

Contents lists available at [ScienceDirect](#)

Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

Growth and unemployment: Short-run and long-run tradeoffs[☆]

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ARTICLE INFO

Article history:

Received 23 January 2017

Revised 13 September 2017

Accepted 20 November 2017

Available online xxx

JEL classification:

O41

O47

J64

Keywords:

Endogenous growth

Unemployment

Labor market search

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.

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1. Introduction

Does enhanced growth reduce unemployment or is there a tradeoff between them? This is a topical question as 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.¹ Conventional growth theory, by assuming either that labor is supplied inelastically, or if endogenously determined, is nevertheless fully employed, is incapable of addressing this issue. To investigate the relationship between growth and unemployment we need to introduce some source of friction into the labor market. We do so by augmenting the standard (Romer, 1986; Barro, 1990) endogenous growth model by introducing search unemployment, together with wage bargaining, as originally pioneered 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.

[☆] The authors thank two referees for their constructive suggestions. An earlier (expanded) version of this paper was presented at a session honoring Carl Chiarella at the 2017 CEF Conference held at Fordham University in June 2017. Much of the research for this paper was done during several visits by Schubert to the University of Washington. Schubert thanks the Free University of Bozen-Bolzano for financial support. Turnovsky's research was supported in part by the Van Voorhis endowment at the University of Washington and this too is gratefully acknowledged.

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¹ A brief anecdotal review of this wide-spread belief is provided by Eriksson (1997). More recently there has been a growing literature linking skill-biased technological change to unemployment across skill classes and wage inequality.

<https://doi.org/10.1016/j.jedc.2017.11.003>

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Please cite this article as: S.F. Schubert, S.J. Turnovsky, Growth and unemployment: Short-run and long-run tradeoffs, Journal of Economic Dynamics & Control (2017), <https://doi.org/10.1016/j.jedc.2017.11.003>

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 that 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. These response patterns suggest little in the nature of a significant long-run tradeoff. 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.

Second, we examine 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 two distortionary tax rates (capital income and labor income). To preserve comparability, in all four scenarios the policies are normalized to represent a uniform fiscal stimulus of 1% of GDP. The two 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.

The paper is related to several bodies of literature. On the theoretical side, this paper is closest to [Eriksson \(1997\)](#) and [Postel-Vinay \(1998\)](#), although 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. This is important since most of the short-run action in the labor market arises from movement in the participation rate, through movements between search 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 rigidities, while clearly important, are also not the only source of unemployment in a macrodynamic system.² Another source of unemployment arises through nominal rigidities associated with Keynesian monetary growth models. This is an area in which Carl Chiarella and his coauthors have made important contributions.³ This too is an important aspect, adding to our understanding of the growth-unemployment relationship. 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 whether unemployment causes growth or vice versa. An important advantage 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 occurring. Bearing this in mind helps reconcile the wide range of often conflicting correlations that have been estimated.⁴

² [Arico \(2003\)](#) identifies several alternative links between economic growth and unemployment.

³ See e.g. [Chiarella and Flaschel \(2000\)](#), and [Chiarella et al. \(2013\)](#), among many contributions.

⁴ 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. 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.⁵

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 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 substitutes 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:

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

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.

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

$$\dot{l}^s = \phi s - \zeta l^s \quad (1b)$$

where ϕ denotes the job finding rate and ζ is the exogenously given rate of job separation. The job finding rate is a function of the job-market tightness, which the individual takes as given, but is determined endogenously in equilibrium.

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

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

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 constraint (1a), and (1b), and the initial stocks of capital, $K(0) = K_0$, bonds, $B(0) = B_0$, and labor supply, $l^s(0) = l_0^s$. The optimality conditions are:

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

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

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

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

together with the transversality conditions

$$\lim_{t \rightarrow \infty} \lambda K e^{-\beta t} = \lim_{t \rightarrow \infty} \lambda B e^{-\beta t} = \lim_{t \rightarrow \infty} \gamma l^s e^{-\beta t} = 0 \quad (3e)$$

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. Eq. (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:

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

⁵ Due to space limitations formal details and analysis of the underlying model are minimized. A more complete discussion is available in the working paper version Schubert and Turnovsky (2017). This is available at <https://econ.washington.edu/people/stephen-turnovsky>.

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. Thus we see that the reservation wage equals the marginal rate of substitution between leisure and consumption, adjusted by the consumption tax rate.

Eqs. (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

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

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 $w_R \equiv q\phi + \sigma_u w$, we see that, *ceteris paribus*, an increase in the shadow price of employment, q , raises the reservation wage and thus search activities.

Eq. (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{q}/γ 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 .

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

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

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

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

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.

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 $Y = F(K, l)$

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

where $\zeta \equiv 1/(1 + \rho)$ 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 , taken to be a weighted average of the economy's aggregate private capital stock, \bar{K} , and public capital, K_G :

$$X \equiv \bar{K}^e K_G^{1-e}, \quad 0 \leq e \leq 1 \quad (7b)$$

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.⁶

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

$$l^d = \varphi v - \zeta l^d \quad (7c)$$

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 reflects costs associated with advertising and hiring (Pissarides, 1987; Mortensen and Pissarides, 1994). Following Pissarides (1987), we assume that the vacancy cost is proportional to average (aggregate) output, \bar{Y} .⁷

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

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

⁶ Justification for specifying the externality as a composite is discussed further by Chatterjee and Turnovsky (2012).

⁷ This assumption is necessary to support an equilibrium of ongoing growth.

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

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

by choosing the amount of capital, K , to rent, vacancies to post, v , and the rate to accumulate labor l^d , subject to equations (7a)–(7c) and the initial stock of labor, $l^d(0) = l_0^d$ and capital. 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:

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

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

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

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

where ξ denotes the shadow value of a filled position. Eq. (9a) determines the amount of capital to be rented, given the interest rate r . Eq. (9b) equates the marginal cost of vacancy to its marginal benefit. The no-arbitrage relation (9c) equates the rate of return on labor, comprising 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 Eq. (9c) for ξ , and imposing the transversality condition (9d), we obtain

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

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. $T_Z = \sigma_T Y$.⁸ Accordingly, using (11)

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

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 Schubert and Turnovsky (2017) we show how solving (11) and imposing the transversality condition, the present value quantity $V \equiv \int_0^{\infty} (T_T(u)/K_0) e^{-\int_0^u (1 - \tau_k)r(s) ds} du$ 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.⁹

⁸ Lump-sum transfers are introduced only to obtain a reasonable ratio of government expenditures to GDP in the calibrated model. As T_Z is lump-sum, it does not have any further effect on the macroeconomic equilibrium.

⁹ 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 et al. (1990).

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. Using (13), and noting that in equilibrium $\tilde{Y} = Y$, it can be expressed as the accumulation equation

$$\dot{K} = (1 - g_K - g_C - mv)Y - C - \delta K \quad (14)$$

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

$$Y = A \left[\alpha K^{-\rho} + (1 - \alpha) (K^e K_G^{1-e} l)^{-\rho} \right]^{-1/\rho} = AK \left[\alpha + (1 - \alpha) \left(\left(\frac{K_G}{K} \right)^{1-e} l \right)^{-\rho} \right]^{-1/\rho} \quad (15)$$

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 aggregate numbers of vacancies and unemployed agents, respectively. We assume a constant returns to scale matching technology of the Cobb-Douglas form¹⁰

$$M(v, s) = \Lambda v^\chi s^{1-\chi}, \quad \Lambda > 0, 0 < \chi < 1 \quad (16)$$

Thus, matches per unemployed agent can be expressed as $\phi = \Lambda(v/s)^\chi$, and matches per vacancy as $\varphi = \Lambda(v/s)^{\chi-1}$. 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, which serves as a measure of labor market tightness, we can write $\phi = \Lambda(x)^\chi$, $\varphi = \Lambda(x)^{\chi-1}$, where we see that matches per searching agent, $\phi(x)$, are an increasing function of the vacancy-search ratio, while 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

$$\dot{w} = \Omega(w_N - w) + w \frac{\dot{K}}{K}, \quad \Omega > 0 \quad (17)$$

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

$$w_N = \pi \frac{\partial Y}{\partial l} + (1 - \pi) \frac{w_R}{1 - \tau_w} \quad (18)$$

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). 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.¹¹

3. 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 (17), and profits are given by (7d).
5. The rental rate r clears the capital market.

¹⁰ Empirical evidence supporting the Cobb-Douglas form is provided by Pissarides (2000).

¹¹ 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.

Table 1A

The benchmark economy.

Preference parameters	$\beta = 0.035, \varepsilon = -0.5, \theta = 1.75, \eta = 0.25$
Production parameters	$\bar{A} = 1.435, \alpha = 0.4, e = 0.6, \rho = 1/3, \delta = 0.05, \delta_C = 0.05$
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 1B

Initial equilibrium of benchmark economy.

u (%)	Dur u	s	x	l	L	K/Y	C/Y	K _C /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.

6. Capital accumulation (investment) \dot{K} adjusts continuously to clear the domestic goods market (14).
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, Eqs. (1b) and (7c) coincide, implying that in equilibrium, $l^s = l^d \equiv l$.

The derivation of the macrodynamic equilibrium involves substantial technical detail, and accordingly is set out in detail in the Appendix to Schubert and Turnovsky (2017). It is described by dynamic equations in $\omega \equiv w/K, k \equiv K_C/K, c \equiv C/K, C, y \equiv Y/K, l, \lambda, \gamma, \xi, s, x$. Of these variables, $\omega, k, c, y, l, s, x, c$ are stationary implying that in steady state (balanced growth) we must have $\dot{\omega} = \dot{k} = \dot{c} = \dot{y} = \dot{l} = \dot{s} = \dot{x} = \dot{c} = 0$. Hence along the balanced growth path K, K_C, Y, C, w all grow at a common constant growth rate. The resulting steady-state is summarized in the Appendix, below.

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 1A, which reflect a time unit of one year. The initial steady-state equilibrium of the corresponding benchmark economy are reported in Table 1B, where the choice of parameters reflect some key features of European countries.¹² The empirical evidence supporting these parameter choices are described in detail in Schubert and Turnovsky (2017).

4. The relationship between growth and unemployment

To address the long-run relationship between growth and unemployment it is instructive to focus on Eq. (A.1b) in the Appendix:

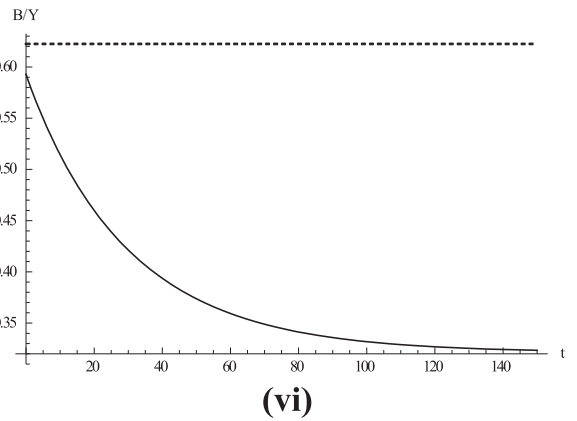
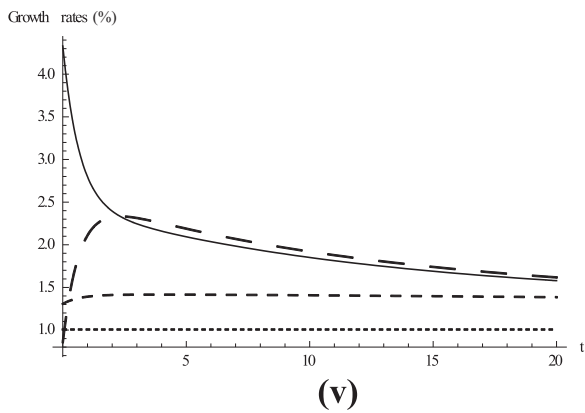
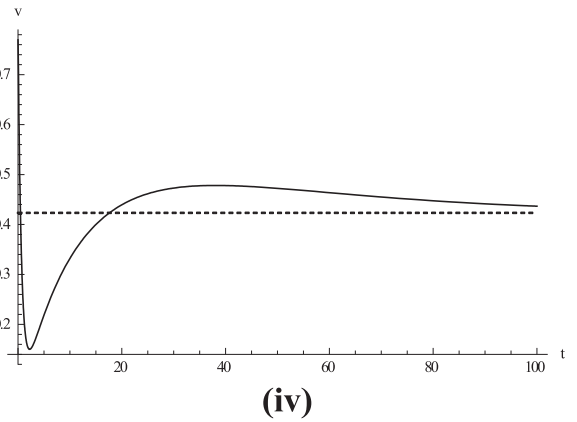
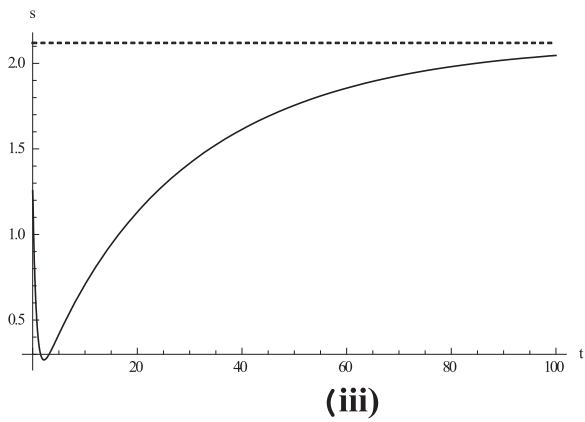
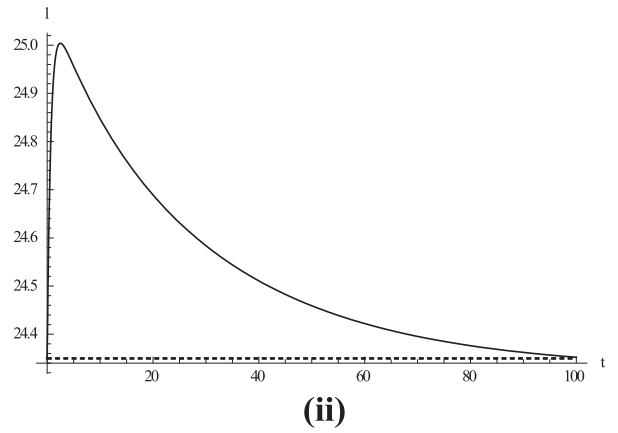
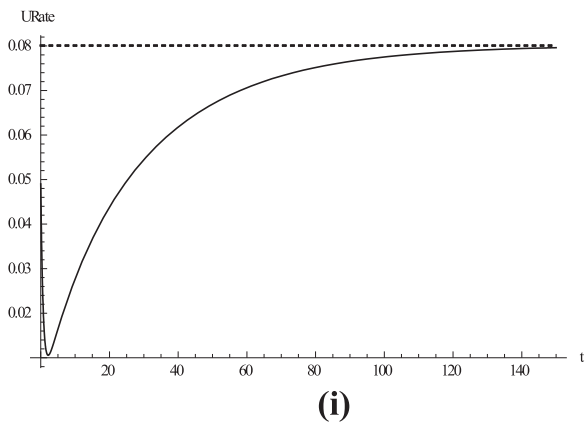
$$\tilde{\psi} = \frac{1}{1 - \varepsilon(1 + \eta)} \left[(1 - \tau_k)(\alpha A^{-\rho} \tilde{y}^{1+\rho} - \delta) - \beta \right] \quad (19)$$

This is a version of the standard relationship expressing the balanced growth rate as the difference between the after-tax rate of return on capital and the rate of time preference, multiplied by the intertemporal elasticity of substitution. Apart from the parameters appearing in (19) the key determinant of the long-run growth rate is the steady-state output-private capital ratio, $\tilde{y} \equiv (Y/K)$.

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 consumption tax rate, see Eq. (5). 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 Eq. (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 how these eventually influence the dynamics of labor, l . As is seen from the examples in Figs. 1–4, 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.

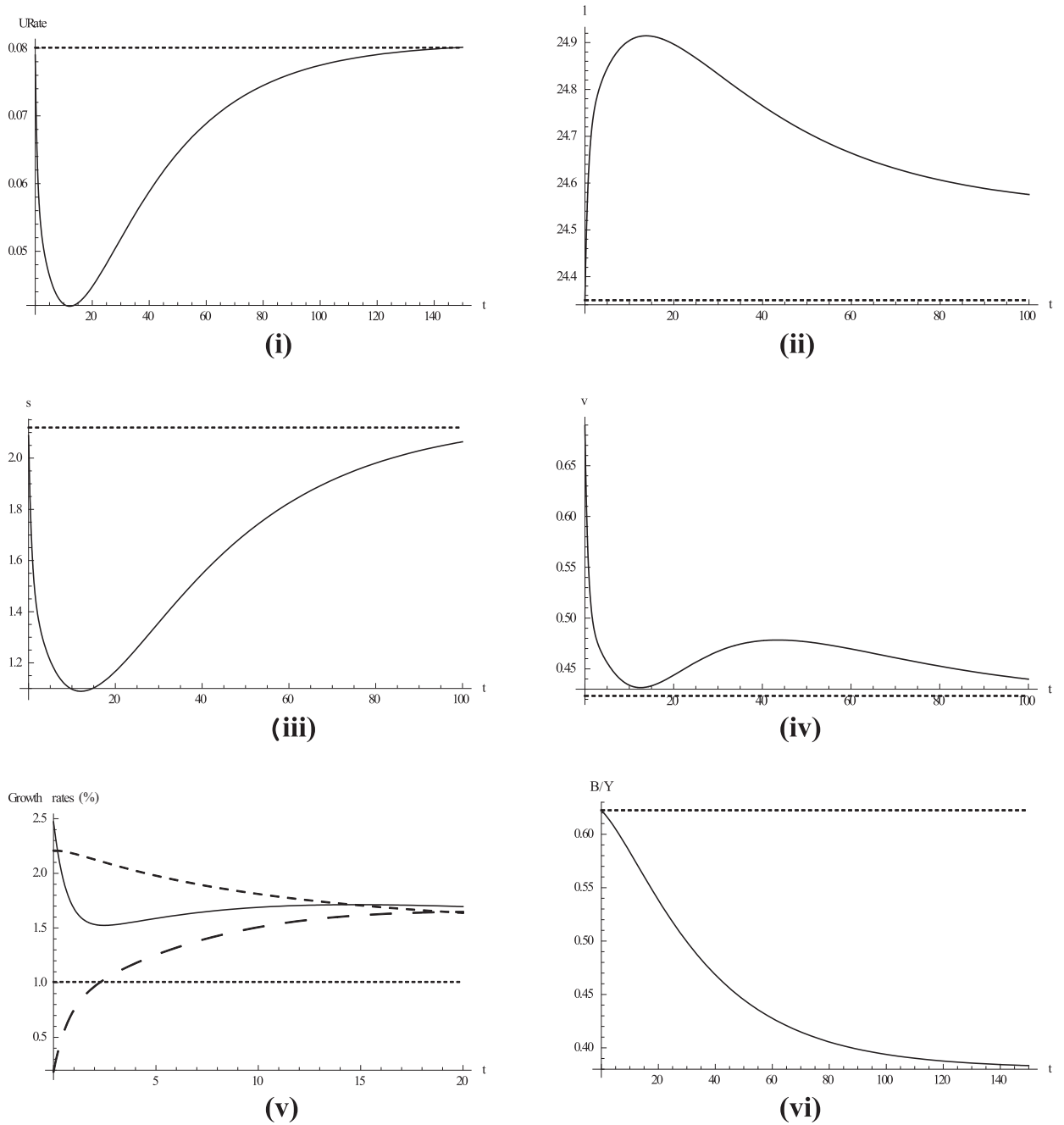
¹² We should note that European economies are in many respects quite diverse, so that in several instances parameter values are determined as averages across economies. We have also calibrated the model to reflect the US economy more closely. The main differences involve (i) the parameterization of the labor market, and (ii) substantially different tax rates. Despite these differences, the qualitative conclusions based on the European parameterization continue to hold.



Legend: dotted line: initial equilibrium

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

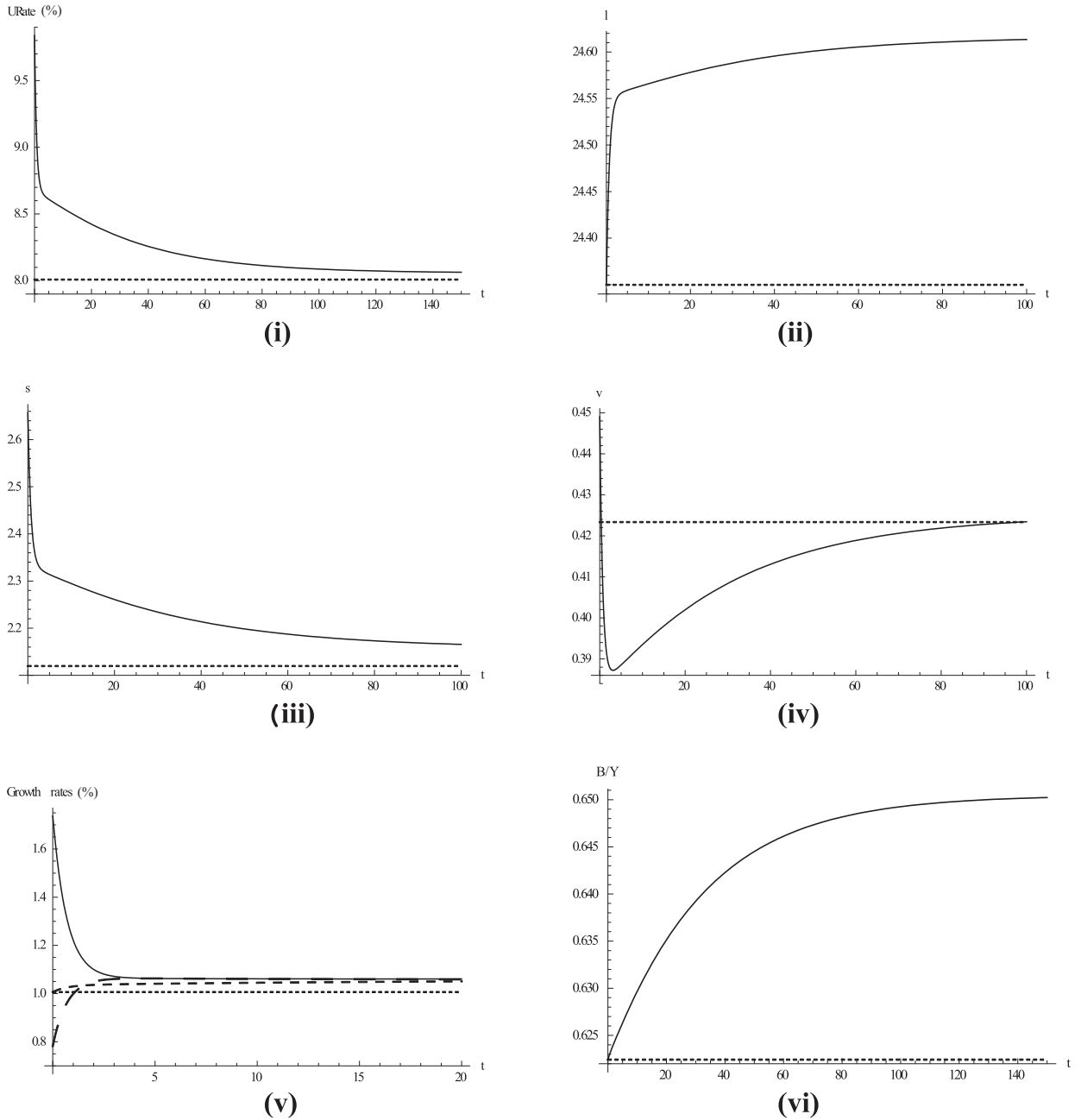
Fig. 1. Increase in TFP.



Legend: dotted line: initial equilibrium

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

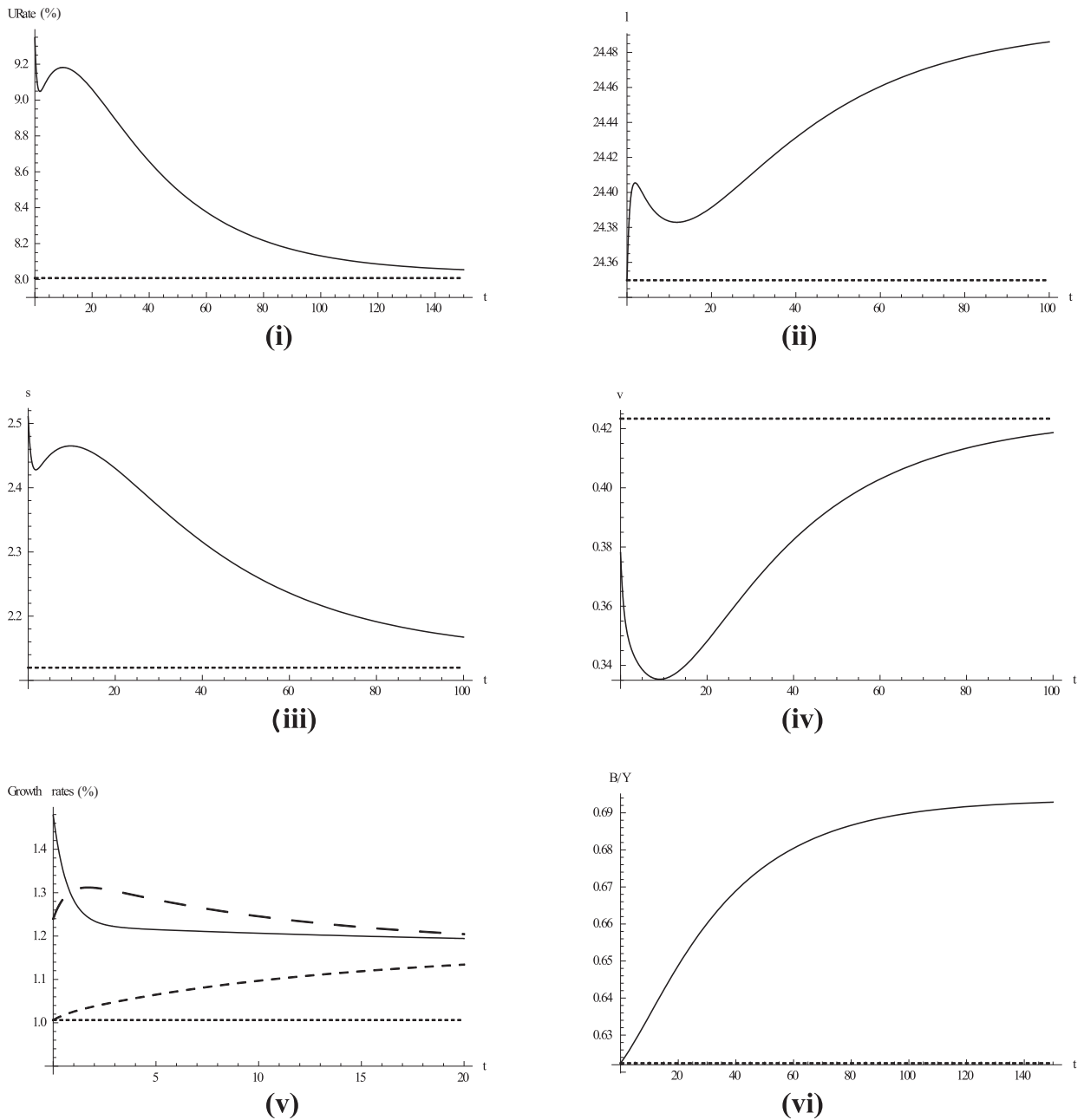
Fig. 2. Increase in public investment (infrastructure).



Legend: dotted line: initial equilibrium

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

Fig. 3. Increase in government consumption.



Legend: dotted line: initial equilibrium

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

Fig. 4. Decrease in capital income tax.

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 $A = 1.435$, $\alpha = 0.4$, $e = 0.6$ $\pi = 0.5$, $\Lambda = 1.789$, $\sigma_u = 0.50$	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: $e = 0.70$	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 $A = 1.435$, $\alpha = 0.4$, $e = 0.6$ $\pi = 0.5$, $\Lambda = 1.789$, $\sigma_u = 0.50$	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

In steady state, however, the unemployment rate is given by

$$\tilde{u} = \frac{\zeta}{\phi(\tilde{x}) + \zeta} \quad (20)$$

It depends only on the structural parameters job separation rate, ζ , and the matching function parameters χ , Λ , which enter the job finding rate $\phi = \Lambda(\chi)^{\chi}$. Hence, any change in the long-run unemployment rate must occur either through a change in labor market tightness, \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. Similarly, 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 Eq. (19)) 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 changes relative to the benchmark economy. The first three compare the tradeoffs involving structural differences pertaining to the productivity characteristics. 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 responses of some key economic variables and the welfare changes due to the 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 Eq. (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 Eq. (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%. However, the higher reservation wage and increased government consumption affect search less than does the reduced marginal utility of wealth (see Eq. (5)). Hence, households immediately reduce their search efforts by 0.86 percentage points (from 2.12% of their time allocation to 1.26%). With employment being initially fixed, as search declines the unemployment rate immediately drops to 4.9%.¹³ Increased private consumption and public consumption (the latter tied to GDP via (13)) and less search (more leisure) all increase the household's utility, resulting in an instantaneous welfare gain of roughly 6.78%.¹⁴

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 same time, the higher employment level reduces the incentive for households to search 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 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.

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 four forms of expansionary fiscal policy – increases in the two forms of government expenditure, g_K, g_C , and decreases in the two tax rates, τ_k, τ_w .¹⁵ 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. 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.

¹³ 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.

¹⁴ The welfare changes are calculated as equivalent variations in the (initial level) of the capital stock, compared to the baseline equilibrium.

¹⁵ In Schubert and Turnovsky (2017) we also consider an equivalent reduction in τ_c . The responses are qualitatively very similar to the corresponding reduction in τ_w .

Table 4

Fiscal policy and growth-unemployment tradeoffs.

A. Short run				
	$u(0)$ (%)	$\psi_y(0)$ (%)	$\psi_k(0)$ (%)	$\Delta W(0)$ (%)
Benchmark	8.008	1.006	1.006	–
$A = 1.435, g_K = 0.05, g_C = 0.16,$				
$\tau_k = 0.17, \tau_w = 0.36, \tau_c = 0.21, \sigma_u = 0.5$				
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
B. Long run				
	\tilde{u} (%)	$\tilde{\psi}$ (%)	\tilde{V}/K_0	$\Delta \tilde{W}$
Benchmark	8.008	1.006	0.507	–
$A = 1.435, g_K = 0.05, g_C = 0.16,$				
$\tau_k = 0.17, \tau_w = 0.36, \tau_c = 0.21, \sigma_u = 0.5$				
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

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_C , 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.¹⁶ 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 5.30%, 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

¹⁶ In comparing the 1 percentage point increase in g_K with the 5% increase in TFP we should note that these are roughly comparable in the sense that they both increase the steady-state y/k ratio from 0.42 to approximately 0.44.

9.84%. Since the increase in government consumption exceeds the decrease in private consumption, while output remains fixed instantaneously, 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 (ν drops to 0.40) causing further employment to increase at a much slower rate.¹⁷ 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, 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 25.15%.

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 reduction in τ_w 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, which increases by 0.73 percentage points.¹⁸ 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.

¹⁷ Note that here ν is measured as fraction of total time, which is normalized to 1.

¹⁸ The effect of the increase in the after-tax reservation wage on search outweighs the effect of the decline in marginal utility of wealth.

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.¹⁹ 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 25.31%. The welfare gain is less than for the equivalent capital income tax cut and reflects the more modest unemployment-growth tradeoff involved.

7. Some policy implications

Comparing the responses to the 4 normalized fiscal expansions summarized in Table 4 and illustrated in Figs. 2–4 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 preferred 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”.²⁰ 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).²¹

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 characteristics 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

¹⁹ Since the transitional paths followed by the key variables are similar to those in response to an increase in g_c they are not illustrated, although they are provided in the working paper version of this paper.

²⁰ 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.

²¹ 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. Policy implications are discussed in further detail in Schubert and Turnovsky (2017).

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 financing the government investment using 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.

Appendix. Steady state

In steady state, all ratios and growth rates remain constant, and $\dot{x} = \dot{s} = \dot{l} = \dot{\omega} = 0$. The following are the key relationships characterizing the steady state:

Production function, normalized in terms of Y/K

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

Equality of growth rates of consumption, private capital, and public capital

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

$$\tilde{\psi} = (1 - g_k - g_c - m \tilde{s} \tilde{x}) y(\tilde{k}, \tilde{l}) - \delta - \tilde{c} \quad (\text{A.1c})$$

$$\tilde{\psi} = g_k \frac{y(\tilde{k}, \tilde{l})}{\tilde{k}} - \delta_c \quad (\text{A.1d})$$

Stationarity of labor market, constancy of vacancy-search ratio, and equilibrium time allocation

$$\tilde{s} \tilde{x} \varphi(\tilde{x}) = \zeta \tilde{l} \quad (\text{A.1e})$$

$$\tilde{s} = (1 - \tilde{l} - \tilde{l}) \quad (\text{A.1f})$$

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

The steady state wage-capital ratio $\tilde{\omega} = \tilde{\omega}_N$

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

Steady-state marginal rate of substitution between consumption and leisure (reduced form)

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

Eqs. (A.1a)–(A.1i) 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 steady-state quantities immediately follow. Thus, vacancies, $\tilde{v} = \tilde{s} \tilde{x}$, while the steady-state unemployment rate $\tilde{u} = \zeta / [\phi(\tilde{x}) + \zeta]$ is a function of \tilde{x} and of parameters. 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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