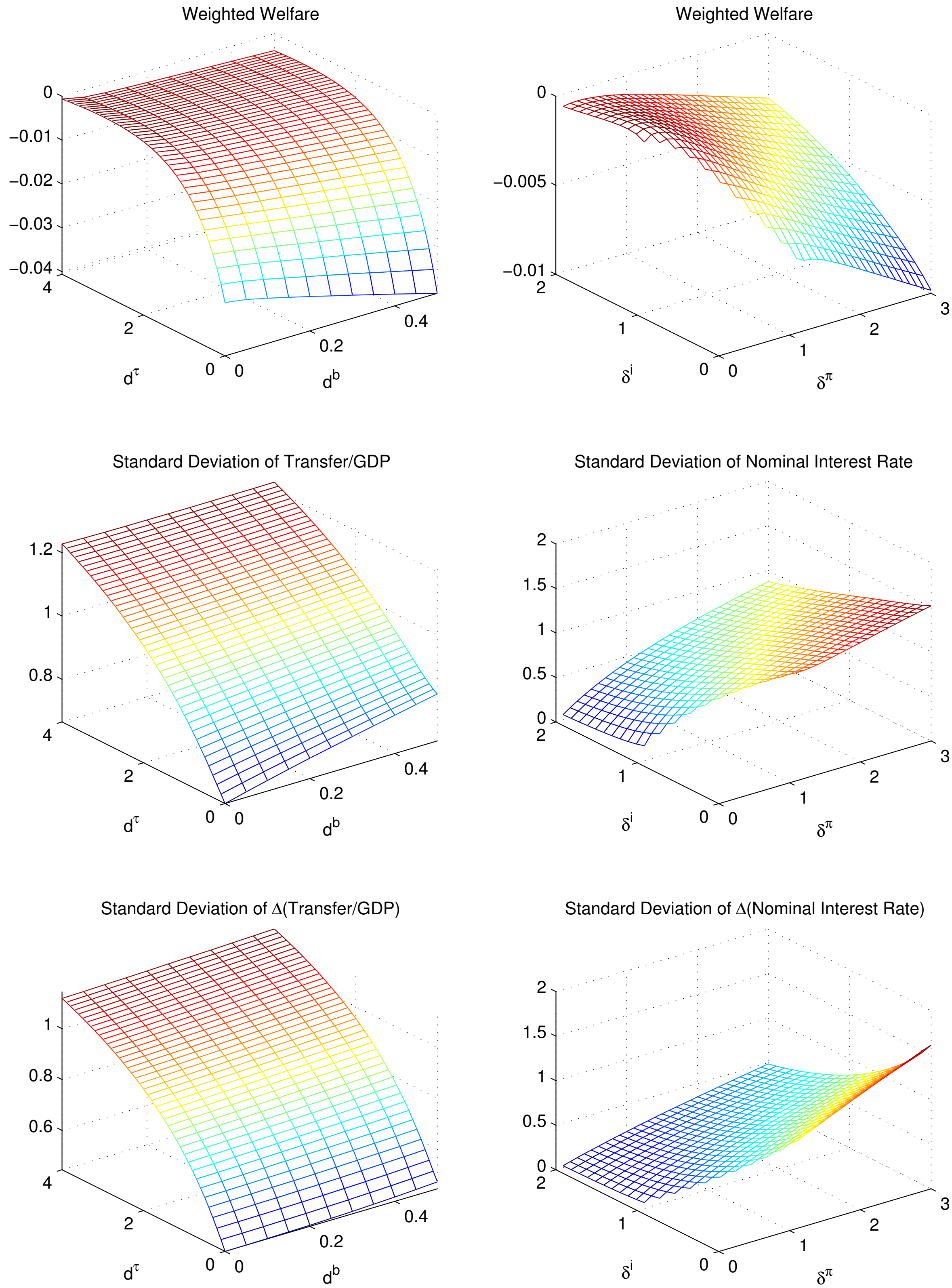

Figure 12: Welfare-Fiscal Volatility Efficiency Frontier

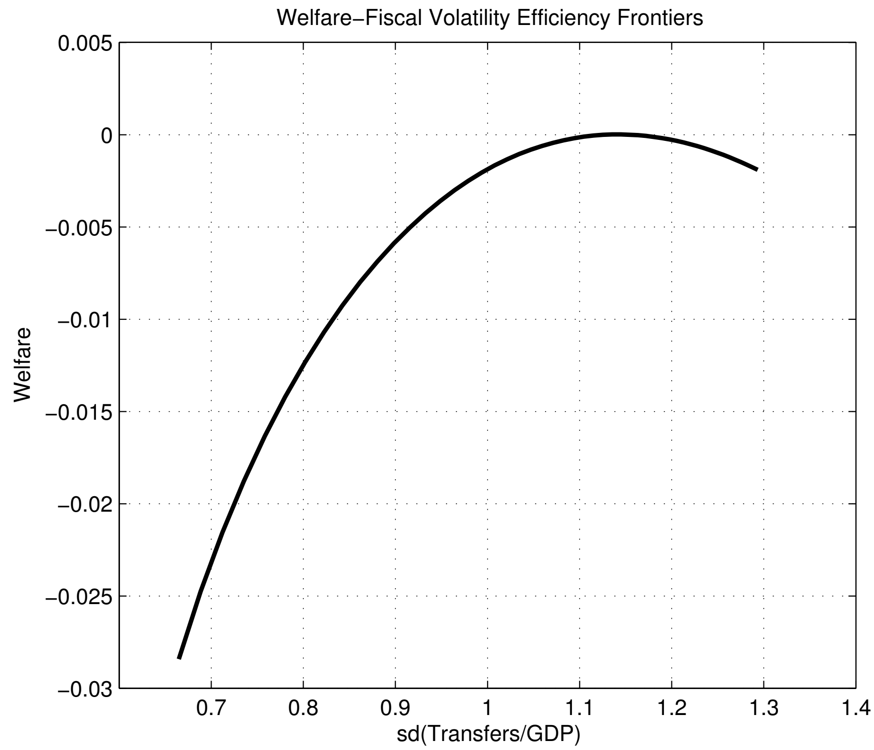

Figure 13: Welfare Comparison across Fiscal Instruments

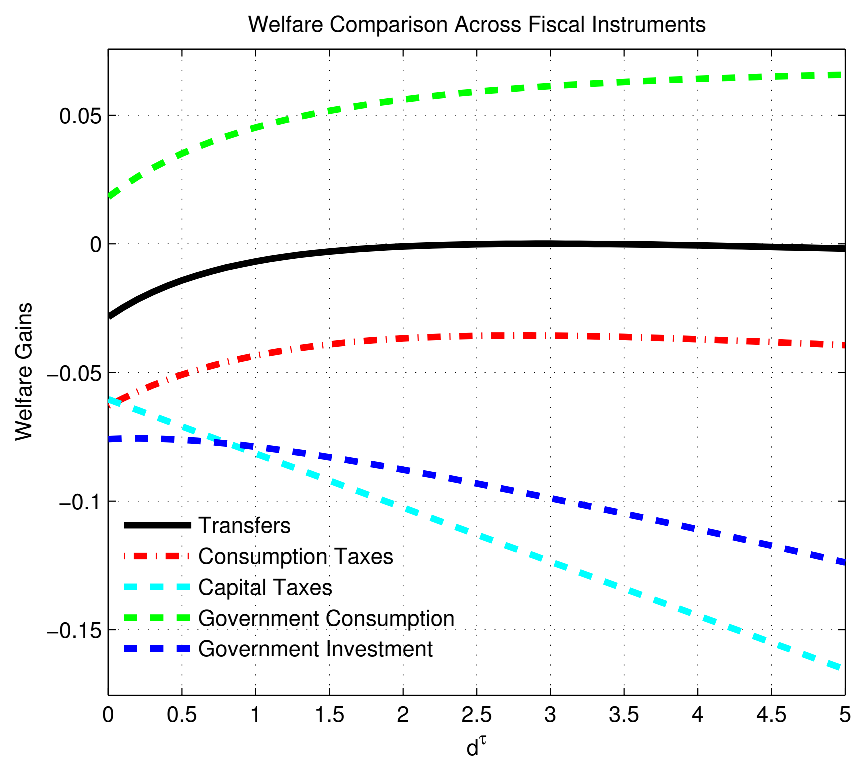

Figure 14: 100 Percent Infinitely-Lived Agents - Welfare - 2 Dimensional

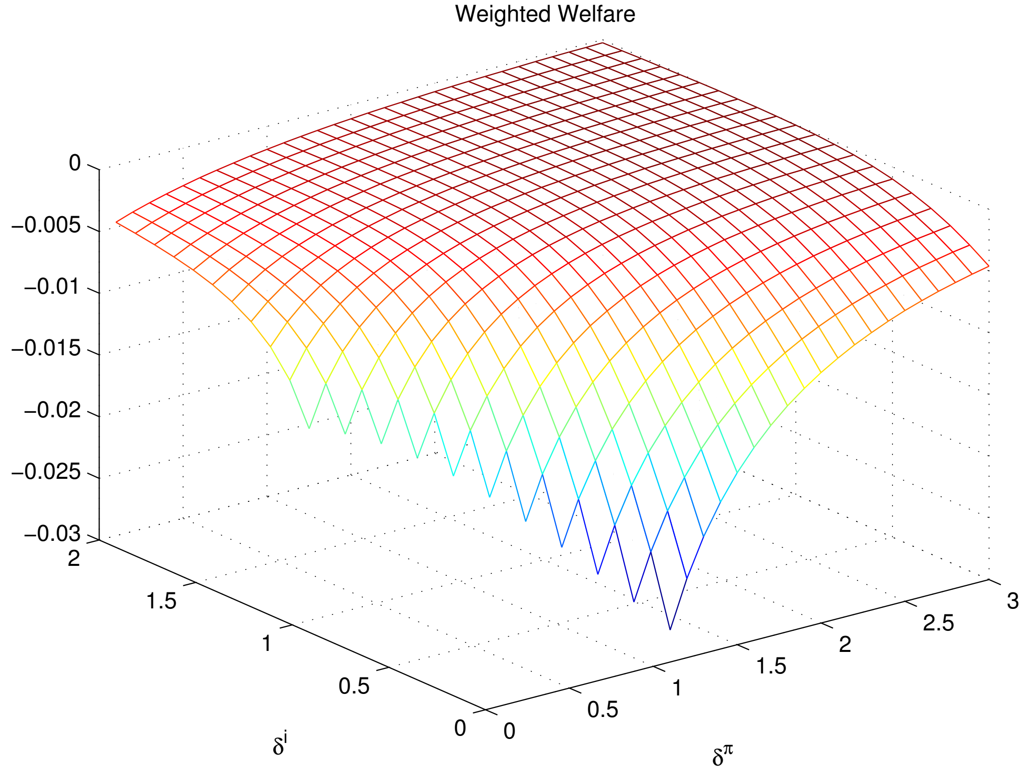

Figure 15: 100 Percent Infinitely-Lived Agents - Welfare - 1 Dimensional

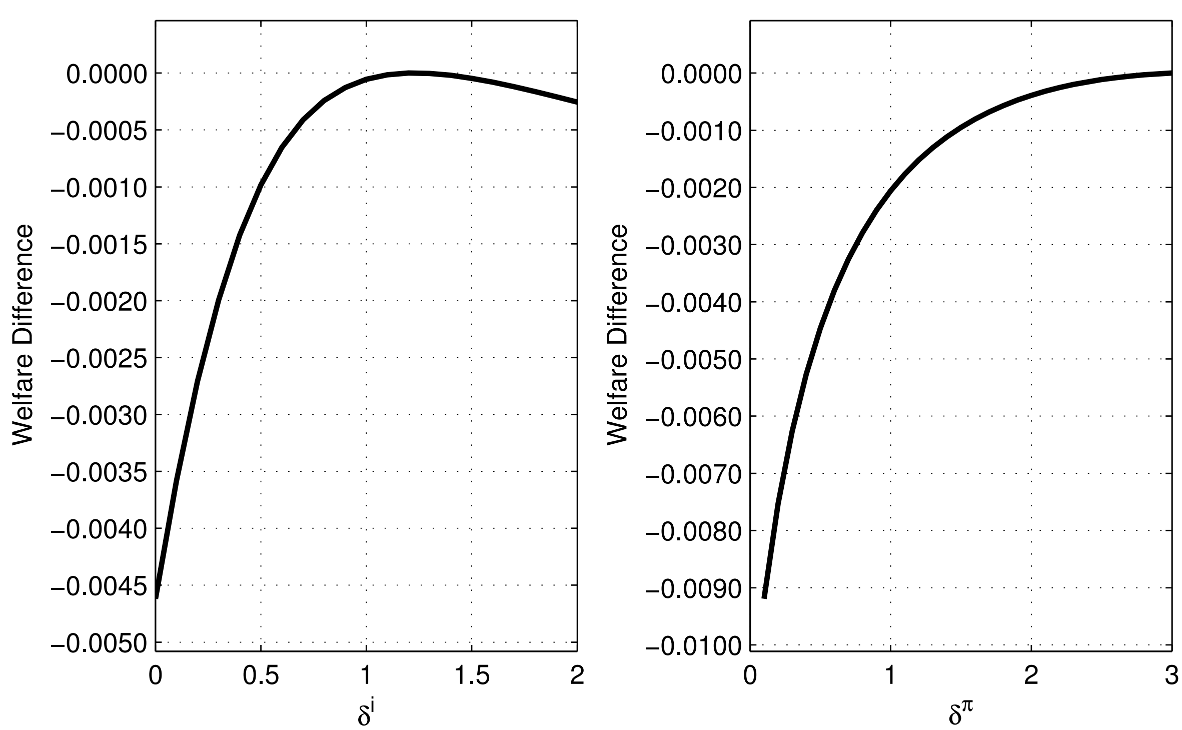

Table 1: Moments of the Data and the Model

Standard Deviations				**Correlations**		
	Data	**Model**			**Data**	**Model**
Investment	3.922	4.015		Investment and Consumption	0.76	0.178
Consumption	1.193	1.152		Investment and Inflation	0.144	0.053
Inflation	1.393	1.318		Consumption and I7nflation	0.148	0.144