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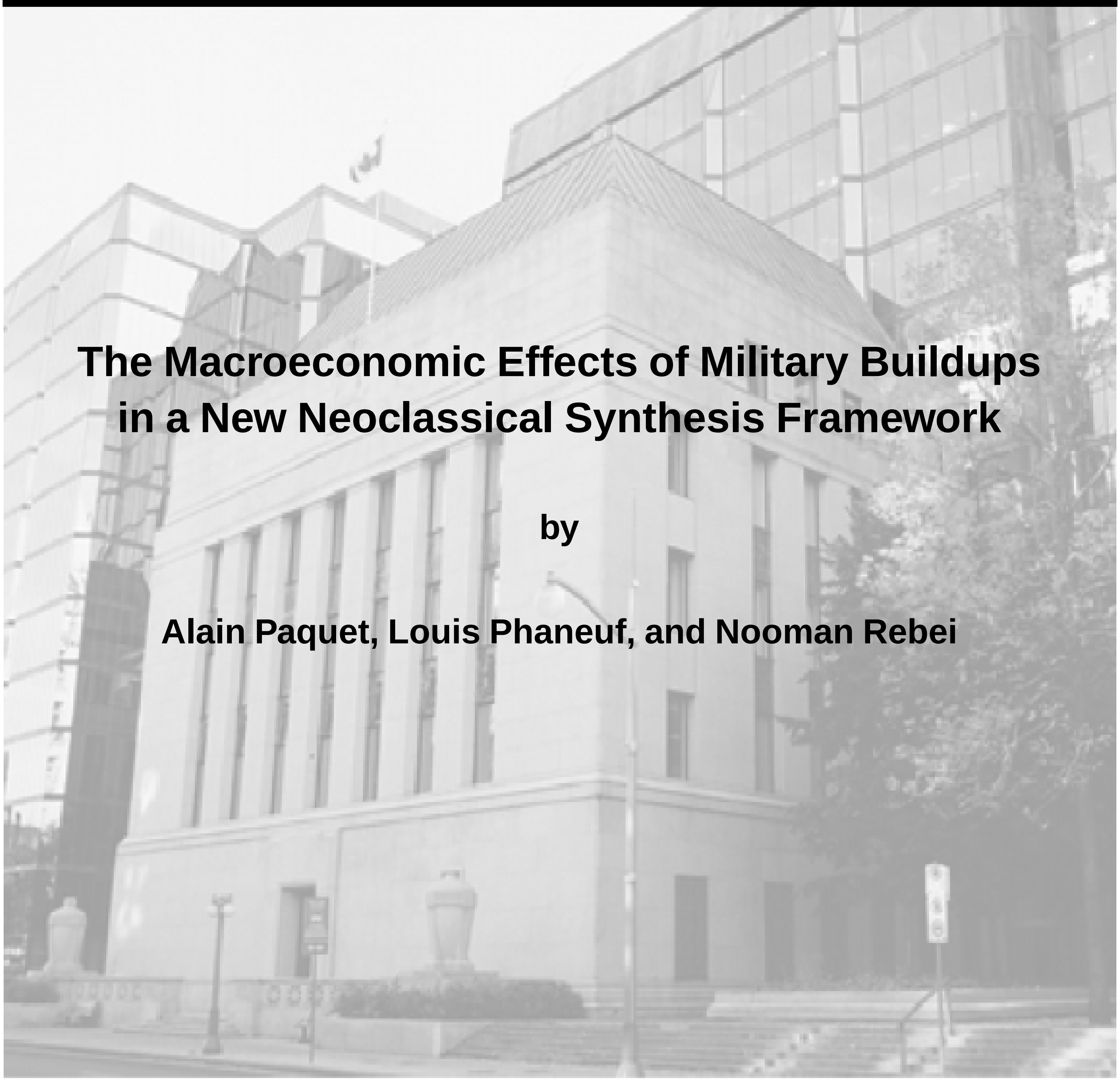

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Abstract

The authors study the macroeconomic consequences of large military buildups using a New Neoclassical Synthesis (NNS) approach that combines nominal rigidities within imperfectly competitive goods and labour markets. They show that the predictions of the NNS framework generally are consistent with the *sign*, *timing*, and *magnitude* of how hours worked, after-tax real wages, and output actually respond to an upsurge in military purchases. The key factors leading to these findings are: (i) variations in the ratio of price to marginal cost resulting from nominal-price inflexibilities, (ii) staggered nominal-wage setting, and (iii) time-varying marginal tax rates. Unlike the standard neoclassical model, the NNS framework successfully explains the macroeconomic effects of military buildups when taxes are distortionary.

JEL classification: H2, E32, E62
Bank classification: Fiscal policy; Economic models; Business fluctuations and cycles

Résumé

Les auteurs étudient l'incidence macroéconomique d'un essor des dépenses militaires à l'aide d'un modèle de la nouvelle synthèse néoclassique qui allie des rigidités nominales à une situation de concurrence monopolistique sur les marchés des biens et du travail. Ils constatent que les prévisions de ce modèle concernant le *sens*, le *moment* et l'*ampleur* de la réaction du nombre d'heures travaillées, du salaire réel disponible et de la production à une poussée des dépenses militaires sont conformes à la réalité. Leurs conclusions s'appuient principalement sur le fait que : i) l'inflexibilité des prix nominaux entraîne des variations du ratio du prix au coût marginal; ii) les contrats fixant les salaires nominaux sont échelonnés dans le temps; iii) les taux marginaux d'imposition peuvent varier d'une période à l'autre. Contrairement au modèle néoclassique habituel, celui de la nouvelle synthèse néoclassique explique de façon satisfaisante les effets macroéconomiques de l'accroissement des dépenses militaires lorsqu'il y a distorsion fiscale.

Classification JEL : H2, E32, E62
Classification de la Banque : Politique budgétaire; Modèles économiques; Cycles et fluctuations économiques

1. Introduction

A vast literature analyzes the macroeconomic consequences of changes in government purchases. Over the years, most studies have followed the neoclassical or equilibrium approach to fiscal policy.[1] Implicit behind this approach is the presumption that market imperfections play a negligible role, if any, in determining the effect of fiscal policy on economic activity. Our paper challenges the conventional view on three fronts. First, we develop a New Neoclassical Synthesis (NNS) framework to fiscal policy that emphasizes imperfectly competitive goods and labour markets as well as inflexibilities in nominal wages and prices.[2] Second, we present evidence suggesting that such market imperfections have been key factors in the transmission of fiscal-policy shocks to the U.S. economy during the post-World War II period. Third, following Baxter and King's (1993) original insight into the importance of the public finance decision in determining the evolution of economic activity, we show that the NNS framework, unlike the standard neoclassical model, better accounts for the actual effects of higher government spending if increases in purchases are financed by means of distortionary taxes rather than lump-sum taxes. This implication gives the NNS framework a significant advantage over the former class of models.

Recent work by Ramey and Shapiro (1998) that covers the U.S. post-war period suggests that exogenous increases in government purchases have been followed by persistent, hump-shaped increases in real GDP and hours worked in total manufacturing, and by persistent decreases in after-tax real wages. These results are obtained using a univariate autoregressive model in which unpredictable movements in government purchases are identified with the help of a narrative approach which isolates political events that have led to unusually large post-war U.S. military buildups.[3] In a similar vein, Burnside, Eichenbaum, and Fisher (1999a) combine the narrative approach with a vector autoregression (VAR) and find that military buildups have given rise to persistent, hump-shaped increases in total government spending, the average marginal income tax rate and total hours worked, and to persistent, hump-shaped decreases in after-tax real wages.

These findings pose a serious challenge to existing macroeconomic theories. For instance, neoclassical theories predict a rise in hours worked and output after an

[1] Prominent examples include Hall (1980), Barro (1981, 1989), Aschauer (1988), Baxter and King (1993), and Ramey and Shapiro (1998).

[2] The New Neoclassical Synthesis label was introduced into the literature by Goodfriend and King (1997) for two main reasons. First, as in new classical macroeconomics and real business cycle analysis, NNS brings intertemporal optimization and rational expectations into dynamic stochastic macroeconomic models. Second, inspired by New Keynesian macroeconomics, it incorporates imperfect competition and nominal rigidities.

[3] Their approach is similar to the one used by Hamilton (1985) to estimate the effect of oil-price shocks and by Romer and Romer (1989) to assess the effect of severe monetary contractions.

increase in government purchases if households willingly supply more labour in response to negative wealth effects. But, as Baxter and King (1993) show, this requires that the short-run labour supply be highly elastic and that higher government purchases be financed by lump-sum taxes.[4] In contrast, according to several studies in the labour literature, the short-run labour supply is not highly elastic (e.g., Killingsworth 1983; Pencavel 1986; and Card 1991). Moreover, if marginal income tax rates are assumed to rise after an upsurge in military purchases, total hours worked and output decrease rather than increase, since the representative household wishes to substitute hours worked away from periods when tax rates are higher towards periods when tax rates are lower. Existing models with market imperfections are also not exempt from problems. In the oligopolistic model of Rotemberg and Woodford (1992), the ratio of price to marginal cost—the markup—falls in response to higher defence spending, inducing a shift in labour demand that raises, rather than lowers, after-tax real wages. Efficiency wage models, on the other hand, do not account for the quantitative responses of real wages and hours worked to a fiscal shock when taxes are distortionary (e.g., Burnside, Eichenbaum, and Fisher 1999b).

We study the macroeconomic effects of large military buildups using a dynamic stochastic general-equilibrium framework inspired by the seminal work of Blanchard (1986) and Blanchard and Kiyotaki (1987). The framework is based on two main assumptions. First, monopolistic competitive firms lower markups in response to higher government purchases, triggering shifts in labour demand. Second, households endowed with differentiated labour skills are not always on their short-run labour-supply curves. We identify fiscal-policy disturbances as the dynamic response of total government purchases and the average marginal income tax rates to military buildups following the procedure proposed by Ramey and Shapiro (1998) and Burnside, Eichenbaum, and Fisher (1999a).

Rotemberg and Woodford (1992) stress the importance of the first feature—shifts in labour demand—but in an entirely different setting. In their model, as in Rotemberg and Saloner (1986), markups vary in response to demand conditions, because a small number of firms within an oligopoly collude to keep prices above marginal cost, threatening to punish deviations from an implicitly agreed-upon pricing path. In our model, markups adjust in response to military buildups because producers reoptimize nominal prices only after a random signal, *à la* Calvo (1983), allows them to do so. We show that shifts in labour demand help to account both for the *magnitude* and *timing* of how hours worked have responded to military buildups during the post-war period. The second feature—households are off their short-run labour-supply curves—stems from the assumption that households reoptimize

[4] See, in particular, Tables 2 and 3 and Figure 4 in Baxter and King (1993).

nominal wages in a random fashion, implying that nominal wages are rigid between periods where they are being readjusted. We show that nominal-wage rigidity has contributed significantly to the observed decline in after-tax real wages after military buildups.

We provide intuition about the mechanisms that are central to our main findings by studying versions of the model with only subsets of theoretical ingredients. Each model assumes that producers use a constant-returns-to-scale production technology and each precludes a highly elastic short-run labour-supply curve. The first model we consider is one with fully flexible nominal wages and prices. Accordingly, households are always on their labour-supply curves and markups are constant. This model, like the standard neoclassical model, predicts that total hours worked and output counterfactually fall in response to increases in military purchases if taxes are distortionary.

The second model postulates that households reoptimize nominal wages at stochastic intervals while nominal prices are perfectly flexible. It differs from the first model in that households are constrained to supply the quantity of labour demanded by the producers at given nominal wages. Since markups are constant, variations in hours worked and real wages primarily reflect movements along the labour-demand curve. With this model, we are able to assess a conjecture by Ramey and Shapiro (1998) in response to limitations of the standard neoclassical model. They argue that sticky-wage theories may successfully explain the strong, negative co-movement between real wages and hours worked after military buildups. Our findings do not support this conjecture. The model's main failure lies in its inability to generate sufficiently large increases in hours worked. To understand the reason behind this apparently surprising result, it is important to distinguish between movements in before-tax real wages and after-tax real wages. With constant marginal tax rates, a fiscal shock is followed by a decline in before-tax real wages that is both delayed and relatively small. Likewise, the increase in hours worked is relatively insignificant. With time-varying distortionary taxes, the fall in after-tax real wages is sharper, reflecting the joint influence of sticky nominal wages and the persistent, hump-shaped increase in the average marginal income tax rate, while in comparison the decline in before-tax real wages is relatively small. Interestingly, the model-simulated and VAR-based impulse responses of after-tax real wages to a military shock correspond almost perfectly. The rise in hours, however, is relatively insignificant, since producers determine the quantity of hours worked on the basis of before-tax real wages, not after-tax real wages.

The third model features sticky nominal prices and perfectly flexible nominal wages, implying that households are always on their labour-supply curves while variations in markups generate shifts in labour demand. Under these circumstances, an exogenous rise in government spending increases both hours worked and real wages. We show that the pure sticky-price model accounts well for the magnitude and timing of how hours worked respond to military buildups under constant and time-varying marginal tax rates. We show that variable markups are an important element of the explanation. Indeed, following a fiscal shock, markups decline in a persistent hump-shaped fashion, which mirrors the persistent, hump-shaped increase in total government purchases. The same pattern occurs in the adjustment of hours worked and output to an increase in military purchases.

These findings lead us to conclude that pure sticky-wage and sticky-price models have opposite strengths and weaknesses with respect to how hours worked and after-tax real wages respond to military buildups. The sticky-wage model provides a satisfactory account of the magnitude and timing of the fall in after-tax real wages, and the sticky-price model accounts well for the magnitude and timing of the rise in hours worked. Therefore, the final step in our investigation is to unify both types of nominal rigidities into a single model. In contrast to the standard neoclassical model, we demonstrate that the NNS framework with nominal-wage and -price rigidities accounts well for the actual effects of military buildups if government raises revenues through distortionary taxation. In particular, the model does well in capturing the timing of the rise in hours worked and output and the timing of the decline in after-tax real wages.

This paper is organized as follows. After briefly summarizing the major features of U.S. military buildups, section 2 describes the empirical procedure used to estimate their effects and discusses the estimation results. Section 3 describes our NNS framework. Section 4 studies the macroeconomic consequences of military buildups in four different economies. Section 5 presents conclusions.

2. Estimating the Effects of Large Military Buildups

Various approaches have been taken in the literature to identify exogenous changes in fiscal policy and to illustrate their macroeconomic effects. Rotemberg and Woodford (1992) identify exogenous movements in government spending with statistical innovations in defence spending, arguing that military purchases are likely to be the most nearly exogenous government purchases. Blanchard and Perotti (1999) exploit institutional information about the tax and transfer systems in different countries and use an exactly identified VAR for government purchases, taxes, and total output to construct VAR-based innovations in fiscal variables as measures of policy shifts. The empirical procedure that we adopt builds on the methodology used in Ramey and Shapiro (1998) and Burnside, Eichenbaum, and Fisher (1999a). The idea behind this procedure is that, to a great extent, large military buildups can be considered as deliberate policy actions, and as such may be used to construct a better measure of fiscal-policy shocks than VAR-based innovations in fiscal variables.[5] We briefly describe this procedure in section 2.1.

2.1 The VAR procedure

Ramey and Shapiro (1998) identify three post-war events that have led to unusually large military buildups: the Korean War, the Vietnam War, and the Carter-Reagan defence buildup. As Figure 1 shows, defence spending, total government expenditures, the share of government purchases in real GDP, and the average marginal income tax rate all increased sharply on those occasions. The fact that tax rates rose significantly at times of military buildups not only suggests that time-varying marginal tax rates should be taken into account when assessing a model's ability to explain the effect of a fiscal shock, it also casts doubts on the usual assumption in general equilibrium models that higher government purchases are financed entirely through lump-sum taxes.

As in Burnside, Eichenbaum, and Fisher (1999a), our procedure combines the narrative approach with a VAR. Based on an interpretative reading of historical events, Ramey and Shapiro (1998) date the beginning of large military buildups at the following quarters: 1950Q3, 1965Q3, and 1980Q1. Defining accordingly a dummy variable, D_t, where $D_t = 1$ if $t = \{1950Q3,1965Q1,1980Q1\}$ and zero otherwise, the VAR that serves for the purpose of estimation is:

$$Z_t = A_0 + A_1(L)Z_{t-1} + A_2(L)D_t + u_t, \tag{1}$$

where Z_t is a $k \times 1$ vector stochastic process, $A_1(L)$ and $A_2(L)$ are finite-ordered matrix polynomials in non-negative powers of the lag operator, $E(u_t) = 0$,

$$E(u_t u'_{t-s}) = \begin{cases} 0 & for \quad s \neq 0 \\ \Sigma & for \quad s = 0, \end{cases}$$

and $\sum$ is a positive definite $k \times k$ matrix. This VAR system can be expressed in terms of its moving-average representation as:

$$Z_t = \Pi_0 + \Pi_1(L)u_t + \Pi_2(L)D_t, \tag{2}$$

with $\Pi_0 = [I - A_1(1)]^{-1}A_0$, $\Pi_1 = [I - A_1(L)L]^{-1}$, and $\Pi_2 = [I - A_1(L)L]^{-1}A_2$. Since D_t and u_t are orthogonal, $\Pi_1(L)$ and $\Pi_2(L)$ characterize the dynamic impulse responses of vector Z_t to changes in u_t and D_t, respectively.

[5] Ramey and Shapiro (1998) also argue that, unlike most measures of monetary-policy shocks, large military buildups are unlikely to be the result of feedback from the domestic economy.

2.2 Empirical findings

The procedure just described is applied to the U.S. post-war economy. We use quarterly data from 1947Q1 to 1994Q4.[6] The variables included in vector Z_t are the log of time t real GDP, the log of hours worked, the log of after-tax real wages, the log of a measure of the average marginal income tax rate, the log of real government purchases, the net three-month Treasury bill rate, and the log of the producer price index of crude fuel. The tax rate series, borrowed from Stephenson (1998), is an updated version of the average marginal statutory tax rate constructed by Barro and Sahasakul (1983). We include six lagged values of all variables in the VAR. Appendix A gives detailed information about the data.

Figure 2 shows the response of total government purchases, the average marginal income tax rate, output, hours worked, and after-tax real wages to a military-shock variable taking the value of unity. For brevity, we call this shock a *fiscal shock*. The impulse responses give the average impact of military buildups on each of these variables.[7] The solid lines represent point estimates of the coefficients of the dynamic response functions; the dashed lines represent Bayesian confidence intervals of 68 per cent computed from Integrated Monte Carlo simulations. The upper-left-hand panel of Figure 2 shows that, after a fiscal shock, total government purchases shortly decline and then increase sharply in a significant persistent, hump-shaped fashion with a peak response of about 12 per cent approximately 6 quarters after the shock. The upper-right-hand panel shows that the average marginal income tax rate also increases in a persistent hump-shaped manner, with a peak of nearly 5.8 per cent about 8 quarters after the shock. The middle-row panels report a persistent, hump-shaped increase in output, with a peak response of about 4 per cent around the fifth quarter, and a persistent hump-shaped rise in hours worked, with a peak of about 3 per cent approximately 7 quarters after the shock. According to the lower-left-hand panel, the fiscal shock induces a persistent hump-shaped decline in after-tax real wages that mirrors the persistent hump-shaped rise in the average marginal income tax rate. Therefore, the fiscal shock gives rise to a strong negative co-movement between hours worked and after-tax real wages. This negative co-movement has been extensively documented in the literature recently and has been shown to be robust to changes in the definition of real wages (e.g., Ramey and Shapiro 1998 and

[6]The length of our sample period is constrained by the data on the marginal income tax rate, which are not available after 1994Q4.

[7]This procedure implies that military buildups have the same intensity. This may be questionable. In unreported work, we have allowed the three episodes to have different intensities while estimating the VAR and simulating the models. Allowing for episodes of different intensities affects the magnitude of the estimated impulse-response functions of the variables included in the VAR. In turn, this has an impact on the magnitude of the impulse responses generated by the model. Using a procedure that accounts for episodes of different intensities does not alter our conclusions.

Burnside, Eichenbaum, and Fisher 1999a).[8]

To a certain degree, the particular selection of military buildup dates can be considered arbitrary, since it depends on an interpretative reading of the narratives around the time of events. To assess the problem that may arise from an arbitrary choice of dates, Edelberg, Eichenbaum, and Fisher (1998) suggest shifting one date backward and forward by one, two, and three periods, respectively.[9] Figures 3a and 3b show the results of this exercise. Shifting the onset of a military buildup backward or forward around the chosen dates does not alter the results significantly. The persistent hump-shaped pattern that characterizes all estimated impulse responses appears to be very robust to changes in the dates. Another question raised by the use of the narrative procedure is whether the selected military buildup dates have any special meaning. In other words, if we were to choose three dates in our sample period repeatedly and randomly, would the results be similar to those reported in Figure 2? Following Edelberg, Eichenbaum, and Fisher (1998), we try to answer this question by randomly choosing three dates in our sample period 500 times and by calculating the 25th lowest and 475th highest values of the corresponding impulse-response coefficients across the 500 impulse-response functions. Figue 4 shows the results of this experiment. The impulse-responses associated with the randomly selected dates are represented by dashed lines, and those obtained using the narrative approach of Ramey and Shapiro (1998) are represented by solid lines. If the dates selected by Ramey and Shapiro were meaningless, the solid lines would lie within the dashed lines. This is clearly not the case.[10]

3. An NNS Framework with Market Imperfections and Nominal Rigidities

To study the macroeconomic effects of a fiscal shock, we develop an NNS model that features monopolistic competition in the goods and the labour markets, with

[8] The evidence reported in Rotemberg and Woodford (1992) shows that real wages increase slightly following an exogenous increase in defence spending. A possible explanation for this result is that it is sensitive to the price index used in deflating the wage. Ramey and Shapiro (1998) report a decline in real wages instead of a rise if the newly revised (May 1997) implicit GDP deflator is used. Another possible explanation is that Rotemberg and Woodford (1992) use a somewhat simpler procedure to identify exogenous movements in defence purchases.

[9] The results are obtained allowing for a shift in the Korean War starting date while keeping the other two dates unchanged.

[10] We have re-estimated the VAR using before-tax real wages instead of after-tax real wages. Although, for space limitations, we do not report these results in this section, we nonetheless use them when we compare the impulse responses estimated from the VAR with those generated by our four models under the assumption that marginal tax rates are constant.

producers setting nominal prices for their products and households setting nominal wages for their labour skills. Specifically, the economy is populated by a continuum of imperfectly competitive households, each endowed with a differentiated labour skill; a representative final-goods-producing firm, which sells its output in a perfectly competitive market; a continuum of imperfectly competitive intermediate-goods-producing firms; and a fiscal authority. The more general framework assumes that both nominal wages and nominal prices are sticky.

3.1 The representative final-goods-producing firm

The representative final-goods-producing firm uses $Y_t(i)$ units of each intermediate good to produce Y_t units of the final good according to the following constant-returns-to-scale technology:

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}, \tag{3}$$

where $\theta > 1$ is a parameter denoting the elasticity of substitution between differentiated intermediate goods. The final-goods-producing firm sells its output at a nominal price, P_t, and chooses Y_t and $Y_t(i)$ for all $i \in [0, 1]$ to maximize its profits,

$$P_t Y_t - \int_0^1 P_t(i) Y_t(i) di, \tag{4}$$

subject to the constraint in equation (3) in each period. The first-order conditions for this problem are equation (3) and

$$Y_t(i) = \left[\frac{P_t(i)}{P_t} \right]^{-\theta} Y_t. \tag{5}$$

Equation (5) expresses the demand for intermediate good i as a decreasing function of its relative price and an increasing function of total output. Integrating (5) and imposing (3) yields the following expression for the price of the final good:

$$P_t = \left[\int_0^1 P_t(i)^{1-\theta} di \right]^{\frac{1}{1-\theta}}. \tag{6}$$

3.2 The intermediate-goods-producing firm

The intermediate-goods-producing firm, i, uses $K_t(i)$ units of capital, $H_t(i)$ units of labour, and aggregate technology, A_t, to produce $Y_t(i)$ units of the intermediate good, i. Specifically, $Y_t(i)$ is produced according to the following technology:

$$Y_t(i) = K_t(i)^{1-\alpha}\left[A_t H_t(i)\right]^{\alpha}. \tag{7}$$

The labour input used in the production of intermediate good i is a composite of all types of labour skills,

$$H_t(i) = \left[\int_0^1 H_t(i,j)^{\frac{\sigma-1}{\sigma}} dj\right]^{\frac{\sigma}{\sigma-1}}, \tag{8}$$

where $H_t(i,j)$ is the labour skill of type j used in the production of intermediate good i. The parameter $\sigma > 1$ denotes the elasticity of substitution between differentiated labour skills.

The non-stochastic technical progress, A_t, is given by:

$$\log(A_t) = A + \log(A_{t-1}), \tag{9}$$

where e^A represents a constant gross growth rate.

The intermediate-goods-producing firm, i, seeks to maximize the discounted sum of current and expected future real profits:

$$Max \quad E_t \sum_{l=0}^{\infty} \beta^l d_p^l \frac{\Lambda_{t+l}}{\Lambda_t} \left\{\frac{D_{t+l}(i)}{P_{t+l}}\right\}, \tag{10}$$

where $D_{t+l}(i)$ represents period $t+l$ nominal dividends of an intermediate-goods-producing firm, i, that last reoptimized in t; $\beta^l \frac{\Lambda_{t+l}}{\Lambda_t}$ is the expected discount factor used by shareholders (i.e., the consumer-workers) to value date $t+l$ profits; and d_p represents a constant probability that the firm does not reoptimize its nominal price in period t. Thus, d_p^l is the probability that prices are not reoptimized from period t through period $t+l$. In turn, nominal dividends earned by the intermediate-goods-producing firm i, $D_{t+l}(i)$, are given by

$$D_{t+l}(i) = P_t^*(i) Y_{t+l}(i) - \int_0^1 W_{t+l}(j) H_{t+l}(i,j) dj - Q_{t+l} K_{t+l}(i), \tag{11}$$

where $P_t^*(i)$ is the optimal price set by intermediate-goods-producing firm i in period t, $W_t(j)$ is the average nominal wage of labour skill j, and Q_t is the nominal rental rate of capital.

Maximizing equation (11) with respect to $K_t(i)$, $H_t(i,j)$, and $P_t^*(i)$ yields the following first-order conditions:

$K_t(i)$:

$$\frac{Q_t}{P_t} = (1-\alpha)\psi_t(i) \frac{Y_t(i)}{K_t(i)}, \tag{12}$$

$H_t(i,j)$:

$$\frac{W_t(j)}{P_t} = \alpha\psi_t(i)\frac{Y_t(i)}{H_t(i)}\left[\frac{H_t(i,j)}{H_t(i)}\right]^{-\frac{1}{\sigma}}, \tag{13}$$

$P_t^*(i)$:

$$P_t^*(i) = \left(\frac{\theta}{\theta-1}\right)\frac{E_t\sum\limits_{l=0}^{\infty}\beta^l d_p^l \frac{\Lambda_{t+l}}{\Lambda_t}\psi_{t+l}(i)Y_{t+l}(i)\left(P_{t+l}\right)^{\theta}}{E_t\sum\limits_{l=0}^{\infty}\beta^l d_p^l \frac{\Lambda_{t+l}}{\Lambda_t}Y_{t+l}(i)\left(P_{t+l}\right)^{(\theta-1)}}, \tag{14}$$

where $\psi_t(i)$ denotes the real marginal cost at date t associated with producer i's maximization problem; it is also equal to the inverse of the markup. According to equations (12) and (13), the marginal products of labour and capital both exceed their respective marginal costs. Equation (14) is the optimal price equation of intermediate-goods-producing firm i, which is derived from the equalization of marginal cost with marginal revenue in a dynamic context.

In a symmetric equilibrium, where $H_t(i) = H_t$ (and $H_t(i,j) = H_t(i)$), $K_t(i) = K_t$, $Y_t(i) = Y_t$, $P_t(i) = P_t$, and $\psi_t(i) = \psi_t$ for all $i \in [0,1]$ and $t = 0,1,2,...$, (12)-(14) become

$$\frac{Q_t}{P_t} = (1-\alpha)\psi_t\frac{Y_t}{K_t}, \tag{15}$$

$$H_t(j) = \left[\frac{W_t}{W_t(j)}\right]^{\sigma} H_t, \tag{16}$$

$$P_t^* = \left(\frac{\theta}{\theta-1}\right)\frac{E_t\sum\limits_{l=0}^{\infty}\beta^l d_p^l \frac{\Lambda_{t+l}}{\Lambda_t}\psi_{t+l}Y_{t+l}\left(P_{t+l}\right)^{\theta}}{E_t\sum\limits_{l=0}^{\infty}\beta^l d_p^l \frac{\Lambda_{t+l}}{\Lambda_t}Y_{t+l}\left(P_{t+l}\right)^{(\theta-1)}}, \tag{17}$$

where W_t is the wage index expressed as:

$$W_t = \left[\int_0^1 W_t(j)^{1-\sigma}dj\right]^{\frac{1}{1-\sigma}}. \tag{18}$$

Equation (16) shows that the demand for labour skill j is a decreasing function of its relative wage and an increasing function of total employment. The case where the intermediate-goods-producing firms reoptimize nominal prices each period corresponds to one where d_p is set equal to 0 in equation (17). Perfect price flexibility then implies that the markup of prices over marginal cost is constant and equal to $\theta/(\theta-1)$.

After log-linearizing equation (17), we obtain the following equation for the optimal price:

$$\widehat{p}_t^* = \sum_{l=0}^{\infty} \beta^l d_p^l (1 - \beta d_p) \left(\widehat{\psi}_{t+l} + \widehat{p}_{t+l} \right), \tag{19}$$

or equivalently,

$$\widehat{p}_t^* = \beta d_p \widehat{p}_{t+l}^* + (1 - \beta d_p)(\widehat{\psi}_t + \widehat{p}_t), \tag{20}$$

where $\widehat{p}_t^* = \log(p_t^*) - \log(p)$, $p_t^* = \frac{A_t P_t^*}{M_t}$, p is the steady-state value of the price index, and $\widehat{\psi}_t = \log(\psi_t) - \log(\psi)$. M_t is money stock. After the same transformation has been applied to P_t, the law of motion for the price index can be written as:

$$\widehat{p}_t = d_p \widehat{p}_{t-1} + (1 - d_p)\widehat{p}_t^*. \tag{21}$$

3.3 The households

The household endowed with labour skill j has preferences defined over real consumption, real money balances, and leisure. Its expected discounted lifetime utility is:

$$E \sum_{t=0}^{\infty} \beta^t \left\{ \log \left[bC_t(j)^\gamma + (1-b) \left(\frac{M_t(j)}{P_t} \right)^\gamma \right]^{\frac{1}{\gamma}} + \eta \log \left[1 - H_t(j) \right] \right\}, \tag{22}$$

with $\frac{1}{1-\gamma} > 0$, $b > 0$, $\eta > 0$. Its budget constraint is given by:

$$\begin{aligned} C_t(j) + I_t(j) + \frac{M_t(j)}{P_t} &= (1 - \tau_t)\frac{W_t(j)}{P_t} H_t(j) + (1 - \tau_t)\frac{Q_t}{P_t} K_t(j) \\ &+ \tau_t \, \delta K_t(j) + \frac{M_{t-1}(j)}{P_t} + \frac{TR_t(j)}{P_t} + \frac{D_t(j)}{P_t}. \end{aligned} \tag{23}$$

As stated on the left-hand side of equation (23), household j allocates its funds to consumption, investment, and real money balances to be carried in the next period, while the right-hand side states that its sources of available funds are the after-tax labour income, the after-tax real capital income, real money balances carried from the previous period, real dividends received from the intermediate-goods-producing firms, and a real lump-sum transfer received from the government. The law of motion for capital accumulation is given by

$$I_t(j) + (1 - \delta)K_t(j) = K_{t+1}(j), \tag{24}$$

where δ is the constant depreciation rate.

Household j maximizes utility subject to constraints (16), (23), and (24). The first-order conditions for this problem with respect to $C_t(j)$, $M_t(j)$, and $K_{t+1}(j)$ are given by

$C_t(j)$:

$$\frac{bC_t(j)^{\gamma-1}}{bC_t(j)^{\gamma}+(1-b)\left(\frac{M_t(j)}{P_t}\right)^{\gamma}}=\Lambda_t(j), \tag{25}$$

$M_t(j)$:

$$\frac{(1-b)\left(\frac{M_t(j)}{P_t}\right)^{\gamma-1}}{bC_t(j)^{\gamma}+(1-b)\left(\frac{M_t(j)}{P_t}\right)^{\gamma}}=\Lambda_t(j)-\beta E\left[\Lambda_{t+1}(j)\frac{P_t}{P_{t+1}}\right], \tag{26}$$

$K_{t+1}(j)$:

$$\Lambda_t(j)=\beta E\Lambda_{t+1}(j)\left[(1-\tau_{t+1})\frac{Q_{t+1}(j)}{P_{t+1}}+\tau_{t+1}\delta+(1-\delta)\right], \tag{27}$$

where $\Lambda(j)$ is the Lagrange multiplier associated with household j's maximization problem. Maximizing utility with respect to the nominal wage of household j yields:

$$\sum_{l=0}^{\infty}\beta^l d_w^l E_t\left[\eta\frac{\sigma}{\sigma-1}\frac{1}{1-H_{t+l}(j)}+(1-\tau_{t+l})\frac{W_t^*(j)}{P_{t+l}}\Lambda_{t+l}(j)\right]H_{t+l}(j)=0, \tag{28}$$

where $W_t^*(j)$ is the optimal nominal wage of labour skill j and d_w^l is the probability that the household does not reoptimize its nominal wage from period t through period $t+l$. In a symmetric equilibrium, where $C_t(j)=C_t$, $I_t(j)=I_t$, $K_t(j)=K_t$, $M_t(j)=M_t$, $W_t(j)=W_t$, $H_t(j)=H_t$, $D_t(j)=D_t$, $TR_t(j)=TR_t$, and $\Lambda_t(j)=\Lambda_t$, for all $j\in[0,1]$ and $t=0,1,2,...$, equations (25) to (28) become

$$\frac{b{C_t}^{\gamma-1}}{b{C_t}^{\gamma}+(1-b)\left(\frac{M_t}{P_t}\right)^{\gamma}}=\Lambda_t, \tag{29}$$

$$\frac{(1-b)\left(\frac{M_t}{P_t}\right)^{\gamma-1}}{b{C_t}^{\gamma}+(1-b)\left(\frac{M_t}{P_t}\right)^{\gamma}}=\Lambda_t-\beta E\left[\Lambda_{t+1}\frac{P_t}{P_{t+1}}\right], \tag{30}$$

$$\Lambda_t=\beta E\Lambda_{t+1}\left[(1-\tau_{t+1})\frac{Q_{t+1}}{P_{t+1}}+\tau_{t+1}\delta+(1-\delta)\right], \tag{31}$$

$$E_t \sum_{l=0}^{\infty} \beta^l d_w^l \left[\eta \frac{\sigma}{\sigma - 1} \frac{1}{1 - H_{t+l}} + (1 - \tau_{t+l}) \frac{W_t^*}{P_{t+l}} \Lambda_{t+l} \right] H_{t+l} = 0. \tag{32}$$

The case where households reoptimize nominal wages each period corresponds to one where d_w is set equal to 0. The log-linearized law of motion of the wage index is:

$$\widehat{w}_t = d_w \widehat{w}_{t-1} + (1 - d_w) \widehat{w}_t^*, \tag{33}$$

where $\widehat{w}_t^* = \log(W_t^*) - \log(w)$, $w_t^* = \frac{A_t W_t^*}{M_t}$, w is the steady-state value of the wage index, which, along with $\widehat{w}_t$, is obtained by applying the same transformation to W_t.

3.4 The government

We assume that the government balances its budget every period. Current government revenues are raised either by means of a lump-sum tax and/or a proportional income tax, and seigniorage. This set-up is consistent with a Ricardian world as a first-order approximation, with deviations from pure Ricardian equivalence arising because of distortionary taxation on income. The government faces the budget constraint

$$G_t + \frac{TR_t}{P_t} = \tau_t \frac{W_t}{P_t} H_t + \tau_t K_t \left(\frac{Q_t}{P_t} - \delta \right) + \frac{M_t - M_{t-1}}{P_t}, \tag{34}$$

where G_t is total government purchases. When focusing on lump-sum taxes, τ_t is set equal to zero. The resource constraint of this economy is

$$C_t + I_t + G_t = Y_t. \tag{35}$$

Government expenditures evolve according to

$$G_t = A_t g_t. \tag{36}$$

The logarithms of total government purchases and of the marginal tax rate can be represented by $MA(q)$ moving-average representations, which are functions of the military buildup dummy:

$$\log(g_t) = \log(g) + \hat{\Pi}_{2,g}^2(L) \varepsilon_{D,t}, \tag{37}$$

and

$$\log(\tau_t) = \log(\tau) + \hat{\Pi}_{2,\tau}^2(L) \varepsilon_{D,t}, \tag{38}$$

where $\hat{\Pi}^2_{2,g}(L)$ and $\hat{\Pi}^2_{2,\tau}(L)$ are polynomials of finite order, q, with positive powers for the lag operator L, while g and τ are the steady-state values of government purchases and of the marginal tax rate, respectively. $\varepsilon_{D,t}$ is a stochastic variable that can equal 0 or 1. To shock the economy by a military buildup, we set $\varepsilon_{D,t}$ equals unity.

4. Results

This section studies the macroeconomic effects of a fiscal shock predicted by the NNS model. First, we describe the values that are assigned to the structural parameters of the model. Then, we examine the predictions of four models, each one corresponding to a different set of assumptions regarding the extent of nominal rigidities in prices and wages. In the first model, labelled FPW, nominal prices and nominal wages adjust each period. The second model, labelled SW, features sticky nominal wages and perfectly flexible nominal prices. In the third model, labelled SP, nominal prices are sticky while nominal wages adjust each period. The fourth model, labelled SPW, which represents our more general NNS framework, incorporates both sticky nominal prices and wages.

4.1 Model calibration

To obtain the models' equilibrium dynamics, we log-linearize the equilibrium conditions, assuming first that nominal prices and nominal wages are fully flexible and then considering alternative staggering mechanisms. The linearized system of equations is solved based on the calibrated parameters. The time period considered in calibrating our model corresponds to 1 quarter.

The parameter η in the utility function is chosen to imply that, in the steady state, households devote about 24 per cent of their time to hours worked, so $\eta = 1.5$. To assign values for b and γ, we use the equilibrium money-demand equation,

$$\log\left(\frac{M_t}{P_t}\right) = -\frac{1}{1-\gamma}\log\left(\frac{b}{1-b}\right) + \log C_t - \frac{1}{1-\gamma}\log\left(\frac{R_t - 1}{R_t}\right), \qquad (39)$$

where R_t is the gross nominal interest rate. A regression of money velocity on nominal interest rates using M2 data from 1959Q1 to 1999Q4 implies that $b = 0.998$ and $\gamma = -1.75$. The implied interest elasticity is 0.36, with a standard error of 0.04. It is similar to the elasticity in Lucas (1988). We set $\beta = 0.99$, implying a steady-state real interest rate of 4 per cent per year. We set $A = 0.003$, implying a quarterly growth rate of per capita income roughly equal to 1.003. We assign a value of 0.022 to δ, the rate of depreciation on capital. The share of labour in the production function, α, is set equal to 0.65, as in several other studies. Following

Rotemberg and Woodford (1992), we assume that θ, the elasticity of substitution between differentiated intermediate goods, is equal to 6.0, implying that the steady-state markup of price over marginal cost equals 20 per cent. We set the elasticity of substitution between differentiated labour skills as $\sigma = 6.0$, which corresponds to the estimate obtained by Ambler, Guay, and Phaneuf (2002) on the basis of U.S. post-war quarterly data. This estimate also is consistent with the micro-evidence produced by Griffin (1992, 1996) using disaggregated firm-level data. The probability, d_p, that monopolistically competitive producers do not adjust nominal prices each period is set equal to 2/3. Likewise, the probability, d_w, that monopolistically competitive households do not reoptimize nominal wages each period is set equal to 2/3. These probabilities imply an average duration of price fixity and of wage fixity of 3 quarters, consistent with the evidence surveyed by Taylor (1999).[11] Two sets of results are presented for each model. The first set corresponds to the case where military buildups are financed entirely by lump-sum taxes. The second set is obtained by assuming that increases in military purchases are financed by distortionary taxes. For flexible-price-model versions where taxes are lump sum, we report the simulated impulse response of output, hours worked, and before-tax real wages. For flexible-price model versions with distortionary taxes, we display the simulated impulse response of output, hours worked, before-tax real wages, and after-tax real wages. For sticky-price-model versions, we also display the markup response to a fiscal shock. For a given variable in a given model version, each graph shows the models' impulse-response function (dashed line) along with its empirical counterpart (solid line).

4.2 The FPW model

The FPW model features perfectly flexible nominal prices and wages (i.e., $d_p = d_w = 0$). It implies constant markups. Thus, as in the standard neoclassical economy, an exogenous rise in government purchases is expected to raise hours worked and output mainly by inducing a negative wealth effect, which increases the labour supply. The results in Figure 5a, corresponding to the lump-sum tax specification, indicate that the fiscal shock in the FPW model has only a small impact on hours worked and output. These results corroborate Baxter and King's (1993) finding that, unless a highly elastic labour supply is assumed, an exogenous increase in government spending should have negligible real effects. Figure 5b shows the response of an FPW economy under the assumption that taxes are distortionary. The results are not better. In the present case, the fiscal shock is followed by a persistent, hump-shaped decline, rather than a rise, in hours worked. The persistent, hump-shaped

[11] In unreported work, we have increased both probabilities to 3/4 and have decreased them to 1/2, without altering significantly any of the results described below.

rise in marginal tax rates creates both intratemporal and intertemporal substitution effects on the labour supply, leading households to work less in periods when income tax rates are high, and to work more in periods when they are low. The households' decision to work less with higher marginal tax rates reduces the labour supply, putting upward pressure on real wages and downward pressure on hours worked. Several quarters elapse, however, before after-tax real wages increase in response to the fiscal shock. Recall that the rise in marginal tax rates that accompanies military buildups is both persistent and hump-shaped. Consequently, in the first 6 or 7 quarters after the fiscal shock, the upward pressure on real wages is more than offset by the gradual rise in marginal tax rates: after-tax real wages fall slightly and then increase when the marginal tax rate slowly returns to its pre-shock value. We conclude that if the only departure from the standard neoclassical model is to assume imperfectly competitive products and labour markets, then both the neoclassical and FPW models share similar predictions about the macroeconomic effects of a fiscal shock.

4.3 The SW model

The SW model combines sticky nominal wages with perfectly flexible nominal prices. Hence, we set $d_w = 2/3$ and $d_p = 0$. Figure 6a shows the results produced by the SW model with lump-sum taxes. Since nominal wages are rigid, the fiscal shock induces a decline in before-tax real wages. The fall in before-tax real wages is delayed, hump-shaped, and relatively small. Therefore, the rise in hours worked also is insignificant. Assuming that nominal wages are sticky in an economy with time-varying marginal tax rates considerably improves the match between the model-simulated and the VAR-based responses in after-tax real wages. This is shown in Figure 6b. The magnitude and timing of the decline in after-tax real wages in the SW model and in the data coincide almost perfectly. This reflects the effect of two forces. First, the nominal wage rigidity puts downward pressure on real wages. Second, the persistent, hump-shaped increase in marginal tax rates puts additional downward pressure on after-tax real wages. In fact, the timing of how after-tax real wages respond to a fiscal shock is very similar to that of marginal tax rates. Unfortunately, the SW model still does not account for the magnitude of the rise in hours worked and output. While households set nominal wages, producers have the right to choose the quantity of hours worked. Producers determine total hours worked taking into account before-tax real wages, not after-tax real wages. Figure 6b shows that the decline in before-tax real wages is much smaller than the fall in after-tax real wages, which explains the relatively small increase in hours worked.

4.4 The SP model

The failure of the FPW and SW models to generate a significant increase in hours worked leads us to examine whether it is possible to elicit a stronger response of hours worked by combining sticky nominal prices with perfectly flexible nominal wages. The SP model sets $d_p = 2/3$ and $d_w = 0$. Because nominal prices are rigid, producers can meet a rise in demand by lowering markups and increasing output. As Rotemberg and Woodford (1992) show, variations in the markup may shift labour demand just as technology shocks do in real business cycle models. Increases in demand, such as those that might be caused by military buildups, may raise hours worked and output even with a constant labour supply, as long as they reduce markups. Figure 7a shows the impulse responses of the SP model with lump-sum taxes. Clearly, the SP model is better than the FPW and SW models at capturing both the timing and magnitude of how hours worked respond to a fiscal shock. Movements in the markup play a major role in accounting for the larger response of hours worked to a fiscal shock. Notice that the timing of the decline in the markup roughly coincides with the timing of the rise in total government purchases, with the maximum decline in the markup and the maximum rise in government purchases occurring roughly 6 quarters after the shock. In turn, the persistent, hump-shaped fall in the markup mirrors the persistent, hump-shaped rise in hours worked. The SP model also produces a persistent, hump-shaped rise in output, with the maximum output response being somewhat smaller in the model than in the data. Given its emphasis on labour-demand shifts, however, the SP model counterfactually predicts that real wages increase, rather than decrease, in response to the fiscal shock.

Figure 7b shows the results of the SP model with distortionary taxes. Unlike the SW model, the SP model does not produce a fall in after-tax real wages, because the downward pressure on those wages that results from the hump-shaped rise in marginal tax rates does not offset the strong upward pressure on real wages that arises from the nominal-price rigidity. The fall in the markup is larger with time-varying marginal tax rates than with lump-sum taxes, with a maximum decline of 4.0 per cent compared with 2.3 per cent. As marginal tax rates rise following a fiscal shock, households reduce the labour supply, inducing a rise in before-tax real wages that is larger than when marginal tax rates are constant. The larger fall in the markup produces a marginally stronger increase in hours worked and output.

4.5 The SPW model

This subsection combines nominal-price and nominal-wage rigidities. Hence, d_p and d_w are both set equal to $2/3$. This model implies that movements in the markup shift labour demand and that households are not always on their labour-supply curves.

The dynamic responses of the SPW model with lump-sum taxes are shown in Figure 8a. As in the SP economy, the fiscal shock generates a persistent, hump-shaped fall in the markup and a persistent, hump-shaped increase in hours worked and output. The fall in the markup is smaller in the SPW economy, with a maximum decline of 1.1 per cent approximately 6 quarters after the shock, than in the SP economy, whose decline reaches 2.3 per cent after 6 quarters. The intuition for the smaller decline of markups in the SPW economy is as follows. In both the SP and SPW economies, imperfectly competitive firms set prices as a markup over marginal-cost. Without nominal-wage rigidity, the marginal production cost results from both a flexible rental rate of capital and a flexible wage index. On the other hand, if both nominal wages and nominal prices are rigid, the marginal production cost results from a flexible rental rate of capital and a sticky-wage index. The sticky-wage index flattens the marginal cost curve of producers. Thus, following a fiscal shock, the marginal cost increases more in the SP economy than in the SPW economy. Because nominal prices are rigid, the smaller increase in marginal cost generated by the SPW model puts less downward pressure on the markup. However, even though the decline in the markup is smaller, the rise in hours worked remains as large in the SPW model as in the SP model. Recall from our examination of the SW model that the nominal-wage rigidity puts downward pressure on before-tax real wages, which induces a modest rise in hours worked. This pressure is present in the SPW model, since nominal wages are sticky, while it is absent in the SP model, since nominal wages are perfectly flexible. Although the SP model generates a significant rise in before-tax real wages in response to a fiscal shock, the downward pressure on before-tax real wages that is present in the SPW model exactly offsets, for all practical matters, the upward pressure arising from the nominal-price rigidity. While the SPW model with lump-sum taxes successfully reproduces the persistent hump-shaped rise in hours worked, it fails to generate a fall in real wages.

The last scenario features nominal-wage rigidities, nominal-price rigidities, and a time-varying marginal tax rate on income. Figure 8b shows the results. A fiscal shock produces a negative co-movement between hours worked and after-tax real wages. The SPW model inherits the persistent, hump-shaped decline in after-tax wages from the SW model and the persistent, hump-shaped increase in hours worked and output from the SP model. Therefore, the SPW model does very well in accounting for the timing and magnitude of how hours worked, after-tax real wages, and output respond to a fiscal shock. In particular, notice that the maximum response of hours worked and output to a fiscal shock in the VAR and in the SPW model occurs before the maximum decline in after-tax real wages.

5. Conclusion

We have studied the joint influence of imperfect competition and nominal rigidities on the macroeconomic effects of military buildups. An attractive implication of the NNS framework is that, unlike the standard neoclassical model, it provides a satisfactory account of the effects of fiscal shocks even when it is assumed that higher government purchases are financed by time-varying marginal tax rates. Furthermore, although it is well-known that nominal rigidities play an important role in the propagation of monetary policy shocks, we have shown that an understanding of such rigidities, when incorporated in an economy with imperfectly competitive markets, is important to understand the impact of fiscal policy on business cycles.

Although an examination of the economy's response to military buildups is especially well-suited to a study of well-defined exogenous fiscal shocks and to discriminate between competing macroeconomic theories, it is admittedly a restrictive fiscal experiment. We believe that in future work, the NNS approach may be a promising way to address other issues, such as the effects of permanent and temporary changes in government purchases, and the impact of government size on economic stability.

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Figure 1: Fiscal Variables and the Military Buildup Dates

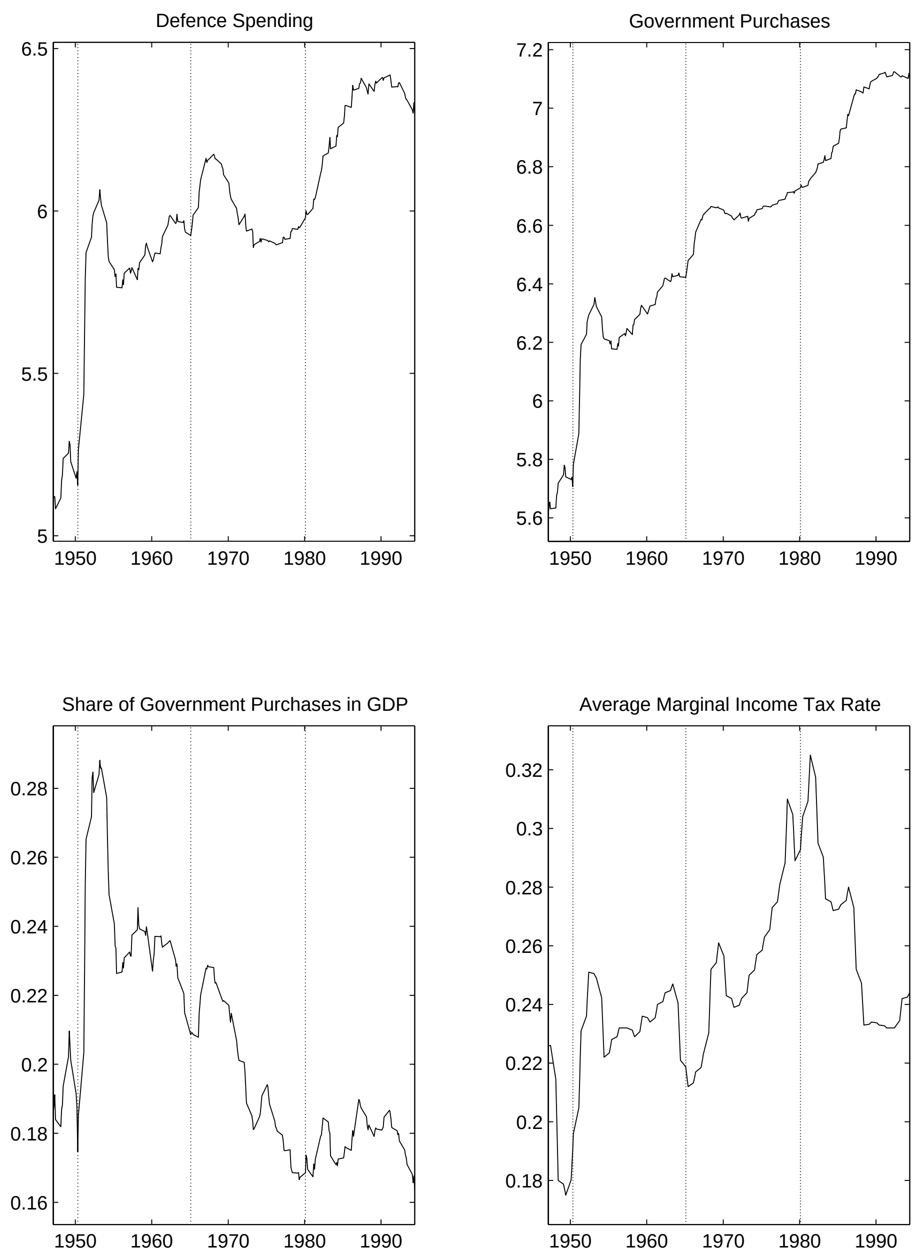
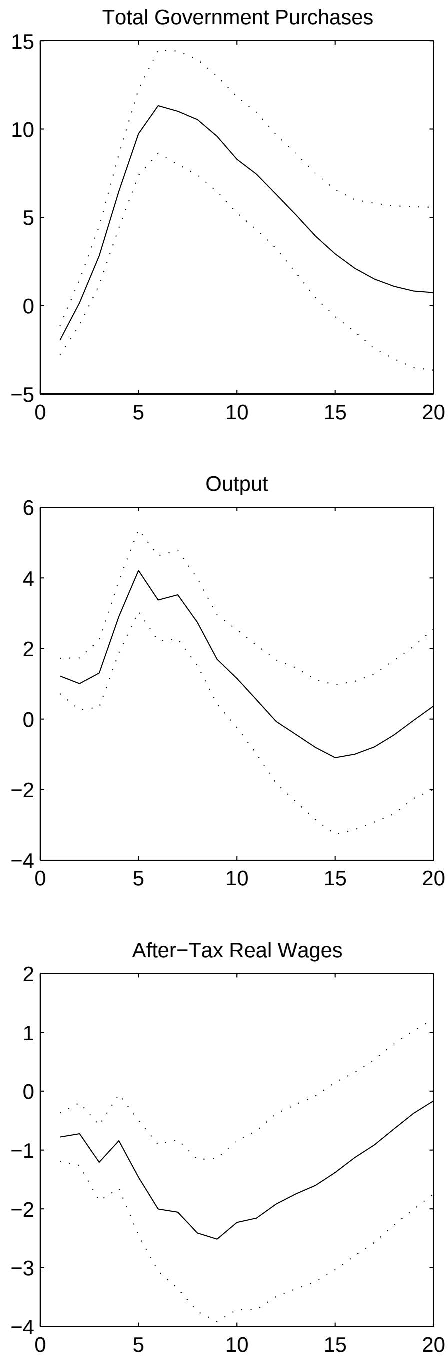


Figure 2: Estimated Response to a Fiscal Shock



—: VAR estimates

...: Confidence intervals

Figure 3a: Estimated Response to a Fiscal Shock - Dates Shifted Backward
(—: $j = 0$, ...: $j = -1$, - -: $j = -2$, and -.-: $j = -3$)

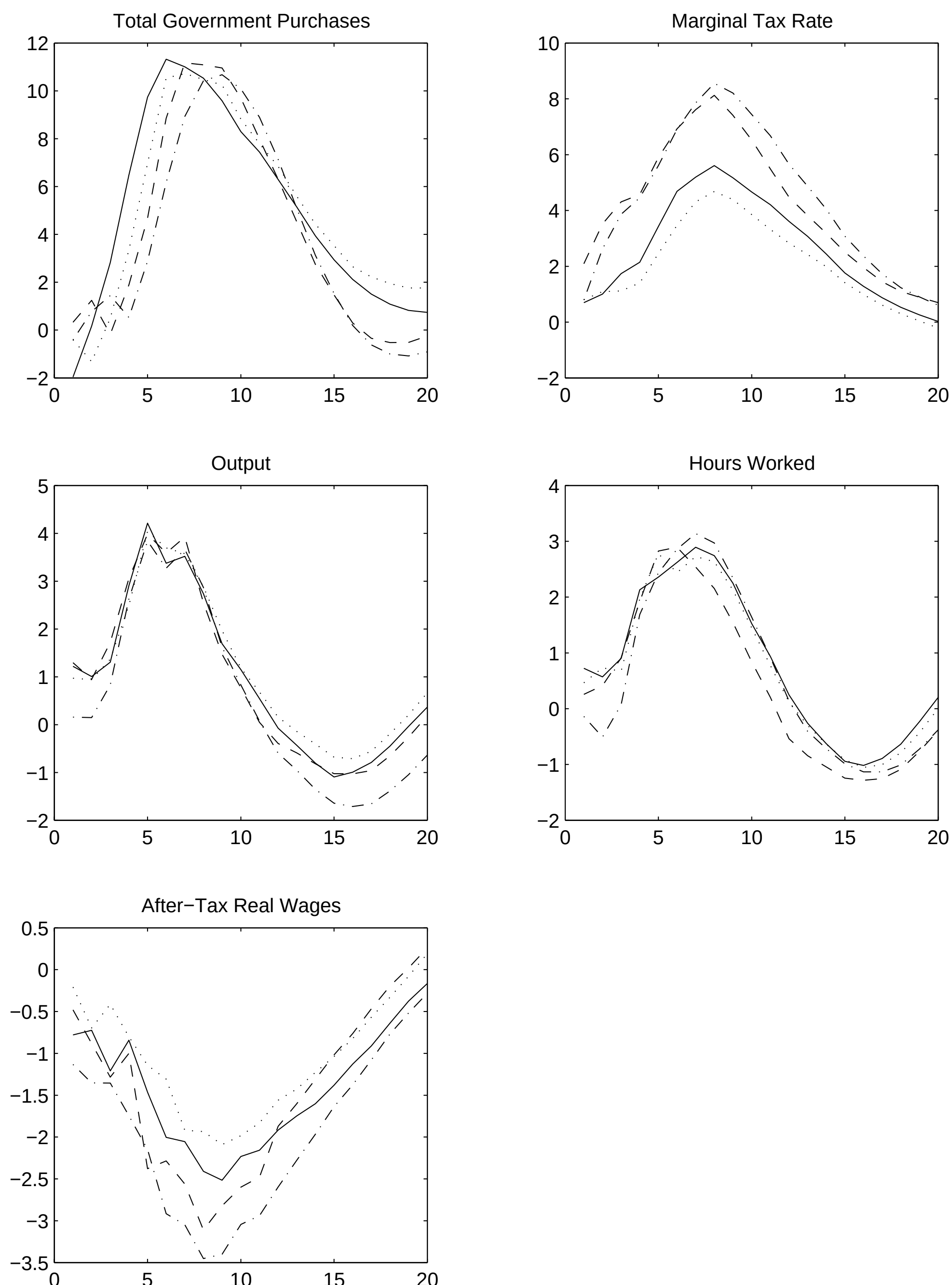


Figure 3b: Estimated Response to a Fiscal Shock - Dates Shifted Forward
(—: $j = 0$, ...: $j = +1$, - -: $j = +2$, and -.-: $j = +3$)

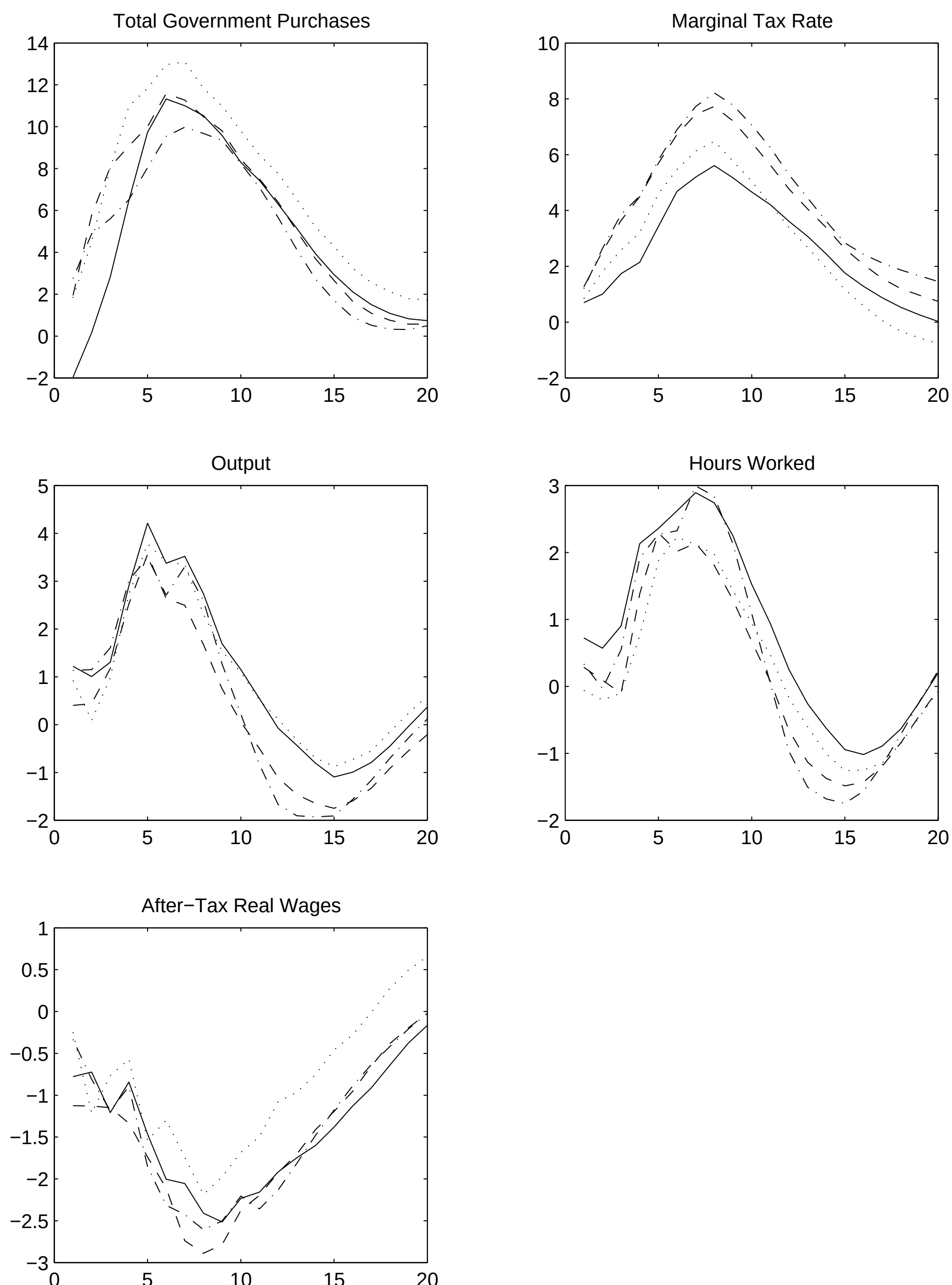
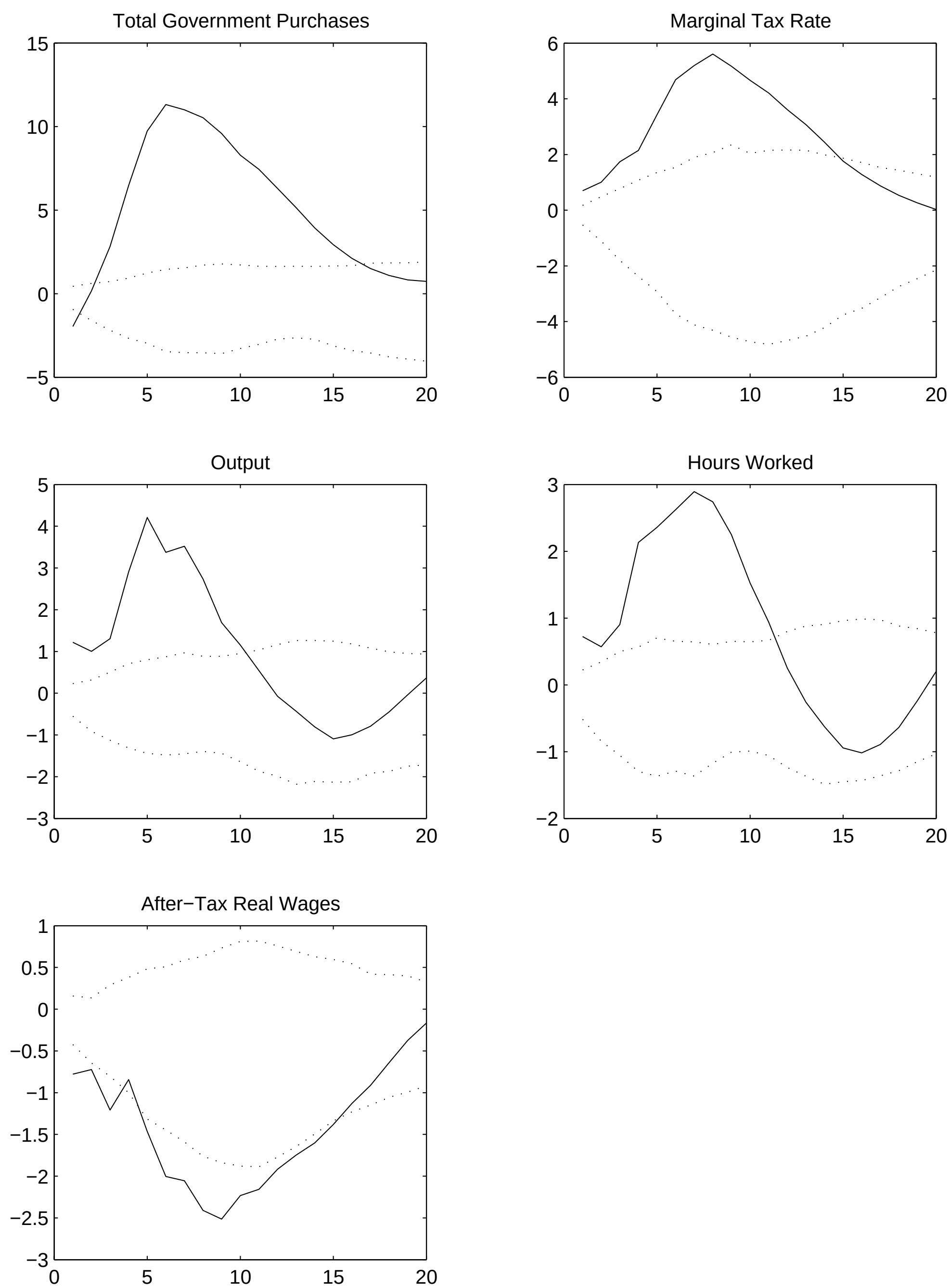
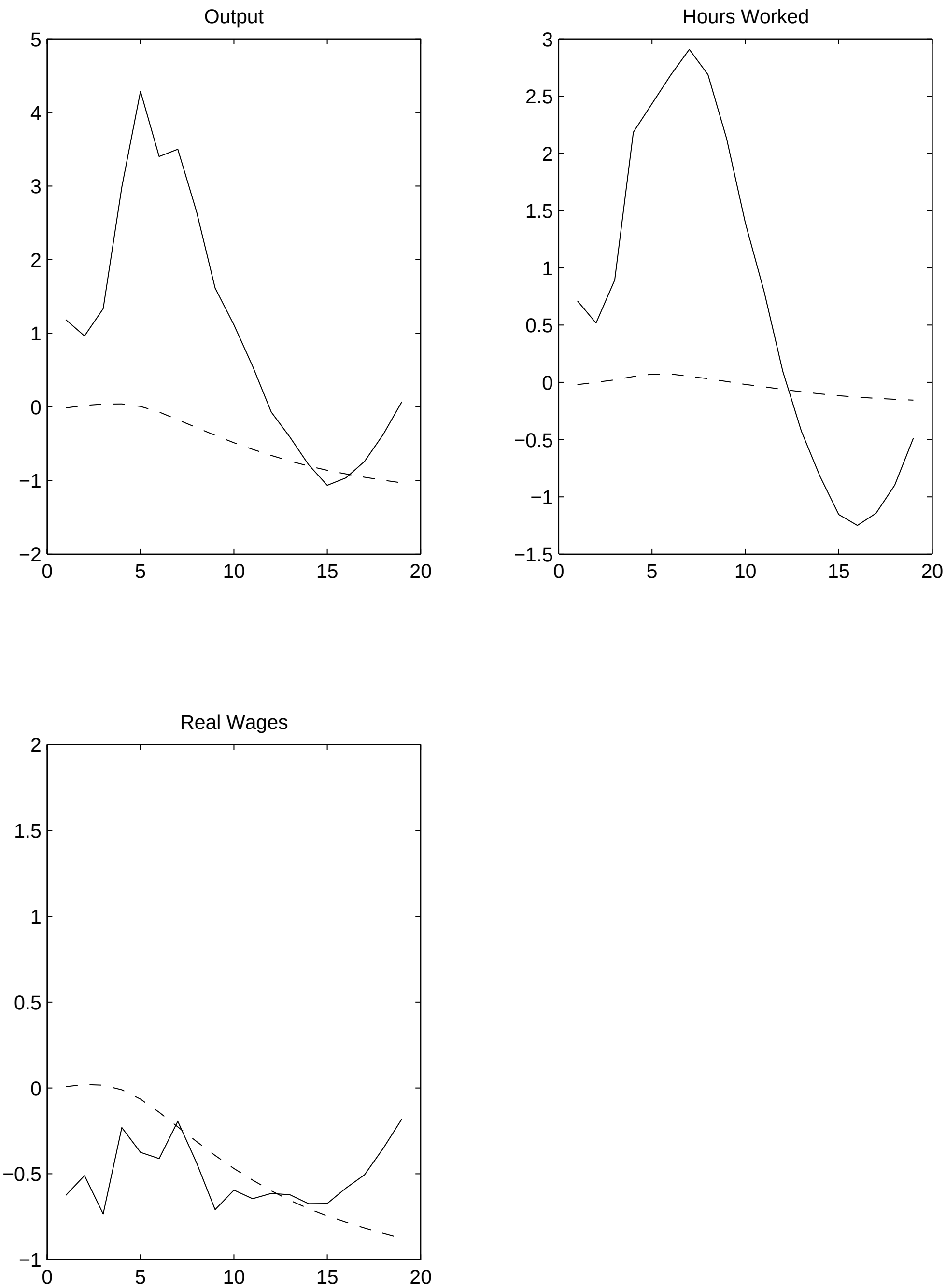


Figure 4: Estimated Response to a Fiscal Shock with Randomly Selected Dates



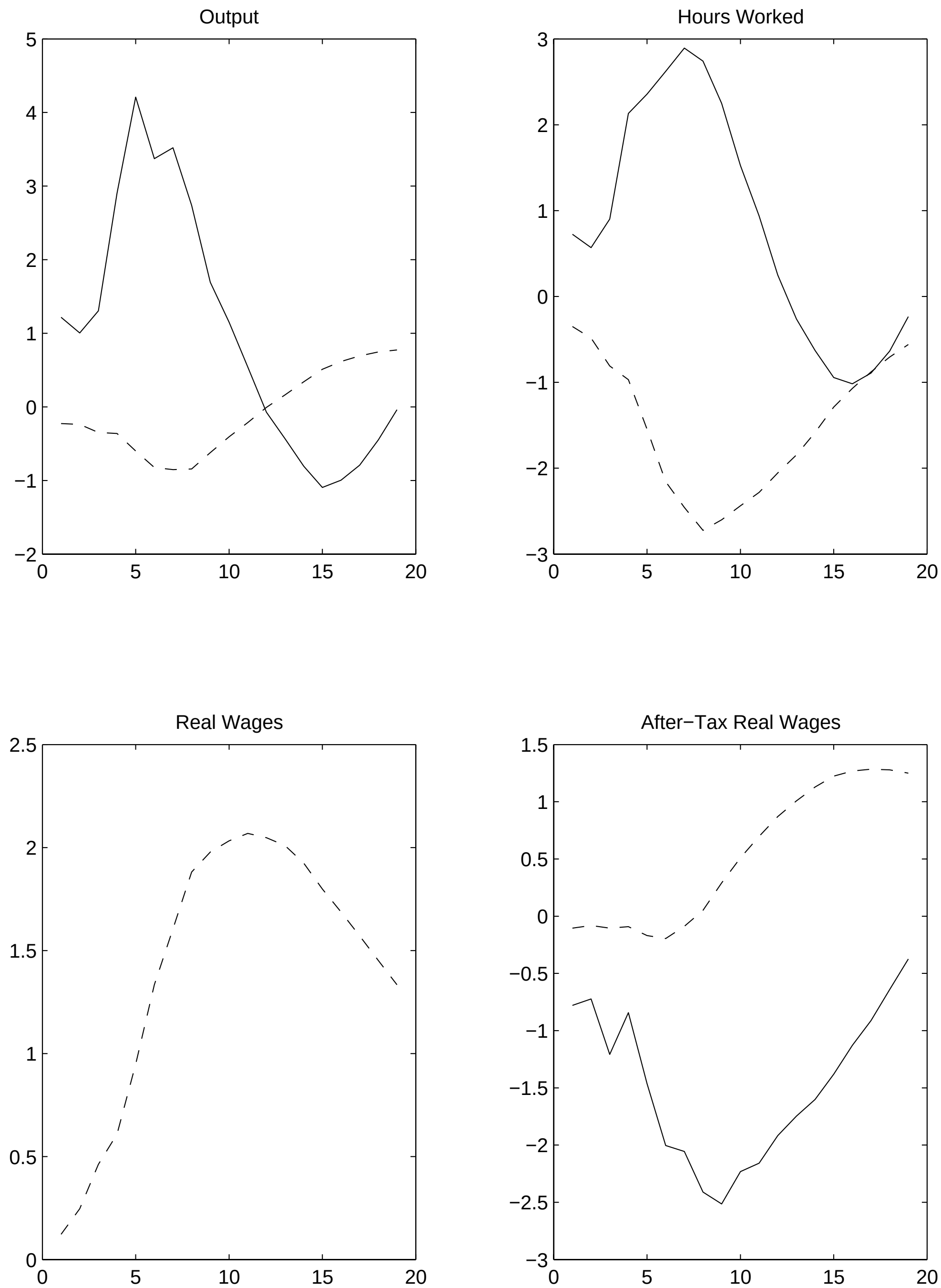
—: VAR estimates
- -: VAR estimates with random dates

Figure 5a: The FPW Model with Lump-Sum Taxes



—: VAR estimates
- -: FPW model

Figure 5b: The FPW Model with Distortionary Taxes



—: VAR estimates
- -: FPW model

Figure 6a: The SW Model with Lump-Sum Taxes

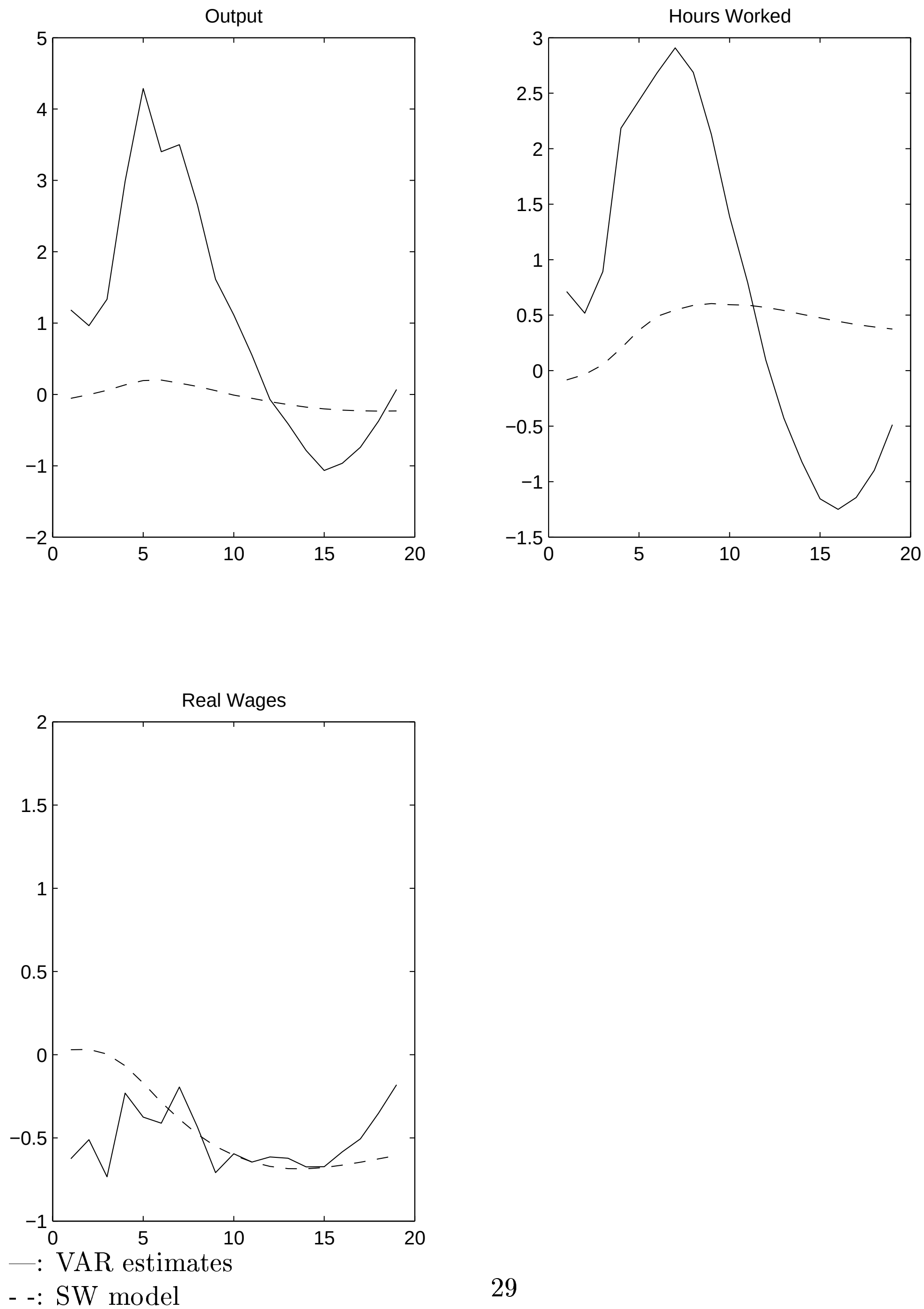
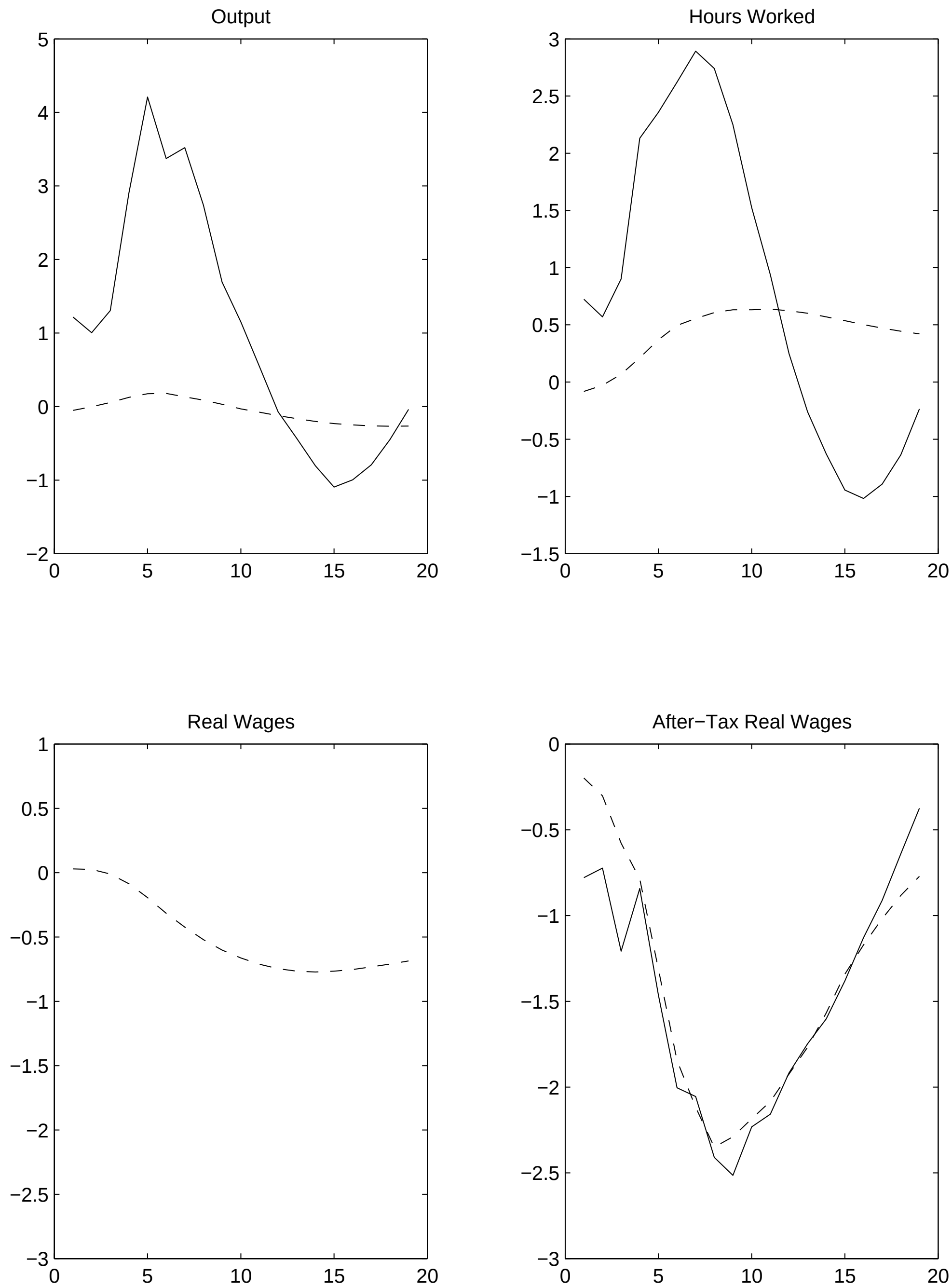


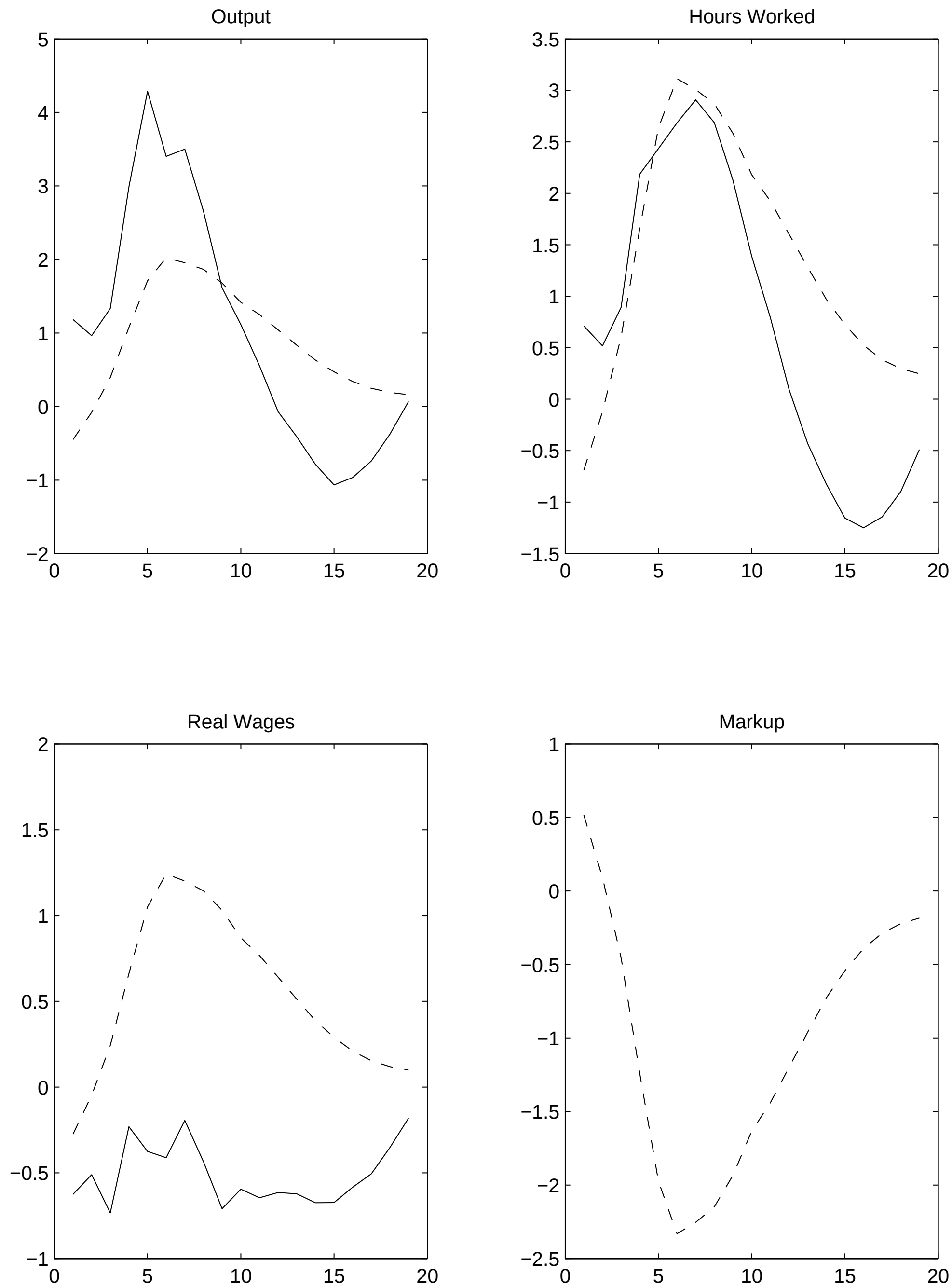
Figure 6b: The SW Model with Distortionary Taxes



—: VAR estimates

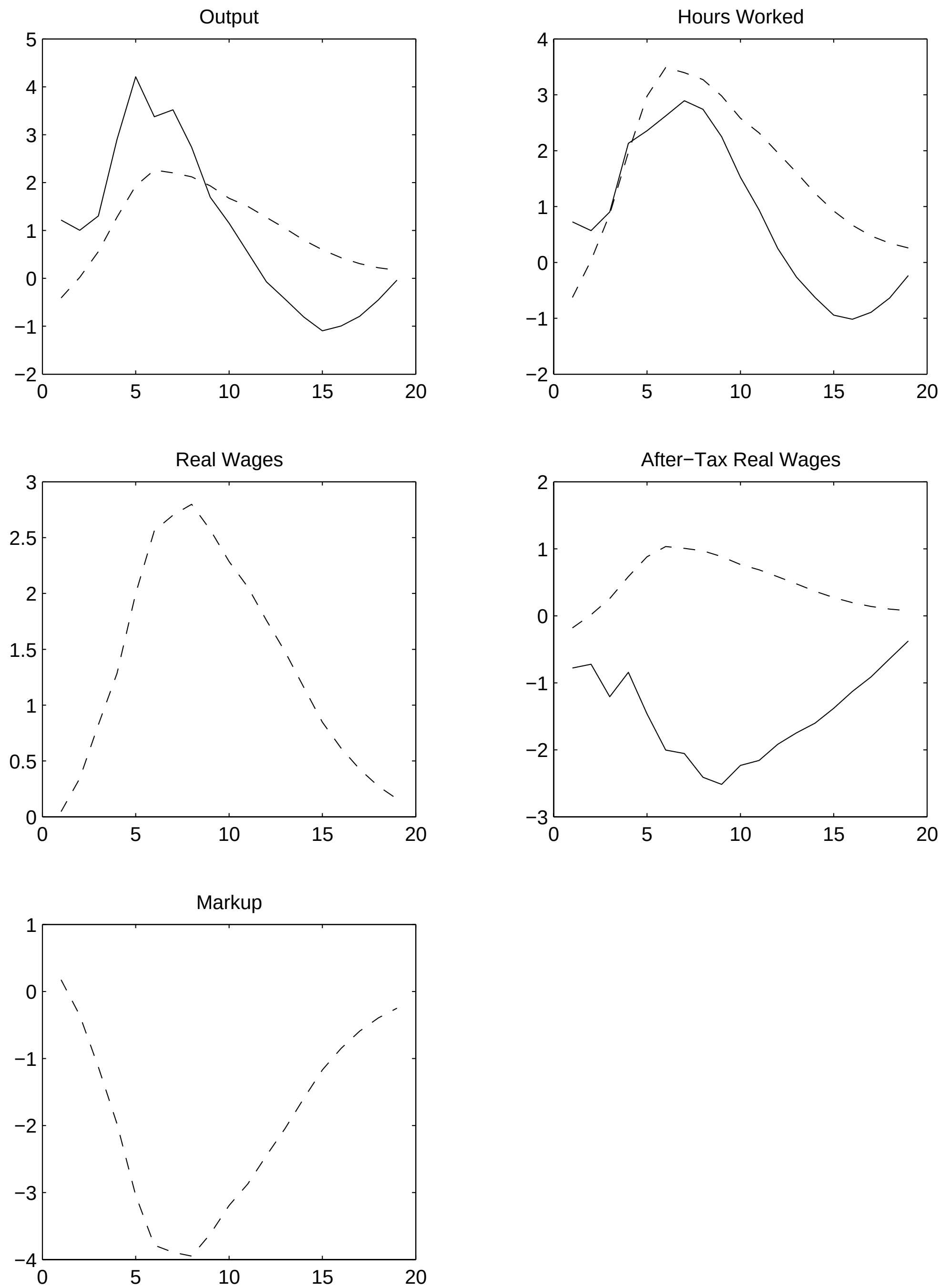
- -: SW model

Figure 7a: The SP Model with Lump-Sum Taxes



—: VAR estimates
- -: SP model

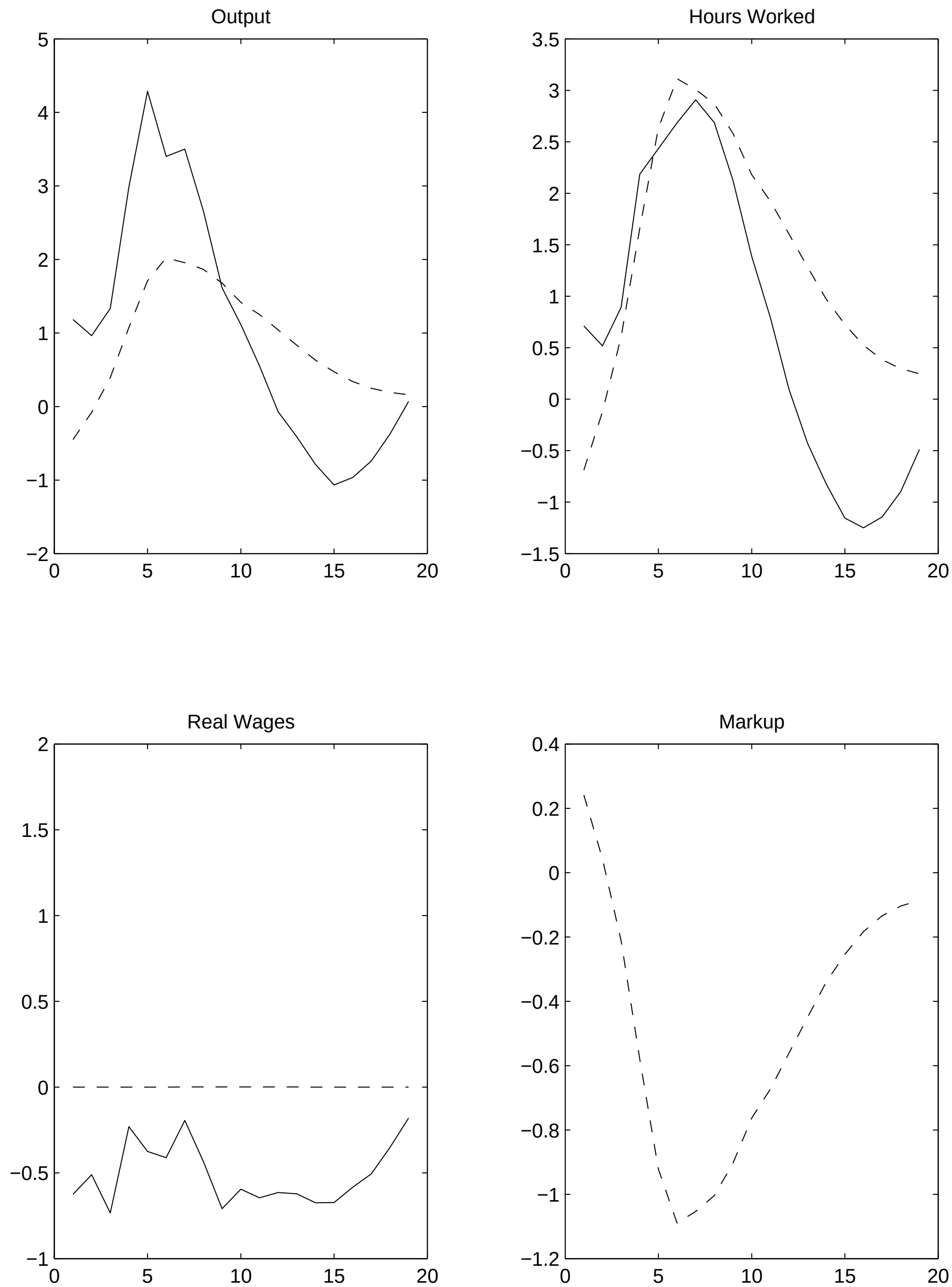
Figure 7b: The SP Model with Distortionary Taxes



—: VAR estimates

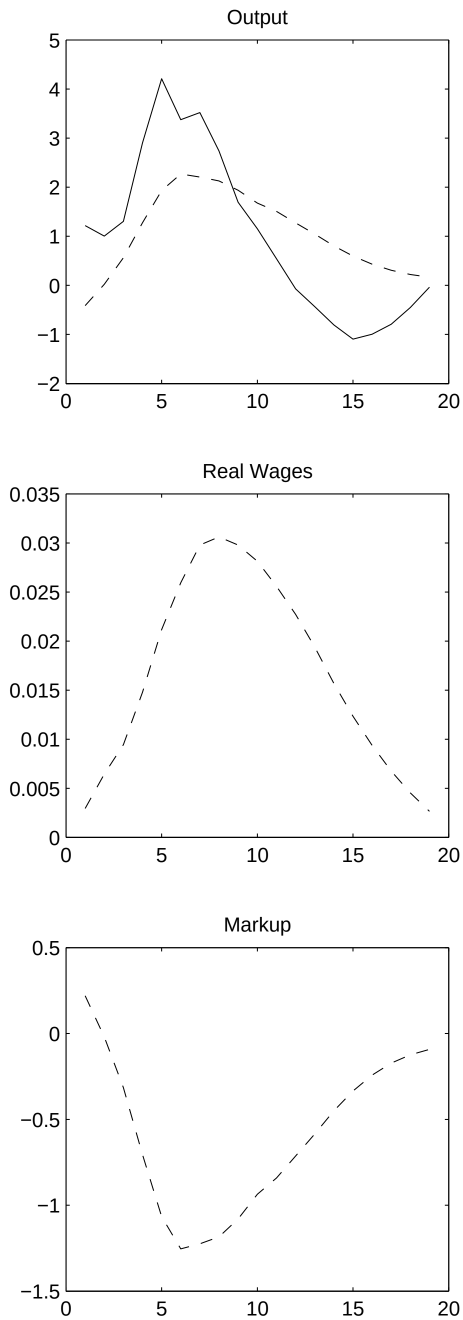
- -: SP model

Figure 8a: The SPW Model with Lump-Sum Taxes



—: VAR estimates
- -: SPW model

Figure 8b: The SPW Model with Distortionary Taxes



—: VAR estimates

- -: SPW model

Appendix A: Data

The data are from four main sources. Below we list the series that correspond to each of those sources. All series are seasonally adjusted, apart from interest rates and taxes. Except for taxes, these series were obtained from the DRI BASIC Economics Database. We provide the original database mnemonic.

1. Bureau of Economic Analysis. The real GDP (GDPQ), GDP deflator (GDPD), defence spending (GGFEQ), and government purchases (defence spending plus federal, state, and local consumption expenditures) (GGFEQ+GGOCEQ +GGSCPQ).

2. Bureau of Labor Statistics. Index of hours of all persons in the business sector (LEHM), manufacturing wages (LBMN), and producer price index for crude fuel in manufacuring industries (PW1310).

3. Board of Governors of the Federal Reserve System. Net three-month Treasury Bill secondary market interest rate (FYGM3).

4. Stephenson (1998), Table 1, pp. 391-92. Updated version of Barro and Sahasakul's (1983) income-weighted measure of the average marginal statutory income tax rate. A linear interpolation was applied to generate the quarterly frequency series.

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