Growth and Unemployment: Short-run and Long-run Tradeoffs*

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Abstract

We consider the role of search unemployment and wage bargaining in determining the relationship between growth and unemployment. While the long-run tradeoffs between unemployment and growth are weak, the short-run tradeoffs are much stronger. Their comovement varies along the transitional path and depends upon the underlying structural change. The consequences of the growth-unemployment nexus for fiscal policy are addressed. The analysis provides insights into the debate regarding the appropriate fiscal policy in light of the increased debt following the initial response to the recent financial crisis. Our analysis strongly supports an increase in government investment as the appropriate fiscal policy.

Key words: Endogenous growth, unemployment, labor market search

JEL Classification: O41, O47, J64

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1. Introduction

Does enhanced growth reduce unemployment or is there a tradeoff between them? This is a topical question as national economies continue to recover from the great recession. It is also an old issue in that it has long been suggested that technological change, by stimulating capital accumulation and growth, may create unemployment at least in the short run. Conventional growth theory assumes either that labor is supplied inelastically, or if endogenously determined, it is nevertheless fully employed. Standard growth models, therefore, are incapable of addressing this issue. In order to investigate the relationship between growth and unemployment we need to introduce some source of disequilibrium into the labor market.

We do so by adapting the endogenous growth model pioneered by Romer (1986) and Barro (1990), in which the accumulation of public capital provides a key source of sustained growth. But to analyze the dynamics of unemployment, we must depart from the standard neoclassical approach employed by Turnovsky (2000), in which with perfectly flexible wages, the labor market always clears and unemployment does not exist. To do this we augment the standard representative agent model of a growing economy by introducing search unemployment, together with wage bargaining, as originally developed by Diamond (1982) and Mortensen and Pissarides (1994). In these models unemployment emerges due to the time consuming and costly process of matching vacancies with agents searching for employment.[1] In addition, as suggested by Hall (2005a, 2005b), we introduce sticky wages. Thus, the wage resulting from Nash bargaining by workers and employers determines the target wage, to which the actual wage rate adjusts gradually. The introduction of slow wage adjustment is not only plausible, but it also yields realistically slow and persistent unemployment dynamics, whereas assuming that the wage rate adjusts instantaneously to the bargained wage generates unrealistically fast unemployment adjustment; see, e. g., Heer (2003) or Schubert (2011). The resulting macroeconomic equilibrium is described by a high order dynamic system, for which analytical solutions are infeasible, requiring us to resort to numerical simulations, which we parameterize to approximate a typical European economy.

[1] See Pissarides (2000) for an overview.

Using this framework we address three related issues. First, we investigate the sensitivity of the long-run equilibrium relationship between the aggregate growth and unemployment rates to various structural characteristics of the economy. We show that structural attributes which directly enhance productivity generate significant effects on the long-run growth rate, but have only negligible impacts on the long-run unemployment rate. In contrast, structural differences that impinge directly on the functioning of the labor market have substantial influence on long-run unemployment, but only minor impacts on the long-run growth rate. Thus, a more flexible labor market, in which matches between job seekers and firms are attained more efficiently, reduces the unemployment rate, increases the time allocated to employment, leading to a modest increase in the growth rate. Less bargaining power by workers in wage determination has a similar effect. In either case, less time is spent searching, leaving more time to allocate between leisure and productive labor, the latter enhancing the productivity of capital and increasing the growth rate. In contrast, less generous unemployment benefits can reduce search time so drastically that fewer unemployed succeed in finding matches. Employment declines, leading to a slight decline in the growth rate.

These response patterns suggest little in the nature of a significant long-run tradeoff. Rather, we find that structural attributes associated with productivity enhancement are reflected in the growth rate, with minimal impact on unemployment, while those associated with the labor market have precisely the opposite characteristics. This conclusion is a consequence of two characteristics: (i) the only linkage between long-run unemployment and the growth rate is via the long-run labor market tightness (measured by the vacancy-search ratio) and the output-capital ratio; (ii) these two quantities are only weakly related. An additional finding we obtain, that welfare is more sensitive to structural differences pertaining to production than to labor market characteristics, is a reflection that growth matters more than does unemployment, at least with reasonably generous unemployment compensation, typical of most European economies.

The second issue we examine concerns the comovement over time between unemployment and growth as the economy evolves following some structural change. We focus on a permanent increase in total factor productivity (TFP) and show that it leads to an immediate substantial increase in the growth rate of output, accompanied by an equally substantial drop in unemployment. During the subsequent transition the output growth declines steadily, gradually reverting most of the way back toward its initial equilibrium. The unemployment rate returns essentially fully to its initial equilibrium, but does so via a highly nonmonotonic adjustment path. This implies dramatic swings in the contemporaneous unemployment-growth relationship. Thus, during the early phase of the transition, one would observe a strong *positive* relationship between unemployment and growth (as both decline rapidly), which after a short period switches to a strong *negative* relationship.

The third issue concerns the implications of alternative forms of fiscal expansions in a growing economy, characterized by unemployment. We compare increases in two forms of government expenditure (investment and consumption) with reductions in three distortionary tax rates (capital income, labor income, and consumption). To preserve comparability, in all 5 scenarios the policies are normalized to represent a uniform fiscal stimulus of 1% of GDP. The three expansionary tax policies and the expansionary government consumption expenditure policy all lead to sharp short-run increases in both growth and unemployment. These are substantially moderated over time, and in the case of the wage income tax leads to a moderate long-run decline in unemployment. Overall, increasing government investment is the superior policy. It clearly dominates all criteria in the short run. In the long run it dominates overwhelmingly in terms of yielding a higher sustained growth rate, improved intertemporal welfare, and having the least adverse impact on the government's intertemporal budget balance. But it also leads to a slightly higher long-run unemployment rate than do the others, despite its superiority in the short run.

These results are relevant for the policy debates in the aftermath of the great recession of 2008 that occurred both in Europe and in the United States, with two competing views, one advocating fiscal contraction, the other proposing increased public investment. Our simulation results firmly favor the latter position. Moreover, we can show that by financing the government investment by implementing a combination of a higher consumption tax coupled with a lower tax on labor income it is possible to achieve a higher long-run growth rate and improve welfare, while reducing the long-run unemployment rate and the government's intertemporal fiscal imbalance.

The paper is related to several bodies of literature. First, there is a substantial literature investigating the relationship between growth and unemployment, both from a theoretical viewpoint and empirically. On the theoretical side, this paper is closest to Eriksson (1997) and Postel-Vinay (1998). However, in both instances there are several important differences. Like Eriksson, we emphasize the growth-unemployment tradeoffs. But, while he restricts his analysis to the steady state, we consider their comovements both along the transitional dynamic path, as well as across steady states. We regard this focus on the entire transitional path to be important, because as noted, the direction of the comovement can change dramatically as the economy evolves following a structural change. This is helpful in interpreting the seemingly conflicting empirical estimates linking unemployment and growth, which typically employ short-run data, and therefore depend upon which phase of any transitional adjustment is reflected in the empirical estimates. Second, we employ a more complete specification of the labor market in which agents choose to allocate their time between search, employment, and leisure. While Postel-Vinay (1998) addresses both the transitional dynamics and steady state, he also has a parsimonious specification of the household side of the economy. This, however, offers the advantage of being amenable to a closed-form analytical solution. Third, in contrast to both authors who abstract from policy, we devote particular attention to assessing the merits of alternative fiscal policies, both during the transition and in the long run. Other papers adopting this general approach include Bean and Pissarides (1993), Shi and Wen (1997, 1999), Heer (2003), and Schubert (2011).

Search costs, which are a form of real rigidies, while clearly important, are also not the only source of unemployment in a macrodynamic system.[2] Another source of unemployment arises through nominal rigidites associated with Keynesian monetary growth models. This is an area in which Carl Chiarella and his coauthors have made important contributions; see e.g. Chiarella and Flaschel (1998, 2000). In Chiarella, Flaschel, Groh, and Semmler (2000), and Chiarella, Flaschel, and Semmler (2013) an integrated Keynes-Metzler-Goodwin disequilibrium (growth) model is developed and applied to study the effects of feedback and adjustment mechanisms between the goods, the financial and the labor market on macroeconomic dynamics and on unemployment. This too is an important aspect, adding to our understanding of the growth-unemployment relationship.

[2] Arico (2003) identifies several alternative links between economic growth and unemployment. Among them, one of the most important is the "creative destruction effect" due to Aghion and Howitt (1994).

In this respect the present paper can be viewed as offering a complementary approach to these insightful contributions.

Empirical evidence on the relationship between unemployment and growth originated with the seminal work of Okun (1962). Much of this literature focuses on causality, i.e. whether unemployment causes growth or vice versa. One of the important advantages of developing an underlying theoretical framework is that it becomes clear that both variables are endogenous so that any observed comovements reflect their respective responses to the underlying structural changes that may be occuring. Bearing this is mind helps reconcile the wide range of often conflicting correlations that have been estimated.[3]

The remainder of the paper is structured as follows. Section 2 sets out the analytical framework, which is then calibrated in Section 3 to reflect key features of European economies. Section 4 discusses the steady-state relationship between growth and unemployment and summarizes its sensitivity to key structural characteristics. Section 5 simulates the dynamic responses to a permanent increase in TFP. Section 6 introduces the five normalized forms of fiscal expansion and assesses their consequences for the dynamic comovement of unemployment and growth, as well as for economic welfare and long-run fiscal balance. After drawing some policy implications in Section 7, the paper concludes. Since the derivation of the macrodynamic equilibrium involves substantial technical detail, this and other technical aspects are relegated to the Appendix.

2. Analytical framework

The key feature of the analytical setup is the incorporation of search unemployment into a standard endogenous growth model, where the underlying source of growth is an externality consisting of an amalgam of public and private capital in production, as in Chatterjee and Turnovsky (2012). The economy comprises three sectors: households, firms, and the government.

[3] For example, Caballero (1993) finds a positive correlation between growth and unemployment for both the US and UK at medium or low frequency. At very low frequencies it remains positive for the UK but is either zero or negative for the US. Herwartz and Niebuhr (2011) analyze the growth-unemployment relationship across EU regions and find that it is sensitive to labor market characteristics and accordingly varies across countries.

2.1 Households

The economy is populated by N identical households. Each unit, i, comprises a continuum of agents with a fixed measure. Each household member cares only about the unit's utility. Thus, individual risks in consumption and leisure are completely smoothed within each household (see Shi and Wen, 1997). Each household is endowed with one unit of time that can be used for supplying labor, l^s, searching for employment, s, or enjoying leisure, $L = 1 - l^s - s$. Agents who are searching, s, are called unemployed. The labor force is defined to be $l + s$, and the unemployment rate is $s/(l+s)$, where l denotes the equilibrium level of employment. Besides leisure, each household consumes a consumption good, C. For notational simplicity and without loss of generality, we drop the index i and normalize the number of households, $N = 1$.

The representative household earns wage income from labor, interest income from holding capital, K, and government bonds, B, (which are perfect subsitutes for capital), and receives the profits, Π, of the representative firm it owns. It uses its income to buy the consumption good, C, and to accumulate capital and bonds, subject to the flow budget constraint:

$$\dot{K} + \dot{B} = (1-\tau_\pi)\Pi + (1-\tau_k)r(K+B) + (1-\tau_w)wl^s + \sigma_u ws - (1+\tau_c)C - T \tag{1a}$$

where r is the common rate of return on capital and bonds, w the wage rate, and τ_π, τ_k, τ_w, and τ_c are the tax rates levied on income received from firms (profits), interest income, labor income, and consumption. T denotes a net lump-sum tax, and $\sigma_u ws$ are unemployment benefits, where σ_u is the rate of the unemployment subsidy as a fraction of the wage rate. As Shi and Wen (1999) note, by treating σ_u as constant over time, it should be interpreted as the average unemployment subsidy to all unemployed agents. This is because in reality the subsidy to an unemployed individual typically falls with the duration of his unemployment.

Because of market frictions, labor (employment) l^s changes only gradually according to

$$\dot{l}^s = \phi s - \zeta l^s \tag{1b}$$

where ϕ denotes the job finding rate and ζ is the exogenously given rate of job separation.[4] The job finding rate is a function of the job-market tightness, which the individual takes as given, but is determined endogenously in equilibrium. As Shi and Wen (1999) further observe, there are continuous flows into and out of the state of unemployment, even in steady state. Since the identities of unemployed agents are constantly changing, the unemployment duration, $1/\phi$, should be interpreted as the average duration of all unemployed agents.

The representative household derives utility from consumption, C, leisure, L, and from a government provided consumption good, G_C. It maximizes the iso-elastic utility function W

$$W \equiv \int_0^\infty \frac{1}{\varepsilon}[C(1-l^s-s)^\theta G_C^\eta]^\varepsilon e^{-\beta t}dt, \quad \theta \geq 0, 1 > \varepsilon\theta, 1 > \varepsilon(1+\theta), \eta \geq 0 \tag{2}$$

by choosing the rate of consumption, C, search, s, and the rates of accumulation of capital and bonds and of labor supply, subject to the flow budget constraints (1a) and (1b), and the given initial stocks of capital, $K(0)=K_0$, bonds, $B(0)=B_0$, and labor supply, $l^s(0)=l_0^s$, respectively. β denotes the agent's (constant) rate of time preference. The intertemporal elasticity of substitution is $1/(1-\varepsilon)$, and θ denotes the elasticity of leisure in utility. The optimality conditions are:

$$C^{\varepsilon-1}(1-l^s-s)^{\varepsilon\theta}G_C^{\varepsilon\eta} = (1+\tau_c)\lambda \tag{3a}$$

$$\theta C^\varepsilon(1-l^s-s)^{\varepsilon\theta-1}G_C^{\varepsilon\eta} = \gamma\phi + \lambda\sigma_u w \tag{3b}$$

$$\beta - \frac{\dot{\lambda}}{\lambda} = (1-\tau_k)r \tag{3c}$$

$$\frac{\lambda(1-\tau_w-\sigma_u)w}{\gamma} + \frac{\dot{\gamma}}{\gamma} - \zeta = \beta + \phi \tag{3d}$$

together with the transversality conditions

$$\lim_{t\to\infty}\lambda K e^{-\beta t} = \lim_{t\to\infty}\lambda B e^{-\beta t} = \lim_{t\to\infty}\gamma l^s e^{-\beta t} = 0 \tag{3e}$$

[4] In order not to over-complicate the model, following Shi and Wen (1997, 1999) and Heer (2003), the job destruction rate is assumed to be exogenous. However, as discussed in Pissarides (2000, ch. 2), the dynamics with an endogenous job destruction rate are similar to those derived in a model where the job separation rate is exogenous.

where λ is the marginal utility of wealth, and γ is the shadow price of employment in terms of utility. Condition (3a) equates the marginal utility of consumption to the tax-adjusted marginal utility of wealth. Equation (3b) equates the marginal cost of searching – its (dis)utility – to the marginal benefit of searching, which comprises the utility value of finding a job plus the utility value of the unemployment benefits received while searching. Dividing (3b) by (3a), we obtain:

$$\frac{\theta C}{1-l-s}(1+\tau_c) = \phi\frac{\gamma}{\lambda} + \sigma_u w \equiv w_R \tag{4}$$

Noting that the disutility of search equals the disutility of work, the marginal disutility of work (or search) in terms of output must equal the household's after-tax reservation wage, w_R, which is the sum of the marginal unemployment benefit, $\sigma_u w$, and the value of a job in terms of output, $q \equiv \gamma/\lambda$, times the probability of finding a job (i. e. the expected value of a job). Thus we see that the reservation wage (the minimum after-tax wage necessary to accept a job offer) equals the marginal rate of substitution between leisure and consumption, adjusted by the consumption tax rate.

Equations (3a) and (3b) can be solved for consumption, C, and search, s in terms of employment, the reservation wage, the shadow value of wealth, government consumption, and the consumption tax, with the effects on search being

$$s = s(l, w_R, \lambda, G_C, \tau_c); \quad s_l = -1, s_{w_R} > 0, s_\lambda > 0, s_{G_C} > 0, s_{\tau_c} < 0 \tag{5a}$$

where the signs of the partial derivatives are based on the assumption that the intertemporal elasticity of substitution is less than one ($\varepsilon < 0$), as empirical evidence overwhelmingly suggests. Writing

$$w_R \equiv q\phi + \sigma_u w \tag{5b}$$

we see that that, *ceteris paribus*, an increase in the shadow price of employment, q, raises the reservation wage and thus search activities.

Equation (3c) is the usual Euler condition, equating the rate of return on consumption to the after-tax rate of return on capital and on bonds, i. e. the interest rate. The dynamic no-arbitrage condition, (3d), requires the rate of return on employment, comprising the "dividend yield" of employment, $\lambda(1-\tau_w-\sigma_u)w/\gamma$, the "capital gain" $\dot{\gamma}/\gamma$ and the loss due to job destruction ζ, to equal the "effective" discount rate, $\beta+\phi$, which comprises the rate of time preference adjusted for the probability of finding a job, ϕ. Finally, to ensure that the agent's intertemporal budget constraint is met, the transversality conditions (3e) must hold.

Combining (3c) and (3d), together with (5b), the evolution of $q(t)$ can be described by

$$\frac{(1-\tau_w)w-w_R}{q}+\frac{\dot{q}}{q}=(1-\tau_k)r+\zeta \tag{6}$$

Solving this equation forward and invoking the transverality condition (3e) the solution for $q(t)$ is

$$q(t)=\int_t^\infty\left[(1-\tau_w)w(z)-w_R(z)\right]e^{-\int_t^z(\zeta+(1-\tau_k)r(u))du}dz \tag{6'}$$

The value of a job, expressed in terms of output, equals the household's discounted flow of the difference between the net wage $(1-\tau_w)w$ and the after-tax reservation wage w_R, i. e. the present value of the rent the household gets from working, where the discount rate equals the after-tax interest rate, $(1-\tau_k)r$ adjusted for the rate of job destruction. Equivalently, equation (3d) can be solved to yield

$$q(t)=\int_t^\infty\left[(1-\tau_w-\sigma_u)w(z)\right]e^{-\int_t^z(\zeta+\phi(u)+(1-\tau_k)r(u))du}dz \tag{6''}$$

which expresses the value of a job as the household's discounted flow of the effective net wage.

2.2 Firms

The economy also includes a large number of identical firms, which for convenience we normalize to unity. Firms produce a good, Y, by combining private capital, K, and labor (demand), l^d, by means of the CES production function $Y=F(K,l)$

$$Y=A\left[\alpha K^{-\rho}+(1-\alpha)\left(Xl^d\right)^{-\rho}\right]^{-1/\rho};\quad -1\le\rho<\infty \tag{7a}$$

where $\varsigma\equiv 1/(1+\rho)$ is the elasticity of substitution in production, A reflects total factor productivity, and α denotes the share of private capital, K, in production.

In addition, production is influenced by an aggregate externality, X, which we take to be a weighted average of the economy's aggregate stock of private capital, $\bar{K}$, and public capital (infrastructure), K_G:

$$X \equiv \bar{K}^e K_G^{1-e}, \quad 0 \le e \le 1 \tag{7b}$$

That is, "raw" labor interacts with the composite production externality to create labor efficiency units, which in turn interact with private capital to produce output. The production function thus has constant returns to scale in both the private factors and in the accumulating factors, and accordingly can potentially sustain an equilibrium of ongoing growth. The composite externality represents a combination of the role of private capital as in Romer (1986), together with public capital as in Barro (1990), Futagami et al. (1993), and subsequent authors, and can be justified in two ways.[5] First, it facilitates the calibration of the aggregate economy, something that is generically problematic in the conventional one-sector AK growth model. Second, the notion that the economy's infrastructure contributing to labor efficiency comprises a combination of both private and public components is itself a plausible representation of reality; see e.g. Calderón and Servén (2014).

Parallel to (1b), the representative firm's labor demand follows

$$\dot{l}^d = \varphi v - \zeta l^d \tag{7c}$$

where, as already noted, workers separate from a job at rate, ζ. The individual firm takes the rate, φ, of filling a vacancy v as given, although, like ϕ, this is dependent upon labor market tightness and is determined in equilibrium. The firm pays a cost for maintaining a number of job vacancies equal to $m\bar{Y}v$. This cost includes advertising costs (Pissarides, 1987), and can also be thought as a hiring/recruiting cost (Pissarides, 1986, Mortensen and Pissarides, 1994), and/or as the cost of a human resources division. Following Pissarides (1987), we assume that the vacancy cost depends on output.[6] Vacancy costs are linearly homogeneous in average (aggregate) output, $\bar{Y}$. This assumption is necessary to support an equilibrium of ongoing growth.

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[5] This is discussed further by Chatterjee and Turnovsky (2012).

[6] See Pissarides (1987), who states that "it is reasonable to assume that the cost of a vacancy is a constant fraction of output to avoid the implication that as output per job grows the cost of hiring labor becomes less and less important."

The firm's operating profit (capital earnings) is given by

$$\Pi = Y - wl^d - (r+\delta)K - m\bar{Y}v \tag{7d}$$

where δ denotes the depreciation rate of private capital. The firm's objective is to maximize the value of the firm, *V*,

$$V = \int_0^\infty (1-\tau_k)\left[F(K,l^d) - wl^d - (r+\delta)K - mv\bar{Y}\right] e^{-\int_0^t (1-\tau_k)r(z)dz} dt \tag{8}$$

by choosing the amount of capital K to rent, vacancies to post, v, and the rate of accumulating labor l^d, subject to equations (7a) – (7c) and the initial stock of labor, $l^d(0) = l_0^d$. In making its decisions, the individual firm takes the stock of aggregate private capital, $\bar{K}$, as well as average output, $\bar{Y}$, as given. Hence, from the firm's perspective, the externality X is a parameter, though with all firms being identical, in equilibrium $\bar{K} = K, \bar{Y} = Y$.

Solving the firm's optimization problem yields the first order conditions:

$$\frac{\partial Y}{\partial K} \equiv \alpha A^{-\rho}\left(\frac{Y}{K}\right)^{1+\rho} = r + \delta \tag{9a}$$

$$(1-\tau_k)m\bar{Y} = \xi\varphi \tag{9b}$$

$$\frac{(1-\tau_k)\left[(1-\alpha)(AX)^{-\rho}\left(\frac{Y}{l^d}\right)^{1+\rho} - w\right]}{\xi} + \frac{\dot{\xi}}{\xi} = (1-\tau_k)r + \zeta \tag{9c}$$

$$\lim_{t\to\infty} \xi l^d e^{-\int_0^t (1-\tau_k)r(z)dz} = 0 \tag{9d}$$

where ξ denotes the shadow price of labor or the shadow value of a filled position. Equation (9a) determines the amount of capital to be rented, given the interest rate r. Equation (9b) equates the marginal cost of vacancy to its marginal benefit. The no-arbitrage relation (9c) equates the rate of return on labor, comprising of a "dividend yield", a "capital gain", and the loss due to wage payments to the rental rate of capital, r, adjusted for job destruction. Finally, the transversality condition (9d) must hold.

The shadow value of a filled position, ξ, is a key variable from the standpoint of the firm's bargaining in determining the equilibrium wage. Solving equation (9c) for ξ, and imposing the transversality condition (9d), we obtain

$$\xi(t) = \int_t^\infty (1-\tau_k)\left[F_l(z) - w(z)\right] e^{-\int_t^z (\zeta + (1-\tau_k) r(u)) du} dz \tag{10}$$

which states that the value of a filled position equals the present value of the stream of the after-tax difference between the marginal product of labor and the wage rate, where the discount rate equals the after-tax rental rate of capital, $(1-\tau_k)r$, adjusted for the job destruction rate ζ. The number of vacancies posted is determined in macroeconomic equilibrium (see below).

2.3 Government

The government uses its revenues to finance its current expenditures, G_K, on infrastructure (public capital), K_G, the provision of the consumption good, G_C, unemployment benefits, and the interest on its outstanding debt, B. These expenditures are subject to its flow budget constraint

$$\dot{B} = rB + G_K + G_C + \sigma_u ws - \tau_\pi \Pi - \tau_k r(K+B) - \tau_c C - \tau_w wl - T \tag{11}$$

Public capital depreciates at rate δ_G and evolves according to

$$\dot{K}_G = G_K - \delta_G K_G \tag{12}$$

Since we are focusing on a growing economy, we assume that the government sets its expenditures as fractions of current output, *Y*, i. e.

$$G_K = g_K Y, \quad G_C = g_C Y. \tag{13}$$

In addition, we assume that the lump-sum taxes, *T*, received by the private sector are net of government transfers, T_Z, that are proportional to output, i.e. $T_Z = \sigma_T Y$.[7] Accordingly, using (11)

[7] Lump-sum transfers are introduced only to obtain a reasonable ratio of government expenditures to GDP in the

$$T_T \equiv T + T_Z = (g_K + g_C + \sigma_T)Y + \sigma_u ws - \tau_\pi \Pi - \tau_k r(K+B) - \tau_c C - \tau_w wl$$

represents the amount of lump-sum taxation (or transfers) necessary to finance the primary deficit and is therefore a measure of current fiscal (im)balance. In the Appendix we show how solving (11) and imposing the transversality condition, the present value quantity $V \equiv \int_0^\infty \left(T_T(u)/K_0\right) e^{-\int_0^u (1-\tau_k) r(s) ds} du$ measures the ratio of the present discounted value of the lump-sum taxes or transfers to the initial capital stock, necessary to balance the budget over time. This serves as a convenient measure of the intertemporal imbalance of the government's budget.[8]

2.4 Goods market clearance

Goods market equilibrium is obtained by combining the household's budget constraint, (1a), the firm's profits, (7d), and the government's budget constraint, (11). It requires that output is allocated to consumption, private capital accumulation, government expenditure and financing vacancy costs:

$$Y = C + \dot{K} + \delta K + G_K + G_C + m\bar{Y}v \tag{14}$$

which, using (13), and noting that in equilibrium $\bar{Y} = Y$, can be expressed as

$$\dot{K} = (1 - g_K - g_C - mv)Y - \delta K - C \tag{15}$$

Note that in macroeconomic equilibrium $l^s = l^d = l$, and (aggregate) output is given by

$$Y = A\left[\alpha K^{-\rho} + (1-\alpha)\left(K^e K_G^{1-e} l\right)^{-\rho}\right]^{-1/\rho} = AK\left[\alpha + (1-\alpha)\left(\left(\frac{K_G}{K}\right)^{1-e} l\right)^{-\rho}\right]^{-1/\rho} \tag{16}$$

2.5 Matching and wage determination

Labor markets are subject to frictions and are characterized by two-sided search. Matching vacancies with searching agents is a time-consuming process. To simplify notation, v and s also denote the

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calibrated model. As T_Z is lump-sum, it does not have any further effect on the macroeconomic equilibrium.

[8] This measure of sustainability of fiscal policy was adopted by Bruce and Turnovsky (1999). It is similar to a previous measure (expressed as a flow) proposed by Blanchard, Chouraqui, Hagemann, and Sartor (1990).

aggregate numbers of vacancies and unemployed agents, respectively. We assume a constant returns to scale matching technology of the Cobb-Douglas form[9]

$$M(v,s) = \Lambda v^{\chi} s^{1-\chi}, \quad \Lambda > 0, 0 < \chi < 1 \tag{17}$$

Thus, matches per unemployed agent can be expressed as $\phi = \Lambda(v/s)^{\chi}$, and matches per vacancy as $\varphi = \Lambda(v/s)^{\chi-1}$. Hence, although individual agents take the rates of finding a job and of filling a vacancy as given, in equilibrium they are endogenously determined. Defining $x \equiv v/s$ as the vacancy-search ratio (or vacancy-unemployment ratio), which serves as a measure of labor market tightness, we can write

$$\phi(x) = \Lambda x^{\chi}, \quad \varphi(x) = \Lambda x^{\chi-1}$$

where we see that matches per searching agent, $\phi(x)$, are an increasing function of the vacancy-search ratio, whereas matches per vacancy, , $\varphi(x)$ are a decreasing function of x.

Following Hall (2005a, b), we introduce sticky wages. This has a profound influence on the search process and hence on unemployment dynamics. We assume that the (real) wage w is formed adaptively, converging to a target wage, w_N, in accordance with

$$\dot{w} = \Omega(w_N - w) + w\frac{\dot{K}}{K}, \quad \Omega > 0 \tag{18}$$

where Ω is the speed of wage adjustment and thus a measure of wage stickiness. The expression $w \cdot \dot{K}/K$ reflects autonomous wage inflation. In steady state the average product of labor, Y/l, grows at the same rate as the capital stock, hence steady state unit labor cost remain constant when wages grow along with average labor productivity.

The target wage rate w_N results from Nash bargaining as originally set out by Diamond (1982); see also Pissarides (2000). When a household seeking a job and a firm posting a vacancy have a successful match, an economic rent equal to $q(t) + \xi(t)$ is created. For the sake of simplicity, we do not index the particular household-firm pairing i. According to Nash bargaining, this rent is shared between the household in proportion to the respective bargaining power of firms and workers.

[9] Empirical evidence supporting the Cobb-Douglas form is provided by Pissarides (2000).

Defining $0 < \pi < 1$ to be the bargaining power of workers, the problem is to maximize

$$\max_{w_N} q(t)^{\pi} \xi(t)^{1-\pi} \tag{19}$$

where $q(t)$ and $\xi(t)$ are given by (6') and (10). The bargaining solution is

$$w_N = \pi \frac{\partial Y}{\partial l} + (1-\pi)\frac{w_R}{1-\tau_w}$$

or, using the definition of the reservation wage, equation (4),

$$w_N = \pi(1-\alpha)(AX)^{-\rho}\left(\frac{Y}{l}\right)^{1+\rho} + (1-\pi)\frac{\theta C}{(1-l-s)}\frac{1+\tau_c}{1-\tau_w} \tag{20}$$

Thus, the target wage is determined as the weighted average of the firm's reservation wage (the marginal product of labor) and the worker's pre-tax reservation wage (the marginal rate of substitution of leisure for consumption), see also Shi and Wen (1997, 1999). Any wage w that is located within the bargaining set, defined by the firm's and the worker's reservation wage ($\partial Y/\partial l$ and w_R), is a Nash equilibrium.[10]

2.6 Macroeconomic equilibrium

The macroeconomic equilibrium is defined as follows (Shi and Wen (1997, 1999), Heer (2003)).

Definition. The competitive search equilibrium is a collection of decision rules $\{C, s, l, \dot{K}, \dot{B}, v, K\}$ and wages $\{w\}$ such that

1. Individual variables equal (average) aggregate variables.
2. Given factor prices, profits, and matching rates, households maximize their utility (2) subject to (1a) and (1b).
3. Given factor prices and matching rates, firms maximize the value of the firm (8) subject to (7a)-(7c).
4. Wages evolve according to (18), and profits are given by (7d).

[10] That is, we require the bargained wage to lie in the range $\partial Y/\partial l \geq w_N \geq w_R$. It is possible in response to major structural changes for the the short-run wage to occasionally lie outside this range during the transition.

5. The rental rate r clears the capital market.
6. Capital accumulation (investment) $\dot{K}$ adjusts continuously to clear the domestic goods market (15).
7. Firms do not take into account the effect of their decisions on the aggregate capital stock and hence on the externality.
8. Agents do not take into account the effect of their decisions on the matching rates ϕ and φ. In equilibrium, $\varphi v = \phi s$.
9. The government budget constraint (11) is satisfied.

Since the flows of workers in and out of unemployment are equal to each other in any symmetric equilibrium, i. e. $\phi(x)s = \varphi(x)v$, equations (1b) and (7c) coincide, implying that in equilibrium, $l^s = l^d \equiv l$.

Note that in macroeconomic equilibrium equation (9b) determines the number of vacancies posted. Because the left hand side $(1-\tau_k)m\overline{Y}$, i. e., the after-tax vacancy cost is given, an increase in the value of a filled position, ξ, requires a reduction in the rate of filling a vacancy, φ. But $\varphi(x)$ is a function of the vacancy-search ratio $x \equiv v/s$. Given unemployment, s, the number of job vacancies has to adjust accordingly to maintain equation (9b). In case of an increase in the value of a job, ξ, x has to increase, and this is achieved by a larger number of job vacancies, v. Intuitively, a higher value of a filled position signals higher profits and induces firms to post more positions.

The derivation of the macrodynamic equilibrium involves substantial technical detail, and accordingly is relegated to the Appendix.

3. The benchmark economy

Because of the model's complexity, to study the long-run equilibrium and the associated transitional dynamics, we resort to numerical simulations. To do so we calibrate the model, using the parameter values shown in Table 1.A, which reflect a time unit of one year. The initial steady-state equilibrium of the corresponding benchmark economy are reported in Table 1.B, where the choice of parameters reflect some key features of European countries. We should note, however, that European economies are in many respects quite diverse, so that in several instances parameter values are deteremined as averages across economies.[11]

The rate of time preference, $\beta = 0.035$, and is non-controversial. The preference parameter $\varepsilon = -0.5$ and corresponds to an intertemporal elasticity of substitution $1/(1-\varepsilon)$ of 2/3. The elasticity of leisure, θ, is the key determinant of the equilibrium labor-leisure allocation and setting $\theta = 1.75$ yields an equilibrium allocation of time of approximately 73.5% to leisure, 24.3% to work, and around 2.1% to job search, generally consistent with empirical evidence for Europe.[12]

The elasticity of substitution in production between labor and capital, $1/(1+\rho)$ is set equal to 0.75 (i.e. $\rho = 1/3$), reflecting recent empirical evidence.[13] The total factor productivity (TFP) parameter $A = 1.435$ to yield a balanced growth rate of 1.00%.[14] The productive elasticity of private capital, $\alpha = 0.4$, yields a ratio of private capital to output of 2.38. The choice of the parameter e, determining the share of private capital in the production externality, is set at $e = 0.6$. The reason for this choice is to yield a productive elasticity for public capital that falls within the range of empirical estimates summarized by Bom and Ligthart (2014).[15]

The labor market parameters are chosen so as to replicate an empirically reasonable characterization of the European labor market. As a benchmark, the bargaining power of workers and firms is assumed to be equal, therefore we choose $\pi = 0.5$. Empirical evidence on the value of χ, i.e., the elasticity of the matching function with respect to vacancies is mixed; estimates range between 0.331 and 0.842, see Borowczyk-Martins et al. (2013) and the literature cited therein.[16] Therefore, we choose an intermediate value and set χ equal to 0.5. The vacancy-unemployment ratio $x = v/s$ is calibrated to a value of 0.2, meaning that for each open position there are five

[11] In a previous version of this paper we have also calibrated the model to reflect the US economy more closely. The main differences involve (i) different parameterization of the labor market, and (ii) substantially different tax rates. Despite these differences, the qualitative conclusions based on the European parameterization continue to hold.

[12] Note that the majority of Western European countries have lower average weekly working hours than do the US, see, e. g., OECD.Stat, https://stats.oecd.org, accessed 01.20.2016.

[13] Recently, Papageorgiou (2008), using a new empirical methodology and a new data set, estimated an elasticity of substitution of roughly 0.7. Other recent studies suggesting that the Cobb-Douglas function overstates the elasticity of substitution include Antras (2004), and Klump et al. (2007).

[14] This equilibrium growth rate is rather low. However, it should be borne in mind that the analysis excludes the accumulation of human capital which has historically been shown to be a major source of economic growth.

[15] For further discussion of this choice see Chatterjee and Turnovsky (2012).

[16] Petrongolo and Pissarides (2001) suggest 0.3 to 0.5 as a plausible range for the elasticity with respect to vacancies, and Pissarides (2009) applies a value of 0.5 for the US.

unemployed job seekers, consistent with European experience.[17] Given $x = 0.2$ and $\chi = 0.5$ we calculate the matching productivity parameter Λ as 1.789 to yield an average duration of unemployment, $1/\phi(x)$, of 1.25 years, roughly resembling average European numbers.[18] The vacancy cost parameter $m = 2.825$ and the job separation rate of $\zeta = 0.0696$ are chosen in a way to obtain a steady-state unemployment rate of 8% and $x = 0.2$.[19] The implied ratio of vacancy costs to GDP is roughly 1% and corresponds to the values in Andolfatto (1996) and Sedláček (2014).

The asymptotic speed of convergence is highly sensitive to the speed of wage adjustment, and setting $\Omega = 0.05$ yields a very plausible rate of convergence of around 3.2%. The initial private capital stock, K_0, is normalized to unity, and the initial stock of government debt is set to $B_0 = 0.262$ resulting in a debt-GDP ratio of 62.2, reflecting the European Union (27 member countries) in 2008 (see AMECO data base).

The benchmark fiscal policy parameters are chosen as follows: The share of public investment in GDP, g_K, is set to 0.05, and the share of government consumption in GDP, g_C, is set to 0.16. In addition, the European Union allocates an average of nearly 29% of GDP on "social protection expenditures"; see Eurostat (2016). These expenditures include unemployment benefits, benefits for old age and survivors, expenditures for sickness and disability, for families and children, and housing and social exclusion. Part of these benefits can be categorized as a form of government consumption, whereas the other parts represent pure transfers to households. Accordingly, we set the share of lump-sum transfers from the government equal to $\sigma_T = 0.20$. Together with an unemployment benefit rate equal to $\sigma_u = 0.5$ (reflecting a reasonable European average), the total share of government expenditures in GDP is roughly 0.44, and comes close to European countries'

[17] The unemployment-vacancy ratio for European countries varies substantially, see European Commission (2014), chart5. We chose an intermediate value of 0.2.

[18] See OECD.Stat, https://stats.oecd.org, accessed 01.11.2016

[19] Empirical evidence on job separation rates is mixed. The job separation rate in our calibration 6.96% at *annual rates* lies within the range of empirical estimates. While it is lower than estimates of Hobijn and Şahin (2009) suggest, it is perfectly in line with other findings. Elsby et al. (2013) find in continental Europe *monthly* inflow rates from employment to unemployment range on average between 0.5% and 1% much lower than in Anglo-Saxon countries, where this rate is higher than 1.5%. Of course the inflow rate into unemployment is not the same as the job separation rate, but nonetheless the inflow rate and its differences between Europe and the Anglo-Saxon countries is a rough indicator for a low job destruction rate. Gómez-Savaldor et al. (2004) find very low job destruction rates in Europe; see Table 2, p. 476, where they report an annual rate of 3.7% for the Euro Area. Foster et al. (2006), Table 1, report an annual gross flow job destruction rate for the US of 8.55% for the period 1994-1998. Given that European labor markets are less flexible than in the US, our choice of a somewhat lower job separation rate seems reasonable.

values in the years preceeding the crisis (see IMF Fiscal Monitor April 2015, Table A6). [20]

The tax rates on profits, capital income, labor income, and consumption approximate European rates and are chosen as in García-Peñalosa and Turnovsky (2011), originally drawn from McDaniel (2007). To maintain a debt-GDP ratio of roughly 0.62, the government has to set the lump-sum tax-GDP ratio equal to $T_T / Y = 0.04975$.

Setting $g_K = 0.05$ and the depreciation rates on private and public capital both equal to 0.05 implies an equilibrium ratio of public to private capital $K_G / K = 0.35$, the ratio of of total capital $K + K_G$ to output equals 3.21 and the ratio of private consumption to output ratio of 0.635, all of which reflect plausible averages of European economies.[21]

4. The relationship between growth and unemployment

To address the long-run relationship between growth and unemployment it is instructive to focus on equation (A.18c) in the Appendix:

$$\tilde{\psi} = \frac{1}{1-\varepsilon(1+\eta)}\left[(1-\tau_k)\left(\alpha A^{-\rho}\tilde{y}^{1+\rho} - \delta\right) - \beta\right] \tag{21}$$

This is a version of the standard relationship expressing the balanced growth rate as the difference between the after-tax net rate of return on capital and the rate of time preference, multiplied by the intertemporal elasticity of substitution. Apart from the parameters appearing explicitly in (21) the key determinant of the long-run equilibrium growth rate is the steady-state output-private capital ratio, $\tilde{y} \equiv (\widetilde{Y / K})$.

The relationship between growth and unemployment is an indirect one. The unemployment rate is defined as $u(t) = s(t)/[s(t) + l(t)]$. In the short run, because of the sluggish adjustment of labor, the unemployment rate is solely determined by search s, which is itself a function of the reservation wage, the marginal utility of wealth, labor, government consumption and the

[20] "Net replacement rates" (i.e. net unemployment benefits) vary substantially across European countries; in 2010 they ranged between 92% in Portugal and 12% in the UK. In many countries they where roughly 60%; see Esser et al. (2013), figure 3. Given that the duration of unemployment benefits varies substantially, too (see Esser et al. (2013), figure 4), and that the model's unemployment subsidy refers to a annual basis, a value of 0.5 is a reasonable approximation. Our numerical simulations are robust with respect to the specific benchmark values of g_C and σ_T.

[21] See World Bank, http://data.worldbank.org/indicator/NE.CON.PETC.ZS, accessed 06.13.2015.

consumption tax rate, see equation (5a). For policies or shocks increasing the growth rate and thus the time path of the effective net wage $(1-\tau_w-\sigma_u)w(t)$, the value of a job [see equation (6'')] and ultimately the reservation wage will increase – viewed in isolation – households' instantaneous search, raising the instantaneous unemployment rate.

During any transition, the evolution of the unemployment rate will reflect those of search and vacancies, [and in turn, these affect matching and the job finding rate $\phi(t)$], and how these eventually influence the dynamics of labor, l. As is seen from the examples in Figs. 1-6, the transitional dynamics of the unemployment rate closely reflects that of search, and its resemblance (or lack thereof) to that of output growth depends critically upon the underlying change to which they are both responding.

In steady state, however, the unemployment rate is given by[22]

$$\tilde{u} = \frac{\zeta}{\phi(\tilde{x}) + \zeta} \tag{22}$$

It depends only on the structural parameters job separation rate, ζ, and the matching function parameters χ, Λ, which enters the job finding rate $\phi(x) = \Lambda x^{\chi}$. Hence, any change in the long-run unemployment rate must occur either through a change in labor market tightness (the vacancy-unemployment ratio) $\tilde{x}$ or in the exogenous job destruction rate ζ. The higher $\tilde{x}$, the higher the job finding rate $\phi(\tilde{x})$ and the lower the unemployment rate. Similarily, a higher job destruction rate leads to a higher unemployment rate, both directly and indirectly via a lower vacancy-unemployment ratio. A higher balanced growth rate, achieved with a higher output-capital ratio $\tilde{y}$ (see equation (21)) affects steady-state unemployment only to the extent that steady-state labor market tightness $\tilde{x}$ changes. The long-run tradeoff between growth and unemployment thus revolves around the relationship between $\tilde{y}$ and $\tilde{x}$.

Table 2 summarizes the long-run growth-unemployment tradeoffs corresponding to six structural differences. The first three compare the tradoffs corresponding to structural differences

[22] This follows from setting $\dot{l} = 0$ in equation (1b), solving for $s = l\zeta / \phi$ and inserting this in the definition of the unemployment rate $u = s/(l+s)$.

pertaining to the productivity characteristics to those in the benchmark economy. These include (i) higher TFP; (ii) lower productivity of private capital; (iii) larger production externality. In all cases the responses are reflected in substantial changes in the growth rate, leading to significant welfare changes, but with negligible effects on unemployment. The latter three differences focus on structural properties of the labor market. These include: (i) less union power; (ii) more flexible labor market; (iii) less generous unemployment. In all cases the effects on the unemployment rate are significant, while the impact on the growth rate and on welfare are negligible. Overall, these simulations confirm the absence of any significant long-run tradeoff between a higher balanced growth rate and the unemployment rate, as well as confirming that the relationship between $\tilde{y}$ and $\tilde{x}$ is indeed very weak.

5. Effects of a permanent increase in TFP

We now turn to the transitional dynamics, beginning by considering the effects of a permanent 5% increase in TFP. Table 3 reports the impact reactions of some key economic variables and the welfare changes due to the TFP shock, and Fig.1 illustrates the time paths of some key variables and growth rates.

On impact, the 5% increase in TFP raises output and the marginal products of labor and capital by 5%. This is because both inputs are sluggish and cannot adjust instantaneously at time $t = 0$ when the productivity increase occurs. The sluggishness of the wage adjustment process ensures that the wage rate also remains unchanged at that instant. The positive TFP shock introduces a positive wealth effect, reducing the marginal utility of wealth by around 8.6%, causing households to increase consumption by 5.06%.

From the firm's standpoint, the increase in the marginal product of labor, together with the economy's enhanced growth prospect, increases the value of a filled position [see equation (10)] by 84%, inducing firms to increase job vacancies sharply by 82%. This causes the equilibrium job finding rate, ϕ, to rise by 75%, and to decrease the average duration of unemployment, $1/\phi$, to 0.71 years. With sluggish wages, and an increased probability of finding a job, the shadow price of employment declines [see equation (6")] and thus the value of a job from the household's perspective is reduced by around 32% on impact. Overall, the positive effect of the higher job finding rate on the reservation wage outweighs the reduced value of a job, and on impact the reservation wage rises by roughly 3.8% [see equation (5b)]. However, the higher reservation wage and increased government consumption affect search less than does the reduced marginal utility of wealth [see equation (5a)]. Hence, households immediately reduce their search efforts by 0.86 percentage points [from 2.12% of their time allocation to 1.26%]. Intuitively, the higher reservation wage makes working, and thus searching for a job, more attractive, whereas the lower marginal utility of wealth decreases incentives to work and therefore to search for a job. With employment being initially fixed, as search declines the unemployment rate immediately drops to 4.9%.[23] Increased private consumption and public consumption [the latter tied to GDP via (13)] and less search (i.e. more leisure) all increase the household's utility, resulting in an instantaneous welfare gain of roughly 6.78%.[24]

Immediately following the GDP's initial increase of 5%, the instantaneous growth rate of GDP jumps dramatically from its prior equilibrium rate of 1% to 4.33%. As Fig. 1(ii) suggests, this is accomplished primarily by a rapid growth in employment, resulting from the fact that as firms post more vacancies, searching households encounter more open positions. At the same time, the increases in private consumption, government consumption, and government investment [the latter two being tied to GDP via the spending rules (13)], as well as increased vacancy costs outweigh the GDP increase, and on impact the rate of private capital accumulation actually declines slightly from 1% to 0.86%. The growth rate of public capital is determined by $\psi_{K_G} = g_K y / k - \delta_G$ and increases slightly to 1.31%, reflecting the initial rise in the y/k ratio resulting from the productivity increase.

During the earliest phase of the transition, the increased employment raises the marginal product of capital, leading to an increase in the rate of capital accumulation. As jobs get filled, the growth rate of employment declines, causing the growth rate of output to decline as well. At the

[23] We should keep in mind that the unemployment rate generated by the model does not necessarily correspond with the officially reported rate, because in the model, unemployment is defined as searching for a job, whereas in official statistics, several criteria have to be fulfilled to be counted as unemployed.

[24] The change in the welfare measure (2) is expressed in terms of equivalent variations in the permanent flow of income necessary to equate the initial levels of welfare to what they would be following the shock and policies, both in the short run and in the long run.

same time, the higher employment *level* reduces the incentive for households to search – see equation (5a) – reflecting a desire to maintain their leisure time. But as the job filling rate declines over time, the product $\phi(t)q(t)$, [i.e. the expected value of a job] decreases, and total search declines. More employment and less search result in a sharp decrease in the unemployment rate.

After about two years, the growth rate of output declines to around 2.4%, and the unemployment rate drops to 1%. Increased employment reduces the marginal product of labor, which together with relatively more rapidly growing wages (compared to what they would be in absence of the TFP increase) causes firms to post fewer jobs. On the other hand, households' incentives to search for a job increase. Hence, labor market tightness decreases, fewer open positions are filled, and employment declines. Less employment and more search cause the unemployment rate to rise. But with wages adjusting slowly, the labor market variables – employment, search, and unemployment – evolve only gradually over time.

Output growth continues to fall, monotonically. The rapid initial increase in employment, followed by the steady decline implies a non-monotonic adjustment in the growth rate of private capital, while with $y(t)/k(t)$ almost constant over time, the growth rate of public capital adjusts to new equilibrium level virtually instantaneously.

The increase in TFP also impacts significantly on the dynamics of the debt-GDP ratio. The 5% increase in GDP immediately reduces the debt-GDP ratio by 5%. This initial increase in productive capacity, coupled with the higher growth rate of output, continuously raises GDP. This increases government expenditures, but also tax revenues, changing the deficit less than proportionally to output, lowering debt accumulation and causing the debt-GDP ratio to decline steadily over time. That this occurs at a gradual rate is a reflection of the facts that (i) most of the tax revenues are obtained from labor income and (ii) with sluggish wages this component adjusts only slowly over time.

Eventually, the economy converges to a new steady state, in which the unemployment rate is marginally higher than its initial equilibrium rate [8.013% vs. 8.008%], with the growth rate increased by around 0.286 percentage points. This suggests an extremely weak long-run trade-off between unemployment and GDP growth. However, the short-run trade-offs are much more dramatic, and are characterized by profound swings. On impact, an *increase* in the GDP growth rate of around 3.33 percentage points is accompanied by a *reduction* in unemployment of 3.1 percentage points. Over the next two years, GDP growth *declines* by around 1.8 percentage points, while unemployment *declines* by a further 4 percentage points. Thereafter, unemployment gradually *increases* to its new equilibrium, accompanied by a further gradual *decline* in the output growth rate. The time paths followed by consumption and leisure during the transition imply that the sustained 5% increase in TFP increases intertemporal welfare by approximately 26.4%.

6. Fiscal expansion and the growth-unemployment tradeoffs

Table 4 summarizes the short-run and long-run tradeoffs between growth and unemployment in response to five forms of expansionary fiscal policy – increases in the two forms of government expenditure, g_K, g_C, and decreases in the three tax rates, τ_k, τ_w, τ_c. To preserve comparability between these alternative scenarios, in each case the corresponding change is normalized so that the initial fiscal stimulus is equivalent to 1% of GDP. The corresponding transitional paths are illustrated in Figs. 2-6. In all cases we assume that the policy is deficit financed, so that the consequences for the long-run fiscal imbalance become a pertinent issue.

6.1 Increase in public investment (infrastructure) g_K

An increase in the rate of public investment impinges on the economy in an analogous way to the productivity increase, namely through its impact on productive capacity, though with the following key difference. Whereas the increase in TFP immediately increases output proportionately, an increase in public investment, by impacting via the accumulation of public capital, K_G, takes effect only gradually. In the short run, only the growth rate of output is stimulated, while its level remains unchanged. The qualitative dynamics of the various growth rates and unemployment rate, as illustrated in Fig. 2 are generally similar to those following the TFP increase, although they are more gradual. This is a reflection of the fact that since it takes time to accumulate the additional public capital and for the enhanced productive capacity to take effect, the early stages of public investment are less potent than those of the 5% TFP increase. Accordingly, the immediate impact is that the output growth rate increases to 2.47%, rather than to 4.33%, while the initial increase in employment and decline in unemployment takes place over around 12 years. Instead of declining monotonically, output growth, following its initial decline, starts to increase after 2 years, reflecting the fact that by that time sufficient public capital will have accumulated to dominate the (fixed) 5% productivity increase. Indeed, over time, sufficient public capital will have been accumulated to enable the economy to eventually sustain a long-run growth rate of 1.44%, exceeding the 1.29% long-run growth rate resulting from the 5% TFP increase.

Despite the higher long-run growth rate, the long-run welfare gain from the increase in government investment is 14.28%, considerably less than that resulting from the TFP increase. This is a consequence of the more moderate improved economic performance during the more heavily weighted early phases of the transition. Also, the public investment has consequences for the government's fiscal balance. While the added productive capacity reduces the debt to output ratio, the additional government investment is not self-financing. Long-run fiscal imbalance increases by 5.32%, although this is a smaller increase than for other fiscal expansions of comparable magnitude.

6.2 Increase in government consumption expenditure g_C

Increasing government consumption expenditures by 1% of GDP from 0.16 to 0.17 generates very different dynamic adjustment paths for all key variables, implying very different intertemporal tradeoffs between unemployment and growth, see Fig. 3. Knowing that the increased government consumption will eventually lead to greater fiscal imbalance and therefore more taxes and less wealth, the marginal utility of wealth increases by 1.17%, inducing the household to decrease private consumption by 0.85%. Both the wealth effect and the increased government consumption encourage search, which increases by 0.54 percentage points of time, causing an immediate increase in the unemployment rate of 1.83 percentage points to 9.84%. Since the increase in government consumption exceeds the decrease in private consumption, while output remains fixed instaneously, goods market clearance is maintained by a small decrease in the rate of private investment, which declines by 0.22 percentage points. The decrease in leisure and the change in the composition of household's consumption (private versus public) yields an instantaneous welfare loss of 0.495%.

The increase in search reduces labor market tightness, making it easier for firms to hire workers, and this increases the growth of employment, thereby the growth rate of output to 1.74%. As this occurs, the marginal product of labor declines and after about one year most of the vacancies have been filled (v drops to 0.40) causing further employment to increase at a much slower rate. [25] Economic growth declines and eventually the economy converges to a new steady state with a slightly higher growth rate than the benchmark (1.06% vs. 1.00%) accompanied by a fractionally higher unemployment rate (8.06% vs. 8.01%). The policy leads to a 1.07% increase in intertemporal welfare, associated with a 27.3% deterioration in the intertemporal fiscal balance.

As for government investment, government consumption expenditure is associated with essentially no long-run tradeoffs between output growth and unemployment. During the transition, however, both move closely in tandem. On the implementation of an increase in government consumption, both output growth and unemployment increase substantially. Thereafter, they both decline monotonically, first at a rapid rate, which is then moderated after about two years.

6.3 Decrease in the tax rate on capital income, τ_K

One way to decrease tax revenues by 1% of GDP and thereby generate a short-run fiscal stimulus of that amount is to reduce the tax rate on capital income by 6 percentage points to $\tau_k = 0.1100$.

The immediate effect of the tax reduction is to increase the after-tax return to capital $(1-\tau_K)r$, thereby increasing the incentive to save and to accumulate wealth. Consequently, the marginal utility of wealth, λ, increases by 1.49%, inducing the representative household to reduce private consumption by 0.67% and to increase its time allocation to job search by 0.39 percentage points. This results in an instantaneous increase in the unemployment rate of 1.34 percentage points, raising it to 9.35%. With employment and capital constrained to evolve sluggishly, output does not change on impact, which in turn means that the rate of public investment remains unchanged as well. Accordingly, in order for goods market equilibrium to be maintained the reduction in private consumption (the increase in private saving) must be met by more private investment; the growth rate of private capital increases from 1% to 1.24%. More search impacts the labor market positively,

[25] Note that here v is measured as fraction of total time, which is normalized to 1.

as more persons seek open positions, and leads to increased employment and a decline in unemployment. Together with more rapid capital accumulation, the instantaneous growth rate of output increases by 0.48 percentage points to 1.48%. The increased search activity (i.e. less leisure) together with the immediate decline in private consumption reduces the household's utility, resulting in an instantaneous welfare loss of around 1.28%.

As Fig. 4 reveals, after about two years the initial increase in employment (decrease in unemployment) is reversed, just as occurred following the TFP increase (see Fig. 1). But in this case due to the more rapidly growing private capital resulting from the reduction in τ_k, this reversal is only temporary. The growing capital stock (both private and public) raises the marginal product of labor inducing firms to resume hiring more labor, thereby reducing the rate of unemployment.

As in previous cases, the reduction in the tax on capital income is associated with significant tradeoffs between output growth and unemployment. Whereas on impact both increase substantially, during the transition output growth declines steadily, while unemployment increases during early phases of the transition, and declines thereafter. In the long run, the consequence of increased private capital accumulation is a substantially higher balanced growth rate (1.19%), accompanied by a slightly higher unemployment rate of 8.035% - a somewhat muted version of the tradeoff associated with an equivalent increase in government investment.

Finally, the higher growth path the economy is following during the transition has a strong positive effect on intertemporal welfare and results in a welfare gain of 3.69%. On the fiscal side, however, the lower tax rate leads to a deterioration of the intertemporal fiscal imbalance of 25.1%.

6.4 Decrease in the tax rate on labor income, τ_w

An alternative way to decrease government's tax revenues by 1% of GDP is to reduce the tax rate on labor income to $\tau_w = 0.3443$.

The lower tax on labor income makes working more attractive. It raises the value of a job, q (23.94%), and the after-tax reservation wage, w_R (2.05%), and reduces the marginal utility of wealth by 0.67%. The increase in the after-tax reservation wage causes the agent to increase his search time [see equation, 5a], which increases by 0.73 percentage points.[26] This causes the unemployment rate to jump up by 2.47 percentage points to 10.48%. On the other hand, the reduced marginal utility of wealth induces the household to increase consumption by 1.04%. The increased search time means less leisure, the effect of which on the agent's utility outweighs the effect of more consumption, causing an instantaneous welfare loss of 0.57%. To clear the goods market with output fixed in the short run, the increase in private consumption must be offset by reduced private investment, causing the growth rate of private capital to decline by 0.31 percentage points.

The increase in consumption demand induces firms to increase their job postings, leading to an immediate growth in employment and increasing the instantaneous growth of output to 2.12%. As positions get filled, the marginal product of labor declines and the growth rate of employment increases at a more gradual rate, eventually converging to a higher long-run employment rate, see Fig. 5. Along this transitional path capital becomes more productive, causing the growth rate of capital to increase, and eventually to converge along with the declining growth rate of output to a common long-run rate of 1.09%, which is slightly above that of initial equilibrium. During this transition the growth rate of output and the unemployment rate move together. After both increasing on impact, they both decline monotonically. The unemployment rate eventually converges to around 7.77%, which lies 0.24 percentage points below its original equilibrium.

Thus, in contrast to the reduction in capital income tax, the reduction in the labor income tax resulting in a tax cut of 1% of GDP leads to a slight increase in the long-run growth rate accompanied by a more substantial reduction in the long-run rate of unemployment. The resulting intertemporal welfare gains from the cut in the labor income tax is 1.89%, while the deterioration in the fiscal imbalance is 25.4%. The welfare gain is less than for the equivalent capital income tax cut and reflects the more modest unemployment-growth tradeoff involved.

6.5 Decrease in the tax rate on consumption, τ_C

A final way that the government can reduce its tax revenues by 1% of GDP is to reduce the

[26] The effect of the increase in the after-tax reservation wage on search outweighs the effect of the decline in marginal utility of wealth.

consumption tax from 21% to 19.32%. Using the optimality conditions for households one can show that this impacts the equilibrium in essentially the same way as does an increase in government consumption expenditure, generating identical dynamics and reflecting similar mechanisms (cf. Fig. 6 and Fig. 3).

The initial responses are as follows: While one effect of the lower consumption tax is to raise the marginal utility of wealth by 1%, and thereby reduce consumption, this is more than offset by its direct incentive to stimulate consumption and on balance the household increases consumption by 0.65%. At the same time, both the increase in λ and the decline in τ_c induce the household to increase their allocation of time to search, increasing it by 0.47 percentage points, thereby immediately increasing the unemployment rate by 1.62 percentage points to 9.63%. With output fixed instantaneously the increase in private consumption is accommodated by a decline in the growth of private capital by 0.20 percentage points. The decrease in leisure resulting from the increase in search more than offsets the benefits of increased private consumption and yields an instantaneous welfare loss of 0.389%.

The transition toward the balanced growth path resembles that following an increase in government consumption. The economy ends up with a slightly higher steady-state growth rate (1.056%) and a marginally higher unemployment rate of 8.051%. The policy generates a long-run welfare gain of 0.983%, and a deterioration in the intertemporal fiscal imbalance of 24.1%.

7. Some policy implications

Comparing the responses to the 5 normalized fiscal expansions summarized in Table 4 and illustrated in Figs. 2-6 reveals several short-run and long-run tradeoffs between key macroeconomic objectives. In the short run, increasing government investment by 1% of GDP is the best from the standpoint of reducing unemployment and stimulating the growth rate of output. It is also the only policy to improve welfare, albeit only slightly by 0.312%. The equivalent reduction in the capital income tax has essentially the opposite effects, raising unemployment, having a much weaker impact on the growth rate of output, resulting in the biggest short-run welfare loss of 1.277%. However, by stimulating private investment it generates much more positive long-run effects, improving intertemporal welfare by 3.689%. Nevertheless, despite being associated with a marginally higher long-run unemployment rate, increasing the rate of government investment, remains superior, yielding a 14.28% increase in intertemporal welfare, mainly due to the substantially higher long-run growth rate. In addition, while all 5 forms of fiscal expansions lead to a deterioration in the long-run fiscal imbalance, increasing government investment has the least adverse effect. Overall, the results in Table 4 suggest that increasing government investment from 5% to 6% of GDP is overwhelmingly the prefered pure expansionary fiscal policy.

The responses reported in Table 4 are relevant to the recent policy discussions regarding the appropriate responses in the aftermath of the great recession of 2008. In this regard, there are two competing views. The first proposed fiscal austerity, fearing that the continued growth of public debt resulting from the initial expansionary policies introduced to mitigate the original downturn could be unsustainable. Accordingly, in 2011 governments in the US and Europe began implementing contractionary fiscal policies known as "fiscal consolidation".[27] Most of the concern was to minimize the short-run output losses, resulting from these contractionary policies. In this regard, Alesina et al. (2015) find that tax increases of 1% of GDP cause much larger losses in short-run GDP than do comparable expenditure cuts, the effects of which are mild. While our focus is on growth rates, and longer-run consequences, our conclusions in this regard are consistent with those of Alesina et al. (2015).[28]

Raising the tax on labor income from 36% to 37.52% or the tax on capital income from 17% to 22.95% are two alternative ways of increasing tax revenues by 1% of GDP. From our simulations we find that these two alternatives reduce the average growth rate of income over the first three years following implementation, doing so by 0.14 and 0.20 percentage points, respectively. Comparable reductions in social public expenditures – in this case reducing government consumption expenditure from 16% to 15% and unemployment benefits from 50% to 43.05% – lead

[27] These policies were a combination of expenditure cuts and tax increases and varied extensively across countries; see e.g. Alesina et al. (2015). Over the period 2011-2013 the annual expenditure cuts and tax increases averaged around 0.93% and 0.70% of GDP respectively.

[28] Other studies lead to somewhat different conclusions. For example, our results tend to contradict Alesina and Ardagna's (2010) finding that tax cuts are more expansionary than are spending increases.

to smaller reductions in the growth rate of 0.10 and 0.05 percentage points respectively.[29] These relative impacts are also reflected in the corresponding long-run welfare losses. Thus, the increases in τ_w, τ_k reduce welfare by 1.31% and 2.96% respectively, while for the comparable expenditure reductions the welfare losses are reduced to 1.01% and 0.04%.

An alternative position is that the government should respond to the recession by adopting an expansionary fiscal policy, and in particular by increasing public investment. Such a view is associated with liberal economists such as Paul Krugman and Joseph Stiglitz, among others.[30] The strong positive impacts of public investment as evidenced in Table 4 and in Fig. 2 are clearly supportive of this position. Accepting this assessment then raises the question of how it should be financed. Table 5 compares the short-run and long-run responses of certain key variables under the benchmark case of debt financing with alternative modes of financing which maintain the current deficit unchanged. Thus, for example, if the increase in government investment from 5% to 6% is matched by raising the tax on capital income from 17% to 20.91% this will maintain the current government deficit in balance.

In all cases, the short-run responses are characterized by an increase in the growth rate of output accompanied by a reduction in the unemployment rate, with a direct tradeoff between the magnitudes of the respective adjustments. Financing the 1% of GDP increase in government investment by raising τ_k to 20.91% yields the largest short-run welfare gains, increasing them by 1.24%. This is accomplished by initially diverting output to current consumption and reducing investment close to zero, $(\psi_K(0) = 0.066\%)$. However, this has adverse long-run consequences, yielding the smallest intertemporal welfare gains.

Comparison of the two parts of Table 5 reveals sharp contrasts between the short-run and long-run preferred modes of finance. It is seen that financing the increase in g_k by raising τ_w to 36.72% yields the largest intertemporal welfare gains, despite the fact that it leads to the highest steady-state rate of unemployment. As evident from Fig. 7, this is a reflection of the fact that during the early phase of the transition unemployment remains very low while at the same time the growth

[29] Reducing government investment from 5% to 4% reduces the output growth rate by 0.28 percentage points, but this was not considered by Alesina et al. (2015).
[30] Much of their writings on this issue appear in OpEd articles appearing in various news outlets.

rate is increasing steadily and that with time-discounting this positive aspect of the transition dominates overall welfare. All four of the compensated increases in government investment reduce the intertemporal fiscal imbalance, although these involve tradeoffs with the welfare gains. Thus, for example, while financing the additional public investment by raising τ_k to 20.91% yields the smallest welfare gains (13.79%) it has the greatest impact on reducing the fiscal imbalance. Finally, the last line of Table 5.B illustrates how a combination of reducing the tax on labor income ($\tau_w = 0.309$) coupled with an increase in the consumption tax ($\tau_c = 0.290$) can raise the long-run growth rate and improve welfare, while reducing long-rate unemployment and the government's intertemporal fiscal imbalance.

8. Conclusions

This paper has introduced search unemployment and wage bargaining into an endogenous growth model in order to examine the relationship between growth and unemployment. Our analysis has yielded two main sets of insights and conclusions on this important issue. First, the long-run tradeoffs between unemployment and growth are weak. This is because long-run unemployment is driven by the ratio of vacancies to search (labor market tightness) while long-run growth is determined by the output-capital ratio, with the link between these two endogenous variables being very weak. Thus, structural characteristics that impinge on the productive capacity are reflected in the growth rate and have little impact on unemployment, while structural characteristics that impact on the labor market have little impact on the growth rate. In contrast, the short-run tradeoffs between output growth and unemployment are much stronger, and the nature of their comovement – whether positive or negative – varies along the transitional path and depends upon the specific structural change. These characterstics are important and help explain the diverse range of empirical relationships between unemployment and growth. In addition we find that the growth rate tends to converge more rapidly than does the unemployment rate, which is consistent with the more sluggish adjustment of labor markets in the aftermath of the great recession.

The second set of issues concerns the consequences of the growth-unemployment nexus for fiscal policy. As a general proposition we find that fiscal expansions, taking the form of reduced distortionary tax rates, all lead to substantial increases in both the short-run growth rate and unemployment, which are dramatically reduced over time. Our analysis also provides insights into the recent debates of whether a contractionary or an expansionary fiscal policy is more appropriate to deal with the debt built up in the initial response to the recent financial crisis. We come down firmly on the side of the latter, strongly favoring an increase in government investment. Indeed we can show that by financing the government investment by an appropriate combination of a higher consumption tax coupled with a lower tax on labor income can achieve a higher long-run growth rate coupled with a lower long-run unemployment rate, while at the same time increasing intertemporal welfare and reducing the government's intertemporal fiscal imbalance.

Table 1.A: The Benchmark Economy

Preference parameters	$\beta = 0.035,\ \varepsilon = -0.5,\ \theta = 1.75,\ \eta = 0.25$
Production parameters	$\overline{A} = 1.435, \alpha = 0.4, e = 0.6, \rho = 1/3, \delta = 0.05, \delta_G = 0.05$
Labor market parameters	$\zeta = 0.0696,\ \pi = 0.5,\ \ \chi = 0.5,\ \Lambda = 1.789,\ m = 2.825,\ \Omega = 0.05$
Initial conditions	$K_0 = 1,\ B_0 = 0.262$
Expenditure parameters	$g_K = 0.05,\ g_C = 0.16,\ \sigma_T = 0.20, \sigma_u = 0.5$
Tax rates	$\tau_\pi = \tau_k = 0.17, \tau_w = 0.36,\ \tau_c = 0.21$

Table 1.B: Initial Equilibrium of Benchmark Economy

u (%)	Dur u	s	x	l	L	K/Y	C/Y	K_G/K	B/Y	ψ (%)
8.00	1.25	2.12	20.0	24.3	73.5	2.38	0.635	0.350	0.622	1.00

Notes: u = unemployment rate in percent of labor force $l+s$, Duration of unemployment Dur u is measured in years, Unemployment (search) s, Labor l and Leisure L are denoted in percent of total time, and the equilibrium growth rate ψ are measured in percent.

Table 2: Steady-State Structural Growth-Unemployment Tradeoff

	$\tilde{s}$ (%)	$\tilde{l}$ (%)	$\tilde{L}$ (%)	$\tilde{x}$	$\tilde{y}$	$\tilde{u}$ (%)	$\tilde{\psi}$ (%)	$\Delta\tilde{W}$ (%)
Benchmark $A = 1.435$, $\alpha = 0.4$, $\nu = 0.6$ $\pi = 0.5$, $\Lambda = 1.789$, $\sigma_u = 0.50$	2.12	24.35	73.53	0.200	0.421	8.008	1.006	
5% Higher TFP $A = 1.507$	2.12	24.33	73.56	0.199	0.442	8.013	1.292	12.45
Lower productivity of capital $\alpha = 0.35$	2.11	24.78	73.11	0.208	0.409	7.863	0.109	-21.96
Larger capital externality $\nu = 0.70$	2.12	24.24	73.64	0.198	0.451	8.042	1.559	21.72
Less union power $\pi = 0.40$	1.73	24.49	73.78	0.303	0.423	6.604	1.036	1.21
More flexible labor market $\Lambda = 2.0$	1.89	24.46	73.64	0.202	0.422	7.188	1.031	1.25
Less generous unemployment $\sigma_u = 0.40$	1.59	24.27	74.14	0.351	0.420	6.160	0.989	0.04

Table 3: Dynamic Responses to 5% Increase in TFP

	s (%)	l (%)	L (%)	x	y	u (%)	ψ_y (%)	ψ_k (%)	ΔW (%)
Benchmark $A = 1.435$, $\alpha = 0.4$, $\nu = 0.6$ $\pi = 0.5$, $\Lambda = 1.789$, $\sigma_u = 0.50$	2.12	24.35	73.53	0.200	0.421	8.008	1.006	1.006	-
Instantaneous response	1.26	24.35	74.40	0.613	0.442	4.901	4.330	0.857	6.78
2 year response	0.27	25.00	74.73	0.566	0.451	1.062	2.394	2.326	8.45
Long-run response	2.12	24.33	73.56	0.199	0.442	8.013	1.292	1.292	26.37

Table 4 Fiscal Policy and Growth-Unemployment tradeoffs

A. Short run

	$u(0)$ (%)	$\psi_y(0)$ (%)	$\psi_k(0)$ (%)	$\Delta W(0)$ (%)
Benchmark $A=1.435, g_K=0.05, g_C=0.16,$ $\tau_k=0.17, \tau_w=0.36, \tau_c=0.21, \sigma_u=0.5$	8.008	1.006	1.006	-
Increase in government investment $g_K=0.06$	7.899	2.471	0.185	0.312
Increase in government consumption $g_C=0.17$	9.838	1.737	0.782	-0.495
Decrease in capital income tax $\tau_k=0.1100$	9.347	1.479	1.240	-1.277
Decrease in labor income tax $\tau_w=0.3443$	10.476	2.122	0.695	-0.568
Decrease in consumption tax $\tau_c=0.1932$	9.628	1.650	0.804	-0.389

B. Long run

	$\tilde{u}$ (%)	$\tilde{\psi}$ (%)	$\tilde{V}/K_0$	$\Delta\tilde{W}$
Benchmark $A=1.435, g_K=0.05, g_C=0.16,$ $\tau_k=0.17, \tau_w=0.36, \tau_c=0.21, \sigma_u=0.5$	8.008	1.006	0.507	-
Increase in government investment $g_K=0.06$	8.080	1.439	0.534	14.28
Increase in government consumption $g_C=0.17$	8.057	1.063	0.646	1.068
Decrease in capital income tax $\tau_k=0.1100$	8.035	1.186	0.635	3.689
Decrease in labor income tax $\tau_w=0.3443$	7.767	1.092	0.636	1.887
Decrease in consumption tax $\tau_c=0.1932$	8.051	1.056	0.630	0.983

Table 5 Increase in government investment from 5% to 6% of GDP

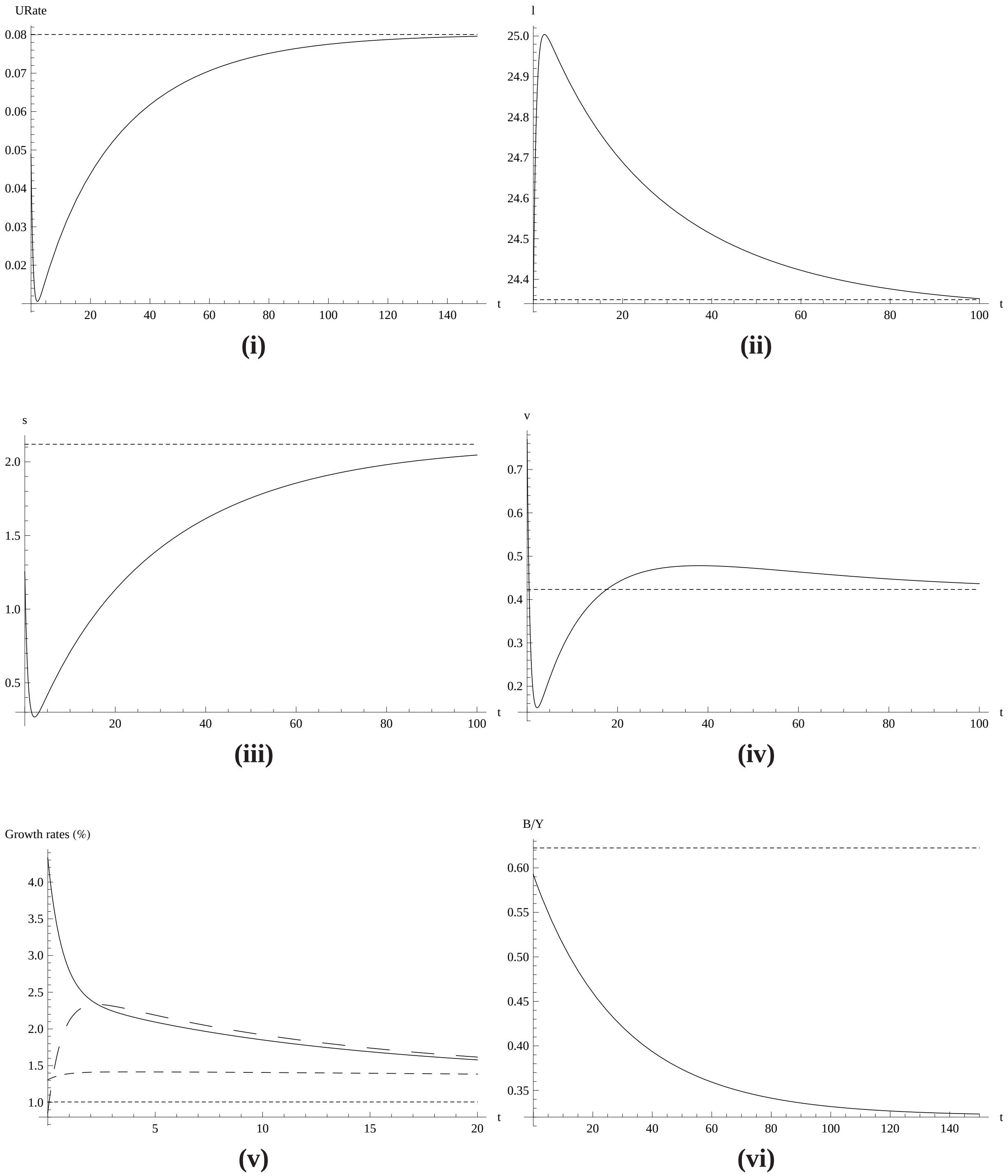
A. Short run

	$u(0)$ (%)	$\psi_y(0)$ (%)	$\psi_k(0)$ (%)	$\Delta W(0)$ (%)
Benchmark $A=1.435, g_K=0.05, g_C=0.16,$ $\tau_k=0.17, \tau_w=0.36, \tau_c=0.21, \sigma_u=0.5$	8.008	1.006	1.006	-
Finance by borrowing	7.899	2.471	0.185	0.312
Decrease in government consumption $g_C=0.1547$	6.895	2.115	0.361	0.545
Increase in capital income tax $\tau_k=0.2091$	6.974	2.248	0.066	1.238
Increase in labor income tax $\tau_w=0.3672$	6.611	2.037	0.418	0.648
Increase in consumption tax $\tau_c=0.2202$	6.903	2.119	0.363	0.541

B. Long run

	$\tilde{u}$ (%)	$\tilde{\psi}$ (%)	$\tilde{V}/K_0$	$\Delta\tilde{W}$
Benchmark $A=1.435, g_K=0.05, g_C=0.16,$ $\tau_k=0.17, \tau_w=0.36, \tau_c=0.21, \sigma_u=0.5$	8.008	1.006	0.507	-
Finance by borrowing	8.080	1.439	0.534	14.278
Decrease in government consumption $g_C=0.1547$	8.054	1.407	0.461	14.280
Increase in capital income tax $\tau_k=0.2091$	8.061	1.304	0.440	13.787
Increase in labor income tax $\tau_w=0.3672$	8.209	1.397	0.471	14.634
Increase in consumption tax $\tau_c=0.2202$	8.054	1.407	0.462	14.275
Overall improving policy $\tau_w=0.309$, $\tau_c=0.290$	7.247	1.482	0.405	12.960

Figure 1: Increase in TFP



Legend: dotted line: initial equilibrium

Legend in (v): solid line: ψ_Y; small dash: ψ_{K_G}; large dash: ψ_K

Figure 2: Increase in Government Investment

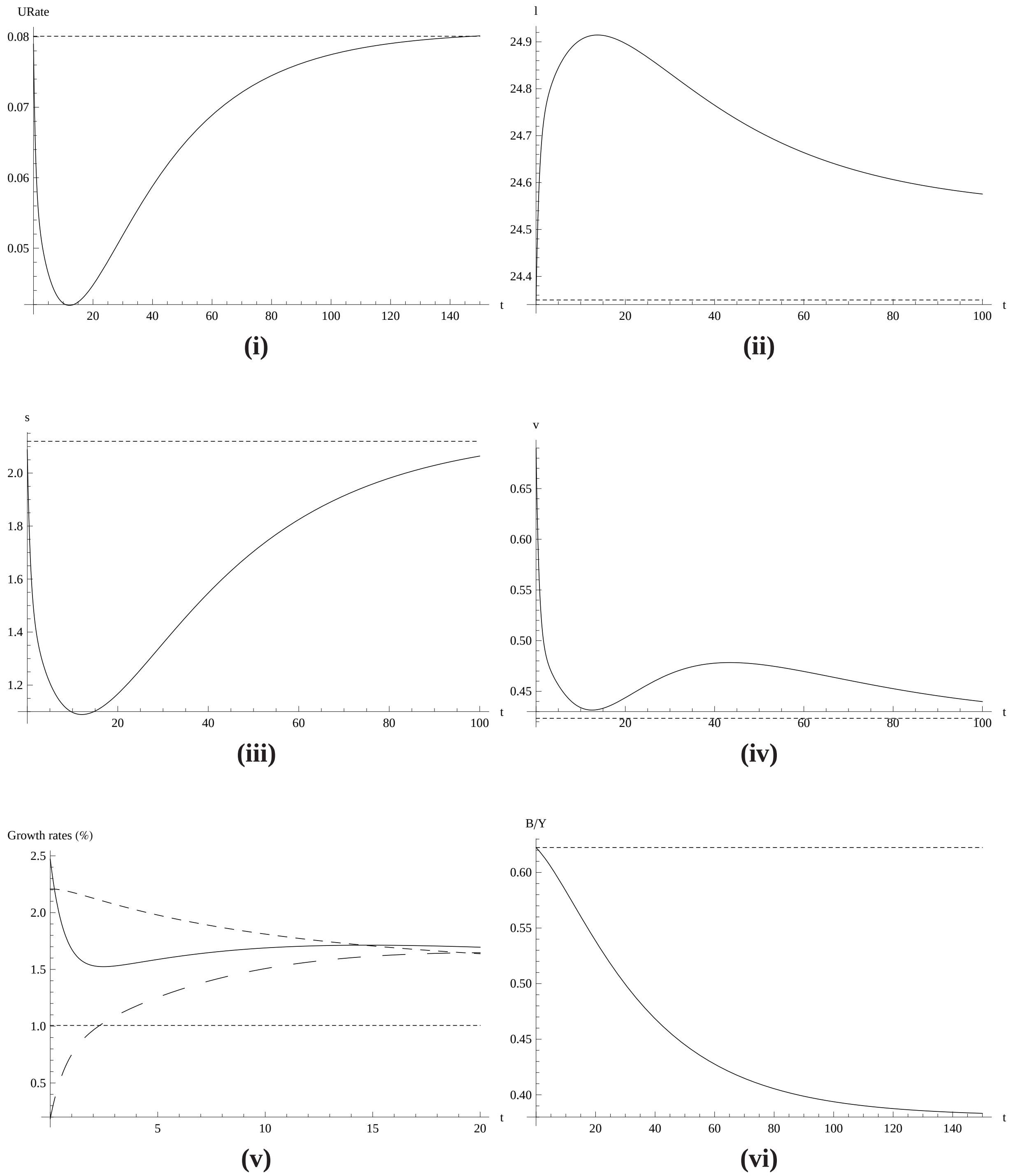


Figure 3: Increase in Government Consumption

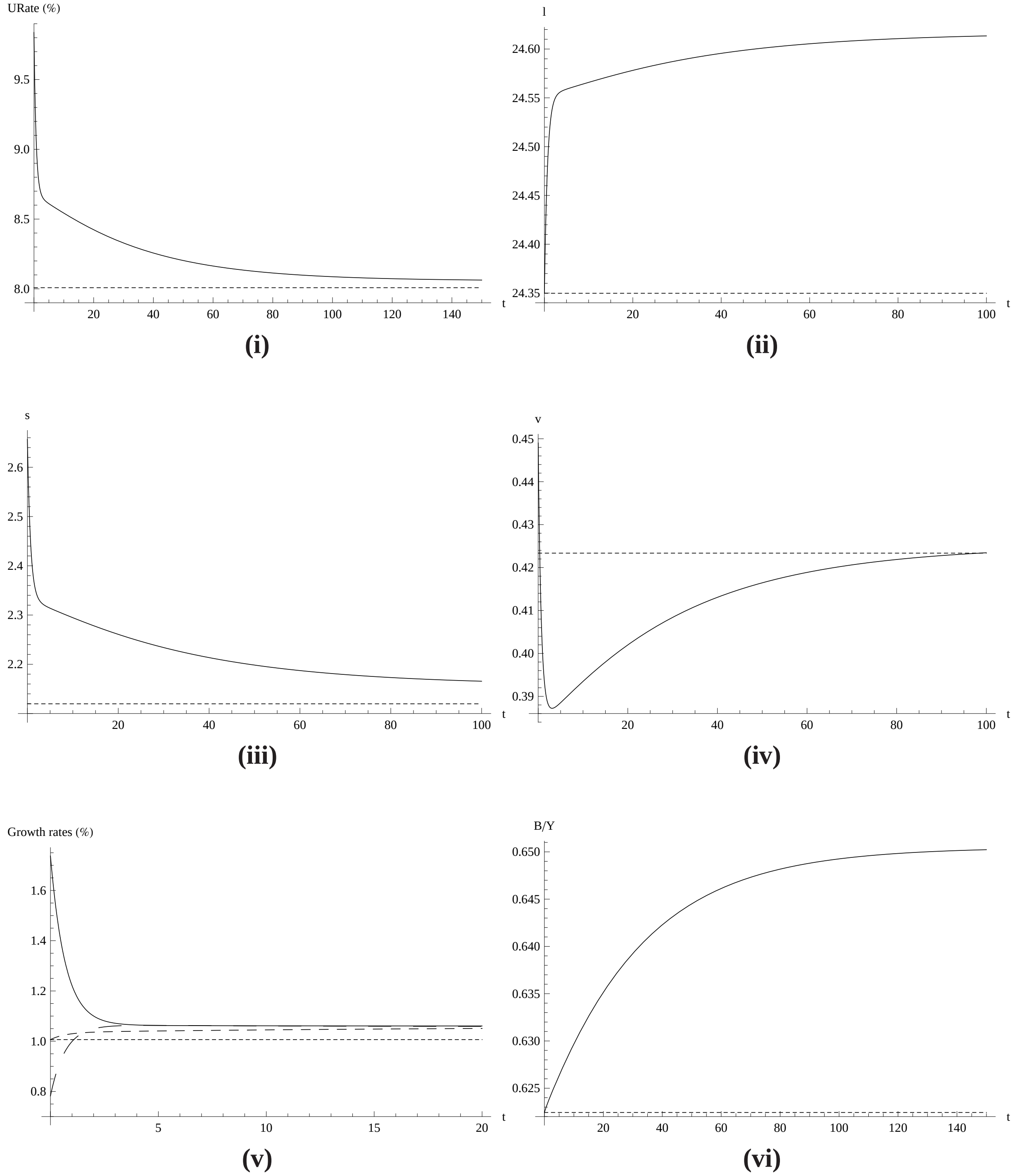
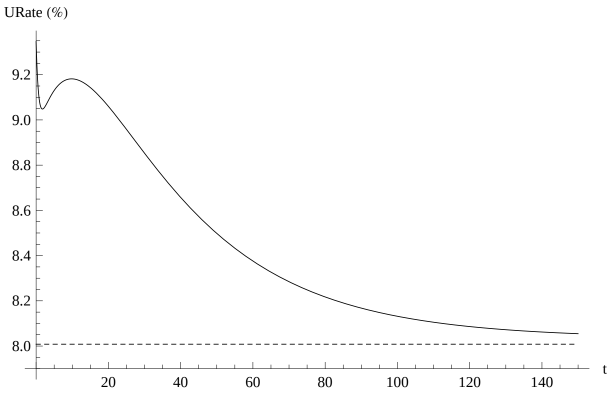
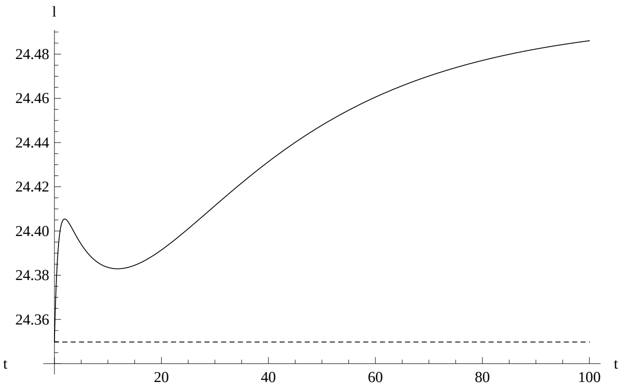


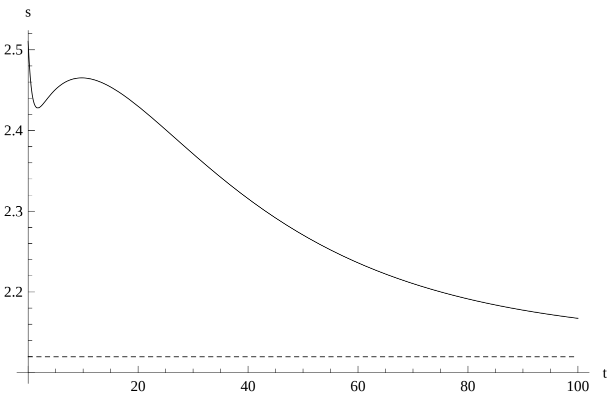
Figure 4: Decrease in Capital Income Tax



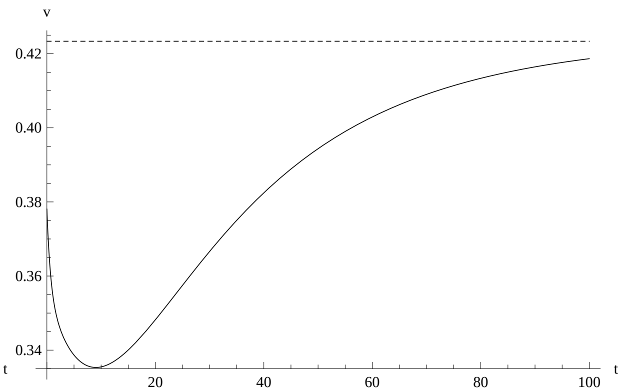
(i)



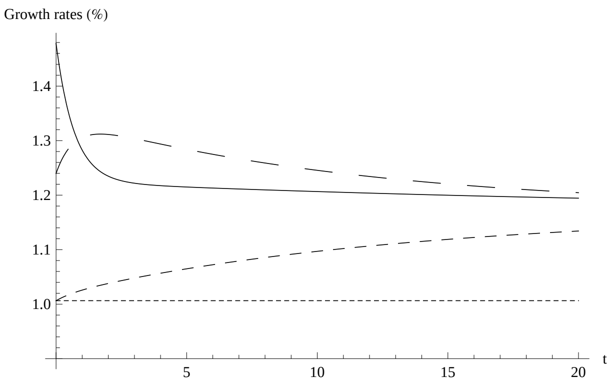
(ii)



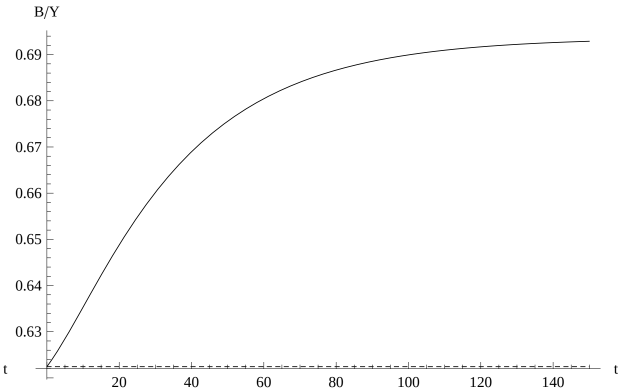
(iii)



(iv)



(v)



(vi)

Figure 5: Decrease in Labor Income Tax

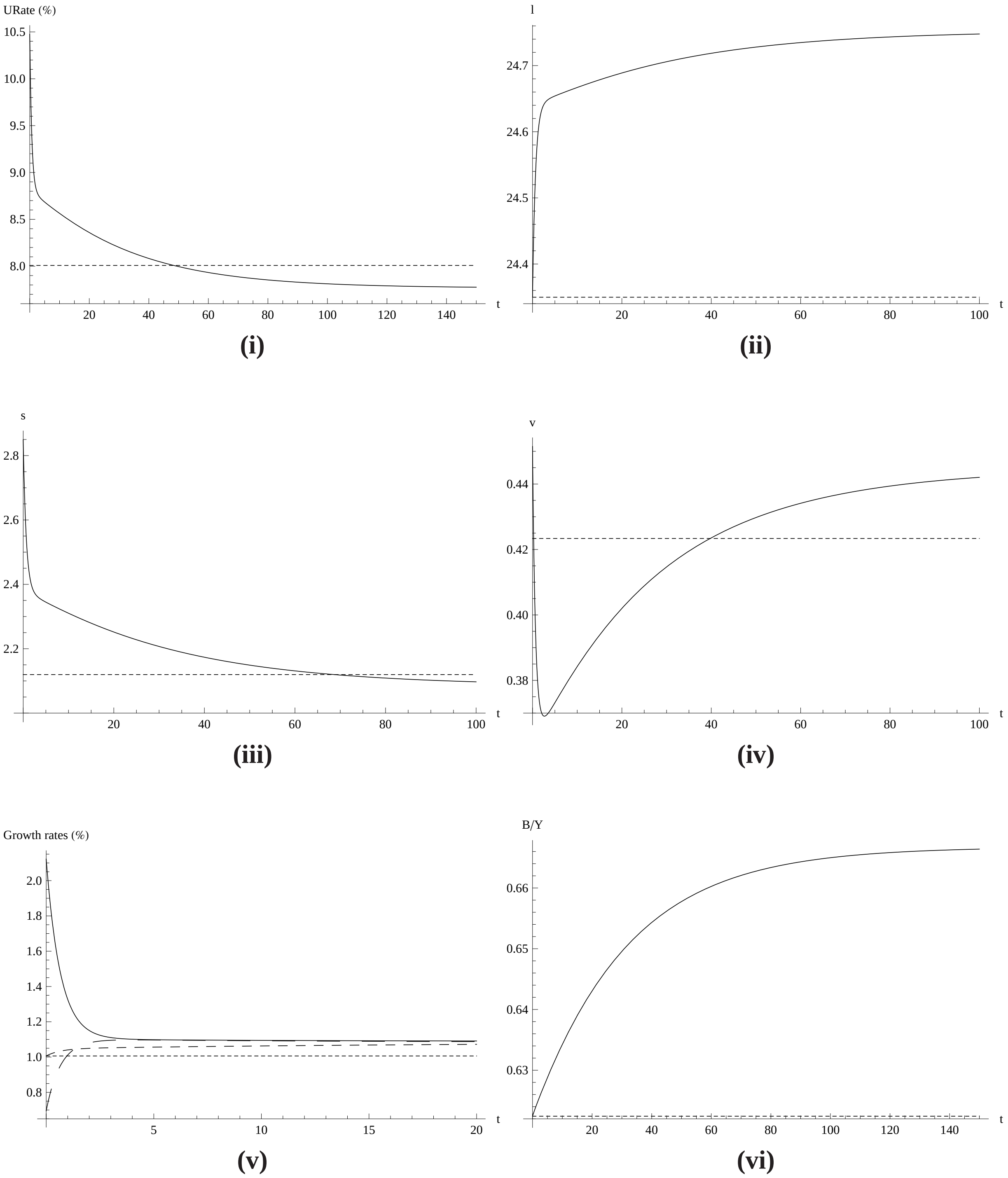


Figure 6: Decrease in Consumption Tax

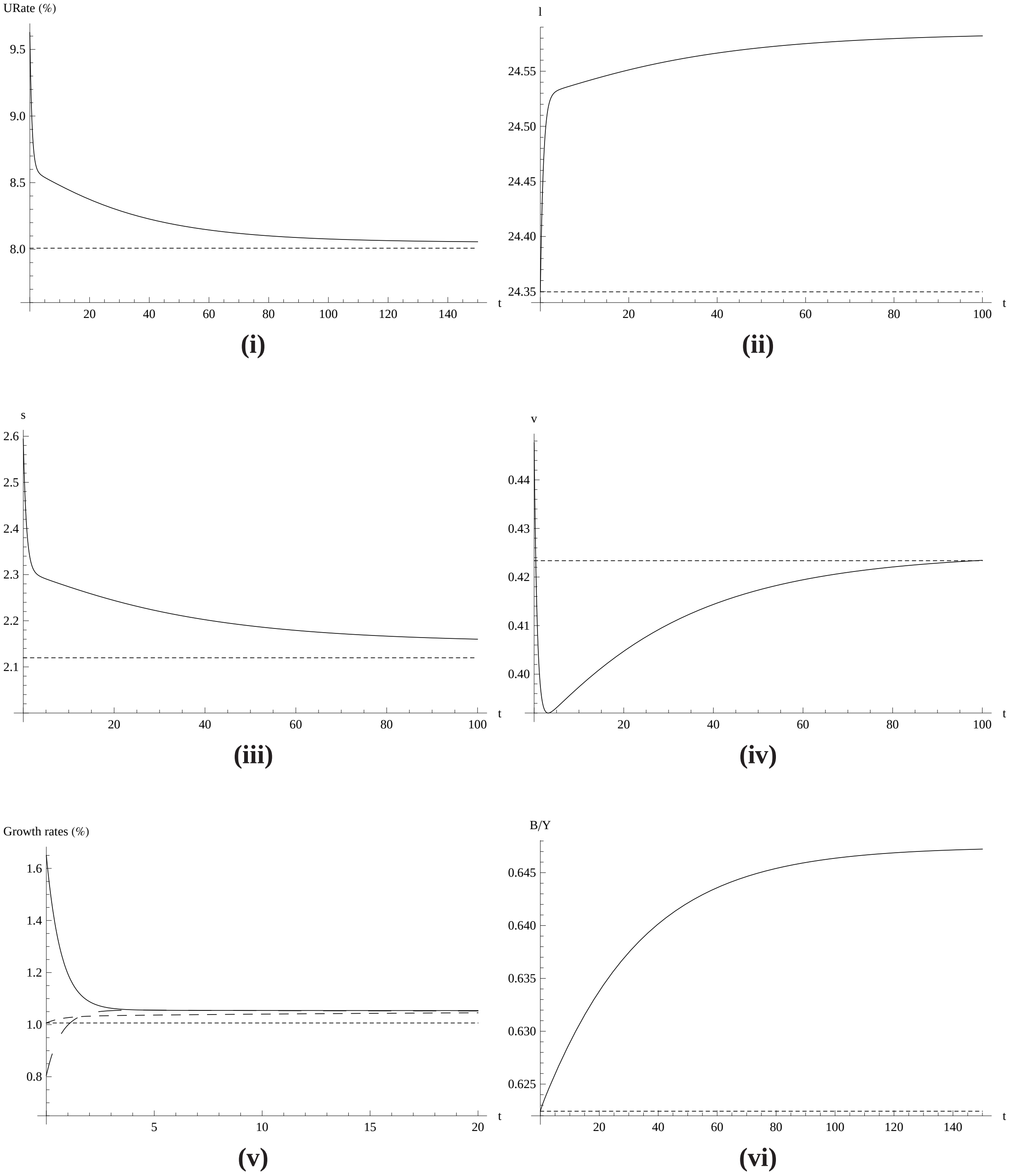
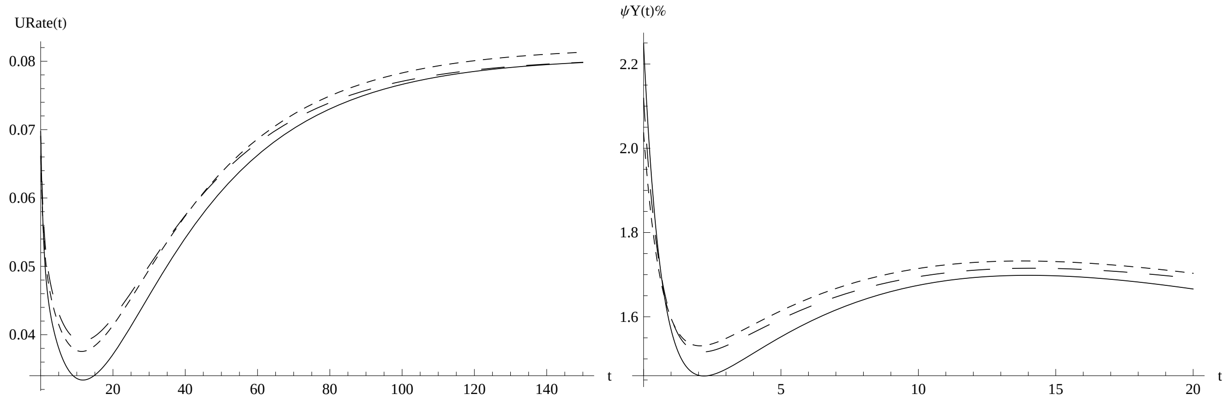


Figure 7: Comparative Financing of Government Investment



(i) **(ii)**

Legend: solid line: tax on capital; small dash: tax on labor; large dash: tax on consumption

Appendix

A. Derivation of equilibrium dynamics

To derive the equilibrium dynamics we first normalize the growing quantities by the growing stock of capital, and thereby define the public-private capital ratio, the consumption-private capital ratio, the wage-capital ratio, and the debt-capital ratio as

$$y \equiv \frac{Y}{K}; \quad k \equiv \frac{K_G}{K}; \quad c \equiv \frac{C}{K}; \quad \omega \equiv \frac{w}{K}; \quad \omega_N \equiv \frac{w_N}{K}; \quad b \equiv \frac{B}{K} \tag{A.1}$$

The production function then can be written in the form:

$$\frac{Y}{K} \equiv y = A\left[\alpha + (1-\alpha)\left(k^{1-e}l\right)^{-\rho}\right]^{-1/\rho} \tag{A.2}$$

and the Nash bargain wage-capital ratio, (20), can be expressed as

$$\omega_N = \pi(1-\alpha)A^{-\rho}k^{-\rho(1-e)}l^{-(1+\rho)}y^{1+\rho} + (1-\pi)\frac{\theta c}{(1-l-s)}\frac{1+\tau_c}{1-\tau_w} \tag{A.3}$$

where $K(1-\alpha)A^{-\rho}k^{-\rho(1-e)}l^{-(1+\rho)}y^{1+\rho}$ equals the marginal product of labor. The sluggish wage process described by (18) can be written as:

$$\hat{\omega} \equiv \frac{\dot{\omega}}{\omega} = \Omega\left(\frac{\omega_N}{\omega} - 1\right) \tag{A.3'}$$

where in general $\hat{Z} \equiv \dot{Z}/Z$ denotes the proportional rate of change. The rental rate follows from (9a) as

$$r = \alpha A^{-\rho}y^{1+\rho} - \delta \tag{A.4}$$

where $\alpha A^{-\rho}y^{1+\rho}$ equals the marginal product of (private) capital.

Combining (3c) with (A.4) yields

$$\hat{\lambda} \equiv \frac{\dot{\lambda}}{\lambda} = \beta - (1-\tau_k)\left[\alpha A^{-\rho}y^{1+\rho} - \delta\right] \tag{A.5}$$

Using (A.2), the specification of government expenditure policy, $G_K = g_K Y$ and $G_C = G_C Y$, noting that $v = sx$, from the evolution of the private and public capital stocks by (15) and (12), we obtain

$$\hat{K} \equiv \frac{\dot{K}}{K} = (1 - g_K - g_C - msx)y - \delta - c \tag{A.6a}$$

$$\hat{k} \equiv \frac{\dot{k}}{k} = g_K\left(\frac{y}{k}\right) - (1 - g_K - g_C - msx)y - (\delta_G - \delta) + c \tag{A.6b}$$

The growth rate of y then follows from (A.2):

$$\hat{y} \equiv \frac{\dot{y}}{y} = \frac{(1-\alpha)\left(k^{1-e}l\right)^{-\rho}}{\alpha + (1-\alpha)\left(k^{1-e}l\right)^{-\rho}}\left[(1-e)\hat{k} + \hat{l}\right] \tag{A.7}$$

Dividing (1b) by l, we may write

$$\hat{l} \equiv \frac{\dot{l}}{l} = \phi\frac{s}{l} - \zeta \tag{A.8}$$

and from the definition of $\phi(x) = \Lambda x^{\chi}$, we get

$$\hat{\phi} \equiv \frac{\dot{\phi}}{\phi} = \chi\hat{x} = \chi\frac{\dot{x}}{x} \tag{A.9}$$

Dividing (3a) by (3b), yields

$$\frac{\lambda}{\gamma} = \phi\frac{L}{\theta C(1+\tau_c) - L\sigma_u w} \tag{A.10}$$

where we recall that leisure is defined as $L = 1 - l - s$. Substituting for $\phi(x)$ and (A.10) into (3d), $\hat{\gamma}$ becomes

$$\hat{\gamma} \equiv \frac{\dot{\gamma}}{\gamma} = \beta + \zeta + \Lambda x^{\chi}\left(1 - \frac{L(1-\tau_w-\sigma_u)\omega}{\theta c(1+\tau_c) - L\sigma_u\omega}\right) \tag{A.11}$$

where we note $C = cK$ and $w = \omega K$.

Substituting the equilibrium condition $\overline{Y} = Y$ into (9b) yields

$$\frac{1}{\xi} = \frac{\varphi}{(1-\tau_k)m\bar{\bar{Y}}} = \frac{\varphi}{(1-\tau_k)myK}$$

Then substituting this equation together with $\varphi(x) = \Lambda x^{\chi-1}$ into (9c) and rearranging we obtain

$$\hat{\xi} \equiv \frac{\dot{\xi}}{\xi} = (1-\tau_k)r + \zeta + \frac{\Lambda x^{\chi-1}}{my}\left[\omega - (1-\alpha)A^{-\rho}k^{-\rho(1-e)}l^{-(1+\rho)}y^{1+\rho}\right] \tag{A.12}$$

where r is given by equation (A.4).

Taking percentage changes of (3a) and (3b) yields the two equations

$$\begin{pmatrix} \varepsilon-1 & -\varepsilon\theta s/L \\ \varepsilon & -(\varepsilon\theta-1)s/L \end{pmatrix}\begin{pmatrix} \hat{C} \\ \hat{s} \end{pmatrix} = \begin{pmatrix} \hat{\lambda} + \varepsilon\theta(l/L)\hat{l} - \varepsilon\eta\hat{G}_C \\ h\hat{\omega} + (\varepsilon\theta-1)(l/L)\hat{l} + h(\hat{\lambda}+\hat{K}) + (1-h)(\hat{\gamma}+\hat{\phi}) - \varepsilon\eta\hat{G}_C \end{pmatrix} \tag{A.13}$$

where, using (3a), (3b),

$$h(\cdot) \equiv \frac{\lambda\sigma_u w}{\lambda\sigma_u w + \gamma\phi} = \frac{L\sigma_u w}{\theta C(1+\tau_c)} = \frac{L\sigma_u\omega}{\theta c(1+\tau_c)} \text{ and } \hat{G}_C = \hat{Y} = \hat{y} + \hat{K}$$

Solving (A.13), for $\hat{C}, \hat{s}$ we obtain

$$\begin{aligned} \hat{C} = \quad & \frac{1}{\Delta}\frac{s}{L}\varepsilon\theta\left[h\hat{\omega} + h\hat{\lambda} + (h-\varepsilon\eta)\hat{K} - \varepsilon\eta\hat{y} + (\varepsilon\theta-1)\frac{l}{L}\hat{l} + (1-h)(\hat{\gamma}+\hat{\phi})\right] \\ & -\frac{1}{\Delta}\frac{s}{L}(\varepsilon\theta-1)\left[\hat{\lambda} + \varepsilon\theta\frac{l}{L}\hat{l} - \varepsilon\eta(\hat{y}+\hat{K})\right] \end{aligned} \tag{A.14a}$$

$$\begin{aligned} \hat{s} = \quad & \frac{1}{\Delta}(\varepsilon-1)\left[h\hat{\omega} + h\hat{\lambda} + (h-\varepsilon\eta)\hat{K} - \varepsilon\eta\hat{y} + (\varepsilon\theta-1)\frac{l}{L}\hat{l} + (1-h)(\hat{\gamma}+\hat{\phi})\right] \\ & -\frac{1}{\Delta}\varepsilon\left[\hat{\lambda} + \varepsilon\theta\frac{l}{L}\hat{l} - \varepsilon\eta(\hat{y}+\hat{K})\right] \end{aligned} \tag{A.14b}$$

where $\Delta = sL^{-1}(\varepsilon(1+\theta)-1)$.

Next, we derive an equation for $\hat{x} \equiv \dot{x}/x$. To do this, we first, take percentage changes of (9b):

$$\hat{\varphi} = \hat{Y} - \hat{\xi} = \hat{y} + \hat{K} - \hat{\xi}$$

recalling that in equilibrium $\bar{Y} = Y$. Taking the percentage change of $\varphi(x)$, and combining with this last equation we get

$$\hat{x} = \frac{1}{\chi - 1}\hat{\varphi} = \frac{1}{\chi - 1}\left(\hat{y} + \hat{K} - \hat{\xi}\right)$$

and substituting (A.12) for $\hat{\xi}$, yields

$$\hat{x} = \frac{1}{\chi - 1}\left[\hat{y} + \hat{K} - (1-\tau_k)r - \zeta + \frac{\Lambda x^{\chi-1}}{my}\left((1-\alpha)A^{-\rho}k^{-\rho(1-e)}l^{-(1+\rho)}y^{1+\rho} - \omega\right)\right] \qquad \text{(A.14c)}$$

The dynamics for c follow directly from $\hat{c} = \hat{C} - \hat{K}$, namely

$$\begin{aligned}\hat{c} \equiv \frac{\dot{c}}{c} = \; & \frac{1}{\Delta}\frac{s}{L}\varepsilon\theta\left[h\hat{\omega} + h\hat{\lambda} + (h - \varepsilon\eta)\hat{K} - \varepsilon\eta\hat{y} + (\varepsilon\theta - 1)\frac{l}{L}\hat{l} + (1-h)(\hat{\gamma} + \hat{\phi})\right] \\ & - \frac{1}{\Delta}\frac{s}{L}(\varepsilon\theta - 1)\left[\hat{\lambda} + \varepsilon\theta\frac{l}{L}\hat{l} - \varepsilon\eta(\hat{y} + \hat{K})\right] - \hat{K}\end{aligned} \qquad \text{(A.14d)}$$

Equations (A.3'), (A.5), (A.6a), (A.6b), (A.7), (A.8), (A.11), (A.12), (A.14a)- (A.14d), completely describe the economy's dynamics in terms of $\hat{\omega}, \hat{\lambda}, \hat{K}, \hat{k}, \hat{y}, \hat{l}, \hat{\gamma}, \hat{\xi}, \hat{C}, \hat{s}, \hat{x}, \hat{c}$. Of these variables, ω, k, y, l, s, x, c are stationary implying that in steady state (balanced growth) we must have $\dot{\omega} = \dot{k} = \dot{y} = \dot{c} = \dot{l} = \dot{s} = \dot{x} = 0$. Hence along a balanced growth path, $\hat{K}, \hat{K}_G, \hat{Y}, \hat{C}, \hat{w}$ all grow at the common constant growth rate:

$$\frac{\dot{K}}{K} = \frac{\dot{K}_G}{K_G} = \frac{\dot{C}}{C} = \frac{\dot{Y}}{Y} = \frac{\dot{w}}{w} \equiv \tilde{\psi}$$

where $\tilde{\psi}$ denotes the steady-state balanced growth rate.

Substituting the rental rate (A.4) into profits (7e), noting $Y = yK$, we obtain

$$\Pi = \left(1 - \alpha A^{-\rho}y^{\rho} - msx\right)yK - wl \qquad \text{(A.15)}$$

In contrast to the standard Walrasian model, profits do not equal zero since, because of wage bargaining, the marginal product of labor exceeds the wage rate.

B. Government debt dynamics

The government's flow budget constraint (11) is

$$\dot{B} = rB + G_K + G_C + \sigma_u ws - \tau_\pi \Pi - \tau_k r(K+B) - \tau_c C - \tau_w wl - T$$

Inserting the government spending rules (13), $T \equiv T_T - T_Z = T - \sigma_T Y$ for net lump-sum taxes, and the definition of profits (A.15), we can rewrite this equation in terms of the debt-capital ratio $b(t) \equiv B(t)/K(t)$,

$$\begin{aligned} &\dot{b}(t) - \left[r(t)(1-\tau_k) - \psi_K(t)\right]b(t) = (g_K + g_C + \sigma_T)y(t) + \sigma_u s(t)\omega(t) - \tau_k r(t) \\ &- \tau_\pi\left[(1-\alpha A^{-\rho} y(t)^{-\rho} - ms(t)x(t))y(t) - \omega(t)l(t)\right] - \tau_c c(t) - \tau_w \omega(t)l(t) - \tau(t) \end{aligned} \qquad \text{(A.16)}$$

Where $\tau(t) \equiv T_T(t)/K(t)$ is the ratio of lump-sum taxes to capital. For notational convenience, we denote the right hand side of (A.16) by $z(t) - \tau(t)$. Solving (A.16) yields

$$b(t) = e^{\int_0^t [(1-\tau_k)r(s) - \psi_K(s)]ds}\left[b_0 + \int_0^t [z(u) - \tau(u)]e^{-\int_0^u [(1-\tau_k)r(s) - \psi_K(s)]ds} du\right]$$

and imposing intertemporal solvency on the government yields the intertemporal budget constraint which we write in the form

$$V \equiv \int_0^\infty \left(T_T(u)/K_0\right)e^{-\int_0^u (1-\tau_k)r(s)ds} du = \frac{B_0}{K_0} + \int_0^\infty z(u)e^{-\int_0^u [(1-\tau_k)r(s) - \psi_K(s)]ds} du \qquad \text{(A.17)}$$

where B_0/K_0 is predetermined. Given the equilibrium time path summarized by $z(u)$, including the tax rates, (A.17) determines the discounted present value of lump-sum taxes necessary for the government to remain intertemporally solvent. This in turn implies the following sustainable time path of the government debt-capital ratio:

$$b(t) = e^{\int_0^t [(1-\tau_k)r(s) - \psi_K(s)]ds}\left(-\int_t^\infty [z(u) - \tau(u)]e^{-\int_0^u [(1-\tau_k)r(s) - \psi_K(s)]ds} du\right) \qquad \text{(A.17')}$$

In our numerical simulations, we use a linearized version of (A.17), where the linearization is performed around the "new" steady state.

C. Steady state

In steady state, all ratios and growth rates remain constant, and $\hat{x} = \hat{s} = \hat{l} = \hat{L} = 0$. Noting that in steady state $\hat{\tilde{\gamma}}$ is constant, equation (3d) implies $\hat{\tilde{\gamma}} = \hat{\tilde{\lambda}} + \hat{\tilde{w}}$. Noting that $\hat{\tilde{w}} = \hat{\tilde{K}}$, and further that $\hat{\tilde{\phi}} = 0$, equation (A.14b) implies

$$\hat{\tilde{\lambda}} = [\varepsilon(1+\eta)-1]\hat{\tilde{K}} \tag{A.18a}$$

Next, rewriting (A.2) as

$$\tilde{y} = A\left[\alpha + (1-\alpha)\left(\tilde{k}^{1-e}\tilde{l}\right)^{-\rho}\right]^{-1/\rho} \equiv y(\tilde{k},\tilde{l}) \tag{A.18b}$$

and combining (A.18a) with (A.5) yields:

$$\hat{\tilde{K}} = \hat{\tilde{C}} = \tilde{\psi} = \frac{1}{1-\varepsilon(1+\eta)}\left[(1-\tau_k)\left(\alpha\bar{A}^{-\rho}\tilde{y}^{1+\rho} - \delta\right) - \beta\right] \tag{A.18c}$$

Since in steady state all quantities grow at the common rate, equations (12), (13) and (A.6a) imply

$$\tilde{\psi} = g_K \frac{y\left(\tilde{k},\tilde{l}\right)}{\tilde{k}} - \delta_G \tag{A.18d}$$

$$\tilde{\psi} = \left(1 - g_K - g_C - m\tilde{s}\tilde{x}\right) y\left(\tilde{k},\tilde{l}\right) - \delta - \tilde{c} \tag{A.18e}$$

where

$$\tilde{s}\tilde{x} = \frac{\zeta\tilde{l}}{\varphi(\tilde{x})} \tag{A.18f}$$

and $\tilde{L},\tilde{l},\tilde{s}$ are subject to the time constraint

$$\tilde{s} = \left(1 - \tilde{L} - \tilde{l}\right) \tag{A.18g}$$

Setting $\hat{\tilde{x}} = 0$ in equation (A.14c), and noting that $\hat{\tilde{Y}} = \hat{\tilde{K}} = \hat{\tilde{K}}_G = g_K \frac{\tilde{y}}{\tilde{k}} - \delta_G$, we obtain

$$\zeta + (1-\tau_k)\left[\alpha A^{-\rho} y\left(\tilde{k},\tilde{l}\right)^{1+\rho} - \delta\right] - \tilde{\psi} = \frac{\varphi(\tilde{x})}{my\left(\tilde{k},\tilde{l}\right)}\left[(1-\alpha)A^{-\rho}\tilde{k}^{-\rho(1-e)}\tilde{l}^{-(1+\rho)} y\left(\tilde{k},\tilde{l}\right) - \tilde{\omega}\right] \quad \text{(A.18h)}$$

The steady state wage-capital ratio $\tilde{\omega} = \tilde{\omega}_N$ follows from (A.3) as

$$\tilde{\omega} = \pi(1-\alpha)A^{-\rho}\tilde{k}^{-\rho(1-e)}\tilde{l}^{-(1+\rho)} y\left(\tilde{k},\tilde{l}\right)^{1+\rho} + (1-\pi)\frac{\theta\tilde{c}}{\tilde{L}}\frac{1+\tau_c}{1-\tau_w} \quad \text{(A.18i)}$$

Finally, noting from (A.10) that $\hat{\tilde{\gamma}} = \hat{\tilde{\lambda}} + \hat{\tilde{K}}$, using (A.18a) for $\hat{\tilde{\lambda}}$, and (A.11) for $\hat{\tilde{\gamma}}$, we obtain

$$\varepsilon(1+\eta)\tilde{\psi} = \beta + \zeta + \phi(\tilde{x})\left(1 - \frac{\tilde{L}(1-\tau_w-\sigma_u)\tilde{\omega}}{\theta\tilde{c}(1+\tau_c) - \tilde{L}\sigma_u\tilde{\omega}}\right) \quad \text{(A.18j)}$$

Equations (A.18b)-(A.18j) provide 9 equations to solve for $\tilde{y},\tilde{k},\tilde{l},\tilde{\psi},\tilde{s},\tilde{x},\tilde{c},\tilde{L},\tilde{\omega}$. Having determined these, other stady-state quantities immediately follow. Thus, vacancies, $\tilde{v} = \tilde{s}\tilde{x}$, while as stated in the text, the steady-state unemployment rate is a function of $\tilde{x}$ and of parameters:

$$\tilde{u} = \frac{\zeta}{\phi(\tilde{x}) + \zeta}$$

Furthermore, the steady-state values of the debt-capital ratio $\tilde{b}$ and the lump-sum tax-GDP ratio $\tilde{\tau}$ follow from the steady-state government budget constraint (not reported).

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