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ACCOUNTING FOR U.S. POST-WAR ECONOMIC GROWTH

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We apply the Chari et al. (2002, 2007) methodology to develop a growth accounting exercise for the U.S. economy during 1954–2017. Unlike them, we focus on perfect foresight models. We obtain three primary findings. First, the efficiency wedges in the entire period accurately account for the evolution of U.S. productivity and labor share. Second, the labor wedge was the main force driving the recovery of output and worked hours per capita in the eighties and nineties as well as after the Great Recession. Finally, if we replace the Cobb-Douglas assumption with a production function, which allows the factor shares to adjust competitively, the forces driving the U.S. Great Recession might not be very different from those in other OECD economies, and the forces driving the 1982 recession in the United States.

Keywords: Growth Accounting, Capital-Efficiency Wedge, Labor-Efficiency Wedge, Labor Wedge, Investment Wedge, Resource Constraint Wedge, Productivity, Labor Share, Worked Hours.

JEL classification: E1, E3, O4.

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I. Introduction

According to the evolution of output per capita and worked hours per capita, U.S. economic growth after World War II (WWII) can be divided in five periods (see Figure 1): (i) *The Long Boom* between $1954 - 1969$, a period of high growth of output per capita and when worked hours per capita remained roughly stable ; (ii) *The First Growth Slowdown* between $1969 - 1982$, a period of low economic growth and decline in worked hours per capita; (iii) *The Great Moderation* between $1982 - 1999$, a period in which the growth rate of output per capita was around its average, but worked hours per capita experienced strong increase; (iv) *The Second Growth Slowdown* between $2000 - 2010$, starting with the dot com bubble burst and finishing with the Great Recession. It was a period of low growth of output per capita and strong decline in worked hours per capita; (v) *The Great Recession Recovery* after 2010, a period in which worked hours per capita experienced strong recovery, while growth of output per capita returned close to its average rate during $1954 - 2017$.

The data raise some questions. Why did the U.S. economy experience a lasting period of high economic growth after the end of WWII? Why did growth reduce after the beginning of the seventies and after the beginning of this century? Why did worked hours per capita experience strong increase in the eighties and nineties? What did the Great Recession cause?

At least from the 1950s, economists have performed growth accounting exercises using the neoclassical growth model to guide economic theory, answering such questions. Solow (1956) calculated his famous residue and concluded that to understand sustained economic growth, we had to go beyond the accumulation of productive inputs and analyze the determinants of his productive efficiency. Kydland and Prescott (1982) argued that shocks on efficiency of productive inputs was the main mechanism impulsing the economic cycles.[1] Prescott (1998) concluded that if we want to understand the enormous differences in per capita income across countries, we need understand why the efficiency of productive inputs is so different across countries. However, these authors confined their focus on the production function.

More recently, Cole and Ohanian (2002), Chari et al. (2002, 2007), and Ohanian and Raffo (2012) perform business accounting exercises using the whole neoclassical growth

[1] The Real Business Cycle Theory follows the approach of Frisch (1933) and Slutzky (1937) who emphasized the exogenous productivity shocks being the impulse mechanism of the economic fluctuations.

model. They conclude that to account for the U.S. post-WWII recessions, we need to understand the reasons behind the worsening of some economic distortions, expressed as wedges in the equilibrium conditions of the standard neoclassical growth model, and not merely the changes in productive efficiency of inputs. In particular, it is necessary to understand the changes in the labor wedge (i.e., in the relationship between the marginal productivity of labor and the marginal rate of substitution between consumption and leisure).

Here, we also use the whole neoclassical growth model to perform a growth accounting exercise for the U.S. economy. However, we primarily focus on the whole macroeconomic performance after WWII, not just on recessions, despite discussing the role of wedges in the main U.S. post-WWII recessions. Our objective is identify the main forces driving U.S. economic growth after WWII.

The accounting growth method has two steps. First, using data with the equilibrium conditions of the neoclassical growth model, it measures the wedges representing the overall distortions to the relevant equilibrium conditions of the model. Second, the measured wedge values are fed back into the neoclassical growth model, one at a time, to assess how much of the observed movements of output, labor, investment, and factor shares in the period $1954-2017$ can be attributed to each wedge. Simulating the model for each wedge alone, we calculate the wedge-alone component of each variable due to each wedge, which reflects the contribution of each wedge to the evolution of the variable in the period $1954-2017$. This growth accounting method reveals the mechanisms through which fundamental processes drive economic performance. Therefore, it is a methodology for determining the most promising type of theories on the primary characteristics of U.S. post-war economic growth.

We compute the wedges and simulate the model using a Cobb-Douglas (CD) production function and a Variable Elasticity of Substitution (VES) production function. Both functions belong to the family of production functions proposed by Kadiyala (1972), which also includes the CES production function. The VES production function allows to account for the post-WWII evolution of the U.S. labor share, which has experienced a particularly steep decline from the beginning of this century. Under a VES specification of the production function, five are the computed wedges as follows: capital-efficiency wedge, labor-efficiency wedge, investment wedge, labor wedge, and the resource constraint wedge. The capital-efficiency wedge and the labor-efficiency wedge are the gaps between capital and hours engaged in production, and given a factor income distribution, optimal capital and optimal labor needed to reach a certain level of output. The labor wedge reflects the gap between the marginal rate of substitution between consumption and leisure and the marginal product of labor. The investment wedge reflects the gap between the intertemporal marginal rate of substitution and the return to capital. The resource constraint wedge reflects the difference between output and its allocation to consumption and investment. Under a CD specification of the production function, the output elasticity for the productive factors is constant, and we can only compute four wedges. In particular, we compute an efficiency wedge reflecting Total Factor Productivity (TFP).

Departing from the CD hypothesis, in addition to allowing us to account for the evolution of U.S. factor income shares, has significant consequences on the calculation of wedges. If we assume a CD production function, changes in the labor share are imputed to the labor and investment wedges. In particular, a fall in the labor share will be compute as a decrease in the labor wedge, and an increase in the investment wedge. In addition, leaving the CD assumption allows us to calculate an efficiency wedge for each productive factor, while using a CD specification of the production function, we can only compute an efficiency wedge reflecting TFP. The change rate of TFP equals the weighted sum of the change rates of the efficiency wedges of the productive factors, being the weights of the respective output elasticities for each factor. Therefore, if the capital-efficiency wedge and the labor efficiency wedge are moving in opposite directions, a small change rate of the TFP might be computed even if both efficiency wedges are undergoing large changes. Moreover, under the CD assumption, the TFP is calculated assuming that the output elasticities for both factors are constants; however, under the VES assumption, the efficiency wedges are computed assuming that output elasticity for labor is equal to the labor share. Therefore, a fall in the labor share results in a fall of the computed TFP under the VES assumption, but not in the computed TFP under the CD assumption. This implies that if the labor share is declining because the output elasticity for labor is falling (which should be the case if the marginal returns of the productive factors equal their rental prices), then a CD specification of the production function overestimates the changes in the labor wedge and underestimates the changes in both the investment and efficiency wedges. It is important take this into account, because of the strong fall in the U.S. labor share from the beginning of this century, and particularly, in the Great Recession.

Here, similar to Cole and Ohanian (2002) and Ohanian and Raffo (2012), we use the deterministic version of the neoclassical growth model to perform our accounting exercise.

However, unlike them, we compute the entire paths of the five wedges mentioned above. Chari et al. (2002, 2007) use the stochastic version of the neoclassical growth model to compute the paths of the wedges and perform their business cycle accounting. [2] To use the neoclassical growth model in its deterministic version implies the assumption of perfect foresight; however, more interestingly, it allows using the nonlinear version of the first-order conditions to compute the wedges and simulate the model, whereas Chari et al. (2002, 2007) use log-linearized versions of these conditions.[3] This is an important point because our estimations suggest that the U.S. economy was transitioning between two different balanced growth paths during the analyzed period and the transitional dynamics might be relevant for the quantitative results. Moreover, using the deterministic version of the neoclassical growth model instead of the stochastic model enables us to use a different method of Chari et al. (2007) to compute the wedges. This different method is relevant in computing the investment wedge. Brinca et al. (2016) develop the stochastic model and compare it with the deterministic model; however, they use a different method than proposed in this study when they compute the investment wedge in the deterministic model. In particular, they set the initial value of the investment wedge to be 1, while we compute the whole path of the wedge consistent with the equilibrium path converging to the Balanced Growth Path (BGP) previously calibrated.

Our results show that the efficiency wedges accurately account for the evolution of productivity and labor share of the U.S. economy in the period $1954 - 2017$. Therefore, we can conclude that our accounting exercise does not call into question the validity of the usual focus of the growth literature on understanding and explaining the efficiency of productive inputs, as the engines of productivity growth. The U.S worked hours per capita did not display any significant long-run trend between 1954 and 2017, which can be accounted, because two forces worked in opposite directions. On one hand, the fall in the resource constraint wedge pushed worked hours per capita down. On the other hand, the increase in the labor wedge pushed worked hours per capita up. Moreover, our results show that the fast economic growth of the fifties and sixties was driven by the increase in the efficiency wedge (in particular, the labor-efficiency wedge if a VES

[2]Other authors have followed in their steps: Cavalcanti (2007), Chakraborty and Otsu (2013), Chakraborty (2006), Cho and Doblas-Madrid (2013), Kersting (2008), Kobayashi and Inaba (2006), Otsu (2010), Sustek (2011), Brinca (2013, 2014), Brinca et al. (2016). None of the previously cited works use a VES production function; they all use CD production functions.

[3]To compute the wedges, we use annual data instead of quarter data, which are more suitable for the deterministic model and the implicit assumption of perfect foresight.

production function is specified). If a VES production function is specified, the main force driving the growth slowdown and the fall in worked hours in the seventies and the first decade of this century was the decrease in the capital-efficiency wedge. However, if a CD production function is specified, the main force driving the growth slowdown and the fall in worked hours in the first decade of this century was the labor wedge. The efficiency wedge was the main force driving the growth slowdown and the fall in worked hours in the seventies. If the First Growth Slowdown in the seventies is compared with the Second Growth Slowdown in this century, we observe the same fact: the VES specification of the production function tends to reduce the importance of the labor wedge. This is because in both periods, the labor share experiences a significant decrease. Under both specifications of the production function, the following result is clear: the labor wedge was the main force driving the economic recovery in the eighties and the boom of worked hours in the nineties as well as the economic recovery of the Great Recession. Finally, we find that the investment wedge played a secondary role in accounting for the evolution of the main U.S. macroeconomic magnitudes in the period $1954 - 2017$. Notably, the increase in the investment wedge contributed to mitigate the economic crisis of the seventies; however, its decline also contributed to slow the subsequent recovery in the eighties.

Our results suggest that to understand the Long Boom, we need to analyze the economic forces that provoked the strong increase in the labor efficiency wedge in the fifties and sixties. To understand the long periods of growth slowdown and decrease in the use of the labor factor in the seventies and in this century, we must focus on the circumstances influencing the capital-efficiency wedge and the labor wedge. However, to understand the periods of economic recovery requires focusing on the circumstances influencing the increase in the labor wedge.

The remainder of this paper is organized as follows. Section II puts our results in context. Section III describes the model, which is also calibrated. The wedges are computed in Section IV. In Section V, the model is simulated to assess the contribution of each wedge to the evolution of output, worked hours, and investment in the United States in the period $1954 - 2017$. We discuss the implications of the specification of the production function in measuring the wedges in Section VI. Section VII analyzes the role of the wedges in the 82' recession and in the Great Recession. Section VIII analyzes the role of different wedges in the OECD countries. Finally, Section IX concludes.

II. Results in context

First, our study relates to the plentiful literature that computes the famous Solow residual after the pioneering work by Solow (1957). It also relates to other studies that have calculated and analyzed other wedges (Chari et al., 2007, review this literature). However, in line with Chari et al. (2002, 2007) and Brinca et al. (2016), we do not confine ourselves to computing the efficiency wedge or any other wedge, but a set of wedges, which allows us to reconcile the model and the data. However, these authors focus on economic recessions, while we adopt a broader perspective, examining the U.S. post-WWII economic growth. Our study also relates to del Río and Lores (2019) in which, using a VES production function, the authors show that the evolution of capital efficiency can accurately account for the evolution of the U.S. labor share after WWII.

To relate our study to previous ones (Chari et al., 2007, Brinca et al., 2016, and Ohanian and Raffo 2012), we have assessed the contribution of different computed wedges to the evolution of output, investment, and labor during the two main recessions suffered by the U.S. economy in the post-war period: the recession at the end of the seventies and the beginning of the eighties, which Brinca et al. (2016) call *the 1982 Recession* and the 2008 crisis usually called the *Great Recession*.[4]

Chari et al. (2007) find that the efficiency and labor wedges play primary roles in accounting for the evolution of output, labor, and investment in the 1982 Recession, and the investment wedge has essentially no role. Ohanian and Raffo (2012) find that the labor wedge accounts for almost all the fall in U.S. output per capita in the Great Recession while the efficiency wedge explains only about 20% of its drop and almost none of the drop in hours. Brinca et al (2016) find a similar result; in the U.S. Great Recession, the labor wedge had a predominant role, while the investment wedge also had an important, but secondary role. However, the efficiency wedge is not important. When using the CD specification of the production function, we also find results that although not alike in detail to those obtained by Ohanian and Raffo (2012) and Brinca et al. (2016) go along the same lines: the efficiency wedge played a prominent role in the U.S. 1982 recession and the labor wedge played a prominent role in the U.S. Great Recession.

However, we obtain different findings under the VES assumption. For the Great Recession, we find that the strong decline in the capital efficiency wedge was the main force

[4]Cole and Ohanian (2002) and Chari et al. (2002) focus on the Great Depression, as do Chari et al. (2007).

driving the drop in output, investment, and worked hours, while the investment and labor wedges played significant, but secondary roles. For the 1982 Recession, the capital efficiency wedge also played a prominent role, while the labor wedge had a significant, but secondary role. Finally, the investment wedge played a negligible role. Therefore, the VES specification of the production function contributes to homogenize the economic performance of the United States in both recessions. We find that the increase in the labor wedge was the main force driving the recovery of worked hours, investment, and output, after both recessions. This is similar to Kersting (2008), who finds that the improvement in the labor wedge was necessary for the recovery of the UK economy, starting in 1984.

Brinca et al. (2016) apply the business accounting methodology to the OECD countries and find that the United States is the only OECD country in which the labor wedge played a dominant role in the Great Recession. Ohanian and Raffo (2012) also find that the drop in the labor wedge, and its contribution to the decrease in growth and worked hours during the Great Recession was much higher in the United States than in other advanced economies (see also Ohanian, 2010). These authors assume a CD production function in their works. However, our findings suggest that if we replace the CD assumption by a production function allowing that the factor shares adjust competitively, the forces driving the U.S. Great Recession might not be very different from the working forces in other OECD economies, and from the forces driving the U.S. 1982 Recession.

III. The Model

A perfectly competitive representative firm produces output, Y_t, according to a VES production function and using as production factors, capital, K_t, and labor, $H_t = h_t L_t$, where h_t is worked time per worker and L_t the number of workers (which equals population), ,

$$Y_t = \left(\alpha \left(q_t K_t\right)^{\omega\psi} \left(z_t \left(1+\gamma\right)^t H_t\right)^{(1-\omega)\psi} + (1-\alpha) \left(z_t \left(1+\gamma\right)^t H_t\right)^{\psi}\right)^{\frac{1}{\psi}}$$

where $\psi \leq 1$, $0 < \alpha < 1$, $0 < \omega < 1$, $\gamma \geq 0$ is the rate of labor-augmenting technological progress, q_t is the *capital-efficiency wedge* and z_t is the *labor-efficiency wedge*. Therefore, detrended output per worker, $y_t = \frac{Y_t}{(1+\gamma)^t L_t}$, is given by

$$y_t = \left[\alpha \left(q_t k_t\right)^{\omega\psi} \left(z_t h_t\right)^{(1-\omega)\psi} + (1-\alpha) \left(z_t h_t\right)^{\psi}\right]^{\frac{1}{\psi}}, \tag{1}$$

where $k_t = \frac{K_t}{(1+\gamma)^t L_t}$ is detrended capital per capita. The representative firm hires capital and labor to equalize their marginal productivities to their rental prices (r_t and W_t),

$$s_t = r_t \frac{k_t}{y_t} \equiv s_{k,t} \tag{2}$$

and

$$1 - s_t = w_t \frac{h_t}{y_t} \equiv s_{h,t}, \tag{3}$$

where $w_t = \frac{W_t}{(1+\gamma)^t}$ is detrended wage per worked hour and

$$s_t = \alpha\omega \left(q_t \frac{k_t}{y_t} \right)^{\omega\psi} \left(z_t \frac{h}{y_t} \right)^{(1-\omega)\psi} \tag{4}$$

is output elasticity for capital and $1 - s_t$ is output elasticity for labor. According to the first order conditions (2) and (3), the capital share, $s_{k,t}$, equals output elasticity for capital and the labor share, $s_{h,t}$, equals the output elasticity for labor. Moreover, both factor shares add 1.

The resource constraint is $Y_t(1 - g_t) = C_t + X_t$, where C_t is household consumption, X_t is investment, and g_t is the *resource constraint wedge*, which is the fraction of output not allocated to investment or consumption. The resource constraint can be rewritten in terms of the detrended variables per capita as follows:

$$c_t + x_t = (1 - g_t) y_t, \tag{5}$$

where $c_t = \frac{C_t}{(1+\gamma)^t L_t}$ is detrended consumption per capita and $x_t = \frac{X_t}{(1+\gamma)^t L_t}$ is detrended investment per capita.

Capital evolves according to the following move law, which includes quadratic investment adjustment costs,

$$K_{t+1} = X_t + (1 - \delta_t) K_t - \frac{\phi}{2} \left(\frac{X_t}{K_t} - \kappa \right)^2 K_t,$$

where $\phi > 0$, $\kappa > 0$ and $0 < \delta_t < 1$ is the economic depreciation rate of capital at time t. The move law of capital can be rewritten in terms of the detrended variables per capita as follows:

$$\left(1+\eta_{t+1}\right)\left(1+\gamma\right)k_{t+1}=x_t+\left(1-\delta_t\right)k_t-\frac{\phi}{2}\left(\frac{x_t}{k_t}-\kappa\right)^2 k_t \tag{6}$$

where η_{t+1} is the population growth rate between t and $t+1$, $\frac{L_{t+1}}{L_t}=1+\eta_{t+1}$.

The representative household at time t is composed of L_t members. Each member of the representative household is endowed with one unit of time, which can be shared between leisure and labor in return for a wage, W_t. Therefore, at equilibrium, $H_t=L_t h_t$, where $1<h_t<0$ is time offered in the labor market by a member of the representative household. The intertemporal utility function of the representative household is

$$U_t=\sum_{t=0}^{\infty}L_t\beta^t\left[\log C_{L,t}+\mu\log\left(1-h_t\right)\right]$$

where $1-h_t$ is leisure per capita, $0<\beta<1$ is the discount factor, $C_{L,t}=\frac{C_t}{L_t}$ is consumption per capita and $\mu>0$ is the value of leisure relative to consumption. The household budget constraint is

$$N_t C_{L,t}+\pi_{x,t}X_t=\pi_{h,t}W_t h_t L_t+r_t K_t+B_t$$

where B_t are lump-sum transfers, $\pi_{h,t}$ is the *labor wedge* and $\pi_{x,t}^{-1}$ is the *investment wedge.*

The first-order conditions characterizing a maximum of the household problem are

$$\frac{1}{\beta}\left(1+\gamma\right)\frac{c_{t+1}}{c_t}=1+i_{t+1} \tag{7}$$

$$r_{t+1}=\frac{\pi_{x,t}\left(1+i_{t+1}\right)}{1-\phi\left(\frac{x_t}{k_t}-\kappa\right)}+\frac{\pi_{x,t+1}}{1-\phi\left(\frac{x_{t+1}}{k_{t+1}}-\kappa\right)}\cdot$$
$$\cdot\left[\frac{\phi}{2}\left(\frac{x_{t+1}}{k_{t+1}}-\kappa\right)^2-\phi\left(\frac{x_{t+1}}{k_{t+1}}-\kappa\right)\frac{x_{t+1}}{k_{t+1}}-\left(1-\delta_{t+1}\right)\right] \tag{8}$$

$$\mu\frac{c_t}{1-h_t}=\pi_{h,t}w_t \tag{9}$$

Here i_{t+1} is the interest rate at time $t+1$. Equation (7) is the Euler equation, according to which the marginal rate of intertemporal substitution equals the gross interest rate. Equation (8) establishes that the rental price of capital equals its user cost which, in addition to the interest rate and the economic depreciation rate, also includes the investment wedge and the investment adjustment costs. Equation (9) states that the marginal rate of substitution between consumption and leisure equals the wage adjusted by the labor wedge.

Given the seven exogenous variables $\{q_t, z_t,\ g_t, \pi_{x,t}, \pi_{h,t}, \delta_t,\ \eta_{t+1}\}_{t=0}^{\infty}$, equation system (1)-(9) together with the transversality condition and an initial condition for the detrended capital per capita, k_0, characterize the dynamic behavior of the economy.

III.1. Calibrating the Balanced Growth Path (BGP)

Along a BGP, both the population growth rate and the economic depreciation rate are constants, $\eta_t = \eta$ and $\delta_t = \delta$, and there are not adjustment costs, $\frac{x_t}{k_t} = \kappa$. Moreover, along a BGP, the resource constraint wedge, g_t, the investment wedge, $\pi_{x,t}$, the labor wedge, $\pi_{h,t}$, the capital-efficiency wedge, q_t, and the labor-efficiency wedge, z_t, remain constant as well as c_t, x_t, k_t, h_t, w_t, y_t and i_t.[5] Given q, z, π_x, π_h, and g, the following equations characterize a BGP:

$$\frac{1+\gamma}{\beta} = 1 + i \tag{10}$$

$$(1+\eta)(1+\gamma) - (1-\delta) = \frac{x}{k} \tag{11}$$

$$sy = \pi_x (i+\delta) k \tag{12}$$

$$(1-s) y = wh \tag{13}$$

$$\mu \frac{c}{1-h} = \pi_h w \tag{14}$$

$$s = \alpha\omega \left(q\frac{k}{y}\right)^{\omega\psi} \left(z\frac{h}{y}\right)^{(1-\omega)\psi} \tag{15}$$

$$y = \left[\alpha (qk)^{\omega\psi} (zh)^{(1-\omega)\psi} + (1-\alpha)(zh)^{\psi}\right]^{\frac{1}{\psi}} \tag{16}$$

$$c + x = (1-g) y \tag{17}$$

The equation (10) is the Euler equation. The equation (11) establishes that the accumulation of capital is such that the ratio of investment to capital is constant. The equations

[5] Of course, if q_t is constant, the production function displays purely labor-augmenting labor technical progress, which is a necessary condition for the existence of a BGP (see Uzawa (1961) and Jones and Scrimgeour (2004)).

(12) and (13) are the profit-maximizing conditions of the representative firm that equalize the marginal productivities of capital and labor to their rental prices. The equation (14) establishes that the marginal relation of substitution between leisure and consumption equals the wedge-adjusted wage rate. The equation (15) gives the output elasticity for capital. The equation (16) is the production function. The equation (17) is the resource constraint.

According to our strategy, we restrict the values of the parameters of the model such that they are compatible with observations from the U.S. economy. (i) We set $x/y = 0.28$, which is approximately the average value of the U.S. ratio in the period $1954 - 2017$ and $c/y = 0.62$, which is around the U.S. average ratio in the last years of the sample.[6] (ii) According to NIPA data, in 2017, the ratio of the current-cost depreciation of NIPA fixed assets to the current-cost net stock of NIPA fixed assets was about 6.4%. Therefore, we set $\delta = 0.064$. (iii) We set $\gamma = 0.0163$ and $\eta = 0.0118$, which are the annual average growth rates of output per worker and population in the United States in the period $1954 - 2017$. (iv) According to our calculations using NIPA data, the U.S. average annual gross labor share in the period $1954 - 2017$ was about 64%. Thus, we set $\frac{wh}{y} = 0.64$. (v) According to our calculations, the U.S. average annual worked hours in the period $1954 - 2017$ represented 22% of annual available time by U.S. non-institutional population between 16 and 64 years; we then set $h = 0.22$. (vi) We set the same annual interest rate as Brinca et al. (2016), $i = 0.04$. (vii) We set $\psi = -1.9$ and $\omega = 0.5$, which are values near the estimated values by del Río and Lores (2019). In particular, del Río and Lores (2019) estimate $\psi = -1.9$ and $\omega = 0.36$. We consider a value of ω higher than the estimated value by del Río and Lores (2019) because to have well-defined series for z_t and q_t, it is necessary that $\omega > s_{k,t}$ for all t. This is because according to the proposed VES production function, ω is an upper bound on the capital share, $s_{k,t}$. (viii) The relative value of leisure is normalized to 1, $\mu = 1$, as well as detrended output per capita, $y = 1$. (ix) We set $\alpha\omega = 0.36$ so that the VES production function converges to a Cobb-Douglas production with output elasticity for capital 0.36. Therefore, $\alpha = 0.72$. (x) Along a BGP, the investment-capital ratio is given by (11),and hence, $\kappa = (1 + \eta)(1 + \gamma) - (1 - \delta) = 0.092$. The function of adjustment costs is quadratic, which is usual in macroeconomic literature and Brinca et al. (2016) use it too. To perform the quantitative analyses, we follow Brinca et al. (2016) and set $\phi = 0.25/\kappa = 2.7174$ to obtain elasticity of the price of capital with

[6] For $\frac{c}{y}$, we do take the average of the period, because this ratio has undergone a significant increases between the mid-fifties and 2017.

respect to the investment-capital ratio of 0.25. Calibrated parameters, variables, and wedges are calculated by solving the equation system (10)-(17) and are displayed in Table 1.

To compare our results with others in the literature, we compare the results obtained from the simulations using our VES production function, with the results obtained from the simulations using the CD production function, arising as a limit case of the VES production function, when ψ goes to 0. In particular, the production function $Ak^{\alpha\omega}h^{1-\alpha\omega}$, where $A = q^{\alpha\omega}z^{1-\alpha\omega}$is Total Factor Productivity or the efficiency wedge. Solving the equation system (10)-(17) with the CD production function, the same variables, parameters, and wedges are calibrated than in the VES case, except that $A = 1.7674$. The CD specification of the production function does not allow identifying q and z, but only the Total Factor Productivity (TFP), A. In the VES case, TFP is $A = q^{s}z^{1-s}$, where s is output elasticity for capital. Under our assumptions, $s = s_k$, and in the VES case, we calculate TFP, as $A = q^{s_k}z^{1-s_k}$

IV. The wedges

In this section, we compute the wedges allowing to match the model and the U.S. data for the period 1954 – 2017. Our strategy is (i) compute the paths of the wedges and the path of detrended capital per capita consistent with the U.S. observations on worked hours per capita, labor share, consumption per capita, investment per capita, and output per capita in the period 1954 – 2017, assuming that the economy is converging to the previously calibrated BGP. Our strategy does not only yields wedges for the observed period but also for the future. The results are not very sensitive to the calibrated final BGP given the property of rapid convergence of the neoclassical growth model.

IV.1. Computing the wedges

The wedges are computed in both VES and CD cases. In the CD case, only the path of the efficiency wedge (i.e. TFP), A_t, can be identified, and not the paths of the efficiency wedges of each factor, q_t and z_t; furthermore, there are four wedges. In the VES case, the path of the TFP is calculated as $A_t = q_t^{s_{k,t}} z_t^{1-s_{k,t}}$. To compute the wedges with the calibrated parameters above, we solve the equilibrium equation system given by (18)-(23) for k_{t+1}, $\pi_{x,t}$, $\pi_{h,t}$, g_t, q_t, and z_t, given the observed paths of η_{t+1}, y_t, c_t, x_t, $s_{k,t}$, δ_t and h_t

in the period 1954 − 2017, and an initial condition for capital k_0

$$c_t + x_t = (1 - g_t)\, y_t \tag{18}$$

$$(1 + \eta_{t+1})(1 + \gamma)\, k_{t+1} = x_t + (1 - \delta_t)\, k_t \tag{19}$$

$$\alpha \left(q_t k_t\right)^{\omega\psi} \left(z_t h_t\right)^{(1-\omega)\psi} + (1 - \alpha)\left(z_t h_t\right)^{\psi} = y_t^{\psi} \tag{20}$$

$$s_{k,t} = \alpha\omega \left(q_t \frac{k_t}{y_t}\right)^{\omega\psi} \left(z_t \frac{h_t}{y_t}\right)^{(1-\omega)\psi} \tag{21}$$

$$\frac{\pi_{x,t}}{1 - \phi\left(\frac{x_t}{k_t} - \kappa\right)} \frac{1+\gamma}{\beta} \frac{c_{t+1}}{c_t} = s_{k,t+1} \frac{y_{t+1}}{k_{t+1}} - \frac{\pi_{x,t+1}}{1 - \phi\left(\frac{x_{t+1}}{k_{t+1}} - \kappa\right)} \cdot$$
$$\cdot \left[\frac{\phi}{2}\left(\frac{x_{t+1}}{k_{t+1}} - \kappa\right)^2 - \phi\left(\frac{x_{t+1}}{k_{t+1}} - \kappa\right)\frac{x_{t+1}}{k_{t+1}} - (1 - \delta_{t+1})\right] \tag{22}$$

$$\mu c_t \frac{h_t}{1 - h_t} = \pi_{h,t}\,(1 - s_{k,t})\, y_t \tag{23}$$

Equation (18) is the resource constraint. Equation (19) is the capital accumulation law. Equation (20) is the production function. Equation (21) is the first order condition for capital of the representative firm. Equation (22) is the Euler condition. Finally, equation (23) is the household condition for the optimal allocation of time.

We set $k_0 = x_0 \left[(1+\eta)(1+\gamma) - (1-\delta_0)\right]^{-1}$, where γ and η are the calibrated values, $\delta_0 = 0.06$, which is around the economic depreciation rate of NIPA fixed assets and durable consumer goods in the fifties, and x_0 equals the U.S. investment rate in year 1954, $x_0/y_0 = 0.2786$, times detrended output per capita in year 1954, $y_0 = 0.87453$. Here, detrended output per capita at year t, y_t, is expressed relatively to the average detrended output per capita in the period 1954 − 2017 (e.g., $y_0 = 0.87453$ means that in year 1954, the detrended output per capita was 87.45% of the average detrended output per capita in the period 1954 − 2017), and since calibrating the BGP, we have normalized $y = 1$; hence, implicitly, we are assuming that the stationary level of detrended output per capita is the average value of this variable in the period 1954 − 2017. After 2017, we assume that variables η_{t+1}, c_t, x_t, y_t, $s_{k,t}$, δ_t and h_t follow the following process:

$$j_t = j_T \mathrm{e}^{-\lambda(t-T)} + j\left(1 - \mathrm{e}^{-\lambda(t-T)}\right)$$

where j_t is η_{t+1}, c_t, x_t, y_t, $s_{k,t}$, δ_t or h_t at period $t \geq T$, $T = 2017$ and j is the constant calibrated value above. We set $\lambda = 0.03$, which is around the speed of convergence estimated in most studies (see Barro and Sala-i-Martin, 1995). Our method allows us to compute converging paths of wedges from the initial period until infinity. In practice, we have computed 1000 periods.

The time-varying wedges together are presented in Figure 2. The main features of the evolution of wedges are as follows: (i) from the beginning of this century until 2009, the capital-efficiency wedge underwent a sharp decline. The decline in the capital-efficiency wedge in this century was similar to its large drop in the seventies. As a consequence of these two large drops, the capital-efficiency wedge has declined around 35% from the middle of the fifties until 2017. (ii) The labor-efficiency wedge experienced a significant increase from the mid-fifties until the mid-sixties and during the first decade of this century; however, it declined from the mid-eighties to the end of the nineties and after the Great Recession (after 2010). (iii) TFP increased from the mid-fifties to the early seventies, subsequently, it decreased until the early eighties, and remained roughly stable from the early eighties to the early years of this century. After this, the TFP decreased, the fall being higher in VES than in the CD. (iv) The labor wedge slightly decreased until the mid-seventies, and subsequently, experienced a strong increase until the end of the nineties. It also increased after the Great Recession (after 2010); however, it decreased from the end of the nineties, and in particular, during the Great Recession ($2007 - 2010$). The fall in this period is higher in CD than in VES. (v) The investment wedge remained roughly stable until the seventies, increased in the seventies, and decreased in the eighties. Its fall in the eighties is higher in VES than in CD and in VES it continued decreasing until de Great Recession, while in CDS remained roughly stable. (v) The resource constraint wedge remained roughly stable until mid-seventies and after experiencing a sustained decline from the middle of the seventies until the Great Recession, during which it increased significantly.

*Remark.*Average levels of the resource constraint wedge, the labor wedge, and the capital-efficiency wedge have undergone a significant change between the beginning of the analyzed period and its end (see Figure 2), which suggests that the BGP of the U.S. economy changed during the analyzed period. Therefore, it may be important to solve the non-linear equilibrium conditions. The economic depreciation rate of capital also experienced a significant increase during the analyzed period; however, its evolution is not presented in a figure, nor is the evolution of the population growth rate. Changes in the depreciation rate and the population growth rate provoke changes in the endogeneous variables in the same way that changes in the wedges do; hereafter, we ignore them, because their impact on the endogenous variables was negligible.

V. The U.S. economic growth 1954-2017

We simulate the model to assess the extent at which the evolution of the wedges can account for the evolution of output per capita, worked hours, and investment, in the United States during $1954-2017$. Ceteris paribus, the simulations of the model together with the corresponding observed variables (output, labor and investment) are displayed in each panel of Figures 3 to 5. Additionally, the evolution of detrended output per worked hour and the labor share, together with their wedge-alone component due to the efficiency wedge in both the CD and VES cases is displayed in Figure 6. The model is simulated for both the calibrated VES and CD production functions. The observed variable is displayed with a solid line and its simulated paths are displayed with a dashed-solid line (VES) and a pointed solid line (CD). For example, in panel (d) of Figure 3, the simulated paths of worked hours per capita (under both the VES and CD specification) are the result of simulating, given k_0, the equilibrium equation system (18)-(23), assuming that π_h follows the computed path above (displayed in Figure 2, panel (d)) and the remaining wedges, and both the depreciation and population growth rate remain in their steady values $q_t = q$, $z_t = z$, $g_t = g$, $\pi_{x,t} = \pi_x$, $\eta_t = \eta$ and $\delta_t = \delta$. Proceeding thus, we can isolate the effect of each wedge on each variable. In particular, in the example, the effect of the labor wedge on the evolution of U.S. worked hours per capita in the period $1954-2017$. We term the variables simulated in this way the wedge-alone components of the observed variables. The growth rates of the wedge-alone components of variables for the five subperiods in which we have divided the U.S. post-WWII growth are displayed in Table 2. In the VES case, we simulate the model jointly changing the capital-efficiency and labor-efficiency wedges to compare the results with the results obtained in the CD case.

To summarize the results, we define the σ-statistic, which captures how closely a particular component tracks the changes in the underlying variable. The σ-statistic for detrended output per capita of wedge i is

$$\sigma_i^y = \frac{1/Var_i\left(y_t - y_{i,t}\right)}{\sum_j \left(1/Var_j\left(y_t - y_{i,t}\right)\right)}$$

where $y_{i,t}$ is the wedge-alone component of output due to wedge i and $Var_i\left(y_t - y_{i,t}\right)$ is the variance of the error, (i.e., the variance of the difference between the variable and the wedge-alone component).[7] We compute similar statistics for worked hours per capita, detrended output per capita, and detrended investment per capita. The statistic lies in $[0, 1]$, sums to one across the five wedges (four under the CD assumption) and reaches its maximum value of 1 when a particular output component tracks output perfectly. We compute the σ-statistics for the period $1954 - 2017$ under the VES and CD assumptions and for the five subperiods described in the introductory section. The σ-statistics are displayed in Table 3. In the VES case, we compute the σ-statistics in the following two ways: computing the wedge-alone components due to each wedge and then computing the σ-statistics of each efficiency wedge and the other wedges, and computing the wedge-alone components due to both efficiency wedges together and then computing the σ-statistics of both efficiency wedges together and the other wedges. We do so to compare them with the CD case.

Worked hours per capita did not display any significant increasing or decreasing trend between 1954 and 2017 (see Figure 3). In both the VES and CD cases, two forces worked in opposite directions. On the one hand, the fall in the resource constraint wedge pushed worked hours per capita down. On the other hand, the increase in the labor wedge pushed worked hours per capita up (see Figure 3, panels (d) and (f)).

In both the VES and CD cases, the efficiency wedges are the main forces driving changes in worked hours, output, and investment between 1954 and 2017. As Table 3 shows, in the VES (resp. CD) case, the σ-statistics for worked hours, output, and investment of both efficiency wedges are 0.43, 0.62, and 0.35 (resp. 0.35, 0.67, and 0.52). However, to accurately adjust the data, we need the other wedges, especially in accounting for the evolution of worked hours per capita and detrended investment per capita. The role played by the wedges differs along the periods in which we have divided the entire sample.

In both the CD and VES cases, the increase in the efficiency wedges (especially, the labor-efficiency wedge in the VES case) accurately account for the increase of detrended output per capita and detrended investment per capita in the Long Boom $1954 - 1969$ (see Figure 4 and Figure 5, panels (a), (b) and (c)). As Table 3 shows, the σ-statistic for output (resp. investment) of the efficiency wedge in the CD case is 0.88 (resp. 0.75) and the σ-statistic for output (resp. investment) of both efficiency wedges in the VES

[7] The σ-statistic is different from the ϕ statistic proposed by Brinca et al. (2017) because while Brinca et al. (2017) use the sum of the quadratic errors to build their statistic, we use the variance of the errors. Both statistics yield the same results if the average of the variable and its wedge-alone component are equal.

case is 0.93 (resp. 0.76). In the VES case, the wedge-alone component for output (resp. investment) of the labor-efficiency wedge performs a better adjustment of the changes in detrended output (resp. investment) per capita during the Long Boom (σ-statistic 0.45 for output and 0.54 for investment) than the wedge-alone component for output (resp. investment) of the capital efficiency wedge (σ-statistic 0.17 for output and 0.13 for investment). As Table 2 shows, between 1954 and 1969, the detrended output (resp. investment) per capita grew by 26.21% (resp. 34.38%), the wedge-alone component of output (resp. investment) due to the efficiency wedge increased by 26.12% (resp. 45.43%) in the CD case (25.44% and 45.75% in the VES case).

In both the VES and CD cases, the primarily responsibility of the subsequent growth slowdown between 1969 and 1982 lies with the decline in efficiency wedges (in particular, of the capital-efficiency wedge in the VES case) (see Figure 3, Figure 4 and Figure 5, panels (a), (b), and (c)). As Table 2 shows, under the VES assumption, between 1969 and 1982, the wedge-alone component of output due to the capital-efficiency wedge decreased by 8.67% (its σ-statistic is 0.42, see Table 3), and under the CD assumption, the wedge-alone component of output due to the efficiency wedge decreased by 8.13% (as Table 3 shows, its σ-statistic is 0.57). In the First Growth Slowdown, detrended output per capita decreased by 12.19%. In the CD case, the σ-statistic for output of the efficiency wedge is 0.57, while, in the VES case, the σ-statistic for output of the capital-efficiency wedge is 0.42 and of both efficiency wedges is 0.62 (see Table 3). Detrended investment per capita experiences a significant decrease between 1969 and 1982 (it decreased by 17.73%), but with significant oscillations (see Figure 5). In both the VES and CD cases, the drop in detrended investment per capita was mostly driven by the decrease in the efficiency wedges (capital-efficiency wedge in the VES case). As Table 2 shows, in the VES case, the wedge-alone component of investment due to the capital-efficiency wedge decreased by 11.60% and the wedge-alone component of investment due to the labor-efficiency wedge decreased by 0.47%, while in the CD case, the wedge-alone component of investment due to the efficiency wedge decreased by 16.24%. In the VES case, the wedge-alone component of investment due to the labor-efficiency wedge accounts for a good part of the oscillations of detrended investment per capita during the First Growth Slowdown, which is reflected in the value of the σ-statistic for investment of the labor-efficiency wedge, at 0.22, while the σ-statistic for investment of the capital-efficiency wedge is 0.18. In the VES case, the σ-statistic for investment of both efficiency wedges is higher, at 0.33, while, in the CD case, the σ-statistic for investment of the efficiency wedge is 0.32 (see Table 3).

In the VES the evolution of worked hours per capita during the First Growth Slowdown was mostly impulsed by the capital-efficiency wedge, while, in the CD case, the evolution of worked hours per capita was mostly driven by the labor wedge, even if the efficiency wedge also played a significant role. As Table 2 shows, in the VES case, the decrease in the wedge-alone component of worked hours due to the capital-efficiency wedge between 1969 and 1982 was higher than the decrease in the wedge-alone component due to the labor wedge (3.14% and 1.64%, respectively). However, in the CD case, the decrease of the wedge-alone components of worked hours due to the efficiency wedge and due to the labor wedge was more similar (3.23% and 4.26%, respectively). In this period, worked hours per capita dropped by 8.1%. In the VES case, the σ-statistic for worked hours of the capital-efficiency wedge is 0.27, that of the labor-efficiency wedge is 0.19, and that of both efficiency wedges is 0.32, while that of the labor wedge is 0.29 (see Table 3). However, in the CD case, the σ-statistic for worked hours of the efficiency wedge is 0.19 and that of the labor wedge is higher, at 0.57. The high value of the σ-statistic in the CD case reveals that in this case, the labor wedge played a significant role in accounting for the evolution of the worked hours per capita during the First Growth Slowdown.

In the VES case, the decline in worked hours per capita and the growth slowdown from the end of the past century until 2010 (and in particular, during the Great Recession) were mainly driven by the fall in the capital-efficiency wedge, while the labor wedge played a significant but secondary role (see Figure 3, Figure 4, and Figure 5, panels (a) and (d)). In the VES case, the σ-statistics for worked hours, output, and investment of the capital-efficiency wedge are 0.38, 0.41, and 0.42, while the same σ-statistics of the labor wedge are 0.24, 0.16, and 0.15 (see Table 3). As Table 2 shows, the wedge-alone components of worked hours, output and investment due to the capital-efficiency wedge decreased by 6.45%, 16%, and 23.32% between 1999 and 2010, while the worked hours per capita, detrended output per capita, and detrended investment per capita fell by 13.72%, 14.12%, and 31.51%.

However, in the CD case, between 1999 and 2010, the main role corresponded to the labor wedge, even if the efficiency wedge also played a prominent role, especially, in accounting for the evolution of detrended output per capita and detrended investment per capita (see Figure 3, Figure 4 and Figure 5, panels (c) and (d)). In the CD case, the σ-statistics for worked hours, output, and investment of the labor wedge-alone components are 0.85, 0.33, and 0.30, while the same σ-statistics of the efficiency wedge are 0.06, 0.40, and 0.28 (see Table 3). As Table 2 shows, the wedge-alone components of worked hours, output, and investment due to the labor (resp. efficiency) wedge decreased by 11.35%, 6.16%, and 12.94% (resp. 0.79%, 5.77%, and 7.86%) between 1999 and 2010.

In both the VES and CD cases, the labor wedge was the main force driving the recovery of growth and worked hours per capita in the eighties and nineties and after the Great Recession(see Figure 3, Figure 4, and Figure 5, panel (d)). As Table 2 shows, in the VES case (resp. CD case) the wedge-alone components of worked hours, output, and investment due to the labor wedge increased by 21.24%, 17.33%, and 23.37% (resp. 21.64%, 17.04%, and 25.55%) between 1982 and 1999 and by 7.47%, 5.09%, and 8.50% (resp. 8.91%, 5.10%, and 10.08%) between 2010 and 2017. Worked hours per capita, detrended output per capita and detrended investment per capita increased by 15.16%, 8.51%, and 18.82%, between 1982 and 1999 and by 7.21%, −2.63% and 4.85%, between 2010 and 2017.

In both the VES and CD cases, the increase in the investment wedge in the seventies contributed to reduce the growth slowdown and to reduce the fall in the worked hours per capita during the First Growth Slowdown. The investment wedge's fall in the eighties contributed to reduce the subsequent recovery of output per capita, investment, and worked hours (see Figure 3, Figure 4, and Figure 5, panel (e) and Table 2). During the Second Growth Slowdown, the investment wedge strengthened the fall of worked hours per capita, detrended output per capita, and detrended investment per capita. As Table 2 shows, in the VES case (resp. CD case) the wedge-alone components of worked hours, output, and investment due to the investment wedge increased by 3.09%, 3.81%, and 11.64% (resp. 5.58%, 6.79%, and 22.76%) between 1969 and 1982, decreased by 3.78%, 3.13%, and 13.05% (resp. 3.66%, 1.41%, and 10.14%) between 1982 and 1999 and decreased by 3.25%, 4.89%, and 12.42% (resp. 1.23%, 1.67%, and 4.92%) between 1999 and 2010.

In the VES case, the labor-efficiency wedge contributed to reduce the growth slowdown and the fall in worked hours per capita during the Second Growth Slowdown, while its impact on the decrease of output and investment growth and worked hours was negligible during the First Growth Slowdown. As Table 2 shows, in the VES case, the wedge-alone components of worked hours, output, and investment due to the labor efficiency wedge increased by −0.14%, 1.28%, and −0.47% between 1969 and 1982, and by 1.01%, 11.39%, and 20.53% between 1999 and 2010.

Productivity and labor share

The evolution of detrended output per worked hour and the labor share, together with their wedge-alone components due to the efficiency wedges in both the CD and

VES cases is displayed in Figure 6. For the effects of the wedges on the evolution of these variables, we only mention three points. First, in both the VES and CD cases, the efficiency wedges accurately account for the evolution of the U.S. output per worked hour between 1954 – 2017 (see Figure 6, panel (b)). In particular, the σ-statistic for productivity of the efficiency wedge in the CD case is 0.89 and the σ-statistic for the productivity of both efficiency wedges in the VES case is 0.83. Second, in the VES case, the efficiency wedges accurately account for the evolution of the U.S labor share between 1954 – 2017 (see Figure 6, panel (d)). In particular, the σ-statistic for the labor share of both efficiency wedges is 0.80. Third, in the VES case, the wedge-alone components of productivity and labor share due to the capital-efficiency wedge mostly account for the changes in these variables, not the wedge-alone components due to the labor-efficiency wedge (see Figure 6, panel (a) and (c)). In particular, in the VES case, the σ-statistic for productivity (resp. the labor share) of the capital-efficiency wedge is 0.36 (resp. 0.60) and the σ-statistic for productivity (resp. the labor share) of the labor-efficiency wedge is 0.14 (resp. 0.11).

VI. Specification of the production function and the wedges

We have computed the labor and investment wedges under the production function with variable output elasticities for factors, (π_h, and π_x^{-1}), assuming that the output elasticities for labor and capital equal their observed income shares. Under the CD production function, the output elasticities for capital and labor are constant, ($s_t = s$ and $1 - s_t = 1 - s$). It follows from the first order conditions (22) and (23) for labor and capital that the labor and investment wedges ($\widetilde{\pi}_h$ and $\widetilde{\pi}_x^{-1}$) computed under the CD assumption are $\widetilde{\pi}_{h,t} = \pi_{h,t} \frac{s_{h,t}}{1-s}$ and $\widetilde{\pi}_{x,t}^{-1} \simeq \pi_{x,t}^{-1} \frac{s_{k,t+1}}{s}$.[8]

Until the end of the nineties, the U.S. labor share remained roughly Stable; however, after the end of the nineties, and in particular, during the Great Recession (between 2007 and 2010) the U.S. labor share experienced a strong decline. Therefore, around this time, the investment and labor wedges calculated with a VES production function and with a CD production function significantly begin to differ (see Figure 2, panel (c) and panel (d)). In particular, the sharp drop in the labor share will be reflected in that the computed decline in the labor (resp. investment) wedge under a CD specification will be higher (resp. lower) than its computed decline under a VES specification.

[8] The relationship between $\widetilde{\pi}_x^{-1}$ and π_x^{-1} is not a very good approach if the capital share s_k is changing too much.

If there are constant returns to scale, the growth rate of TFP is $g_{A,t} \equiv s_t g_{q,t} + (1-s_t)\, g_{z,t} = g_{Y,t} - s_t g_{K,t} - (1-s_t) g_{H,t}$, which can be computed assuming the output elasticities for labor and capital are constants ($s_t = s$ and $\widetilde{g}_{A,t} = g_{Y,t} - s g_{K,t} - (1-s)\, g_{H,t}$) or assuming that the output elasticity for labor equals its observed income share ($1 - s_t = s_{h,t}$ and $\overline{g}_{A,t} = g_{Y,t} - (1 - s_{h,t})\, g_{K,t} - s_{h,t} g_{H,t}$). First, note that if g_q and g_z are moving in opposite directions, it might compute a low value for g_A, even if g_q, and g_z, are experiencing large variations. According to our VES production function, this happened during the Second Growth Slowdown in which both efficiency wedges largely moved in opposite directions (see Figure 2, panel (a) and panel (b)). Therefore, to calculate $g_{A,t}$ ignoring $g_{q,t}$ and $g_{z,t}$ might lead to the wrong conclusion that changes in the efficiency wedges of the factors are not important in accounting for movements in output and labor. Second, if the labor share, s_h, goes down and the ratio of capital to worked hours is increasing, $g_{K,t} - g_{H,t}$, then $\overline{g}_{A,t}$ decreases relative to $\widetilde{g}_{A,t}$. As noted above, until the end of the nineties, the U.S. labor share remained roughly stable; however, after the end of the nineties, and particularly during the Great Recession (2007 – 2010), the U.S. labor wedge experienced a strong decline. Therefore, the efficiency wedge computed using a CD production function and the efficiency wedge implied by our VES specification differ significantly from the end of the nineties. In particular, the decline in the efficiency wedge computed using a CD production function is lower than the decline in the efficiency wedge computed using a VES production function (see Figure 2).[9]

Therefore, the large fall in the U.S. labor share after the end of the nineties explains that after this time, the investment wedge, labor wedge, and the efficiency wedge (i.e., $q^{1-s_h} z^{1-s_h}$) computed using a VES specification of the production function, significantly differ from those computed using a CD production function.

VII. The U.S. economic recessions

In this section, we focus on the role of the wedges in the two main recessions that the U.S. economy faced after WWII. The first is the crisis in the late seventies, which we call the 1982 Recession and the second is the Great Recession, which began in 2007.

Our simulations for the Great Recession under the VES specification of the production function are presented in Figure 7 and those under the CD specification are presented in

[9] They also significantly differ in the late sixties and early seventies, because in this period, the labor share experienced a strong increase.

Figure 9. Figure 8 and Figure 10 display the simulations for the 1982 Recession under the VES case and the CD case, respectively. The observed evolution of detrended output per capita, worked hours per capita, and detrended investment per capita are presented in panel (a) of each figure and the observed evolution of detrended output per capita along with those of the wedges are presented in panel (b) of each figure.[10] In the other four panels of each figure, we display the observed evolution of four variables (detrended output per capita, worked hours per capita, detrended investment per capita, and labor share) along with their wedge-alone components. We report the evolution of all wedges, except the resource constraint wedge, g, and their corresponding wedge-alone components. We do not include g in the analysis because its effects are not very significant. In the VES case, we also report the simulated results of the economy in which both the labor and capital efficiency wedges take their computed values together and the other wedges remain constant, to compare with the results obtained under the CD assumption. We display the percentage changes in the wedges between the start-up year of the recession (2007 or 1978) and the year in which worked hours per capita reached a minimum (2010 and 1982) in Table 4. In Table 5, we compare the changes in the observed variables between 1978 and 1982 and between 2007 and 2010, together with the changes in their wedge-alone components in the same years. In Table 6, we display the σ-statistics of the wedges for the periods $1978-1982$ and $2007-2010$. The changes in both wedges and wedge-alone components are displayed for both the VES and CD cases.

VII.1. The Great Recession

VES case. The primary responsibility of the fall in detrended output per capita, worked hours per capita, and detrended investment per capita lies with the sharp decline in the capital-efficiency wedge (see Figure 7). Between 2007 and 2010, the capital-efficiency wedge experienced a fall of almost 20% (see Table 4), and after 2013, it recovered slightly (see Figure 7). Between 2007 and 2010, the decline in the capital-efficiency wedge was almost of the same magnitude as the drop in detrended investment per capita, and it was more than double the drop in detrended output per capita, and worked hours per capita (see Table 4). Consequently, its contribution to the fall of these variables between 2007 and 2010 exceeded 100% for detrended output per capita and it approximately 70% and 84% for worked hours per capita and detrended investment per capita, respectively(see

[10] Brinca et al. (2017) focus on three variables: output, worked hours, and investment.

Table 5). The ability of the capital-efficiency wedge to account for the evolution of worked hours, output, and investment between 2007 and 2010 is reflected in the high values taken by its σ-statistics displayed in Table 6. In particular, its σ-statistic for worked hours per capita is 0.48, for detrended output per capita is 0.37, and for detrended investment per capita 0.48. However, between 2007 and 2010, the labor-efficiency wedge experienced opposite behavior (see Figure 7, panel (b)) and it contributed to reduce the negative impact of the decline in the capital-efficiency wedge on output, investment, and labor. The combined effect of both efficiency wedges account for 66% of the drop in detrended output per capita, 56% of the drop in worked hours per capita, and 45% of detrended investment per capita between 2007 and 2010 (see Table 5). The combined effect of both efficiency wedges accurately account for the evolution of the labor share during the Great Recession Era (see Figure 7, panel (f)).

Between 2007 and 2010, the fall in the investment and labor wedges was of a similar magnitude, between 3%-4%, and much lower than the decline in the capital-efficiency wedge (see Table 4). The fall in these wedges played a significant but secondary role in the fall of detrended output per capita, detrended investment per capita, and worked hours per capita (see Figure 7). Their contributions to the drop in output per capita between 2007 and 2010 also were similar; about 22% for the investment wedge and 24% for the labor wedge (see Table 5). However, the impact of the decrease in the labor wedge on worked hours per capita was higher than the impact of the decrease in the investment wedge, but the reverse can be said in the case of detrended investment per capita. In particular, the fall in the labor (resp. investment) wedge accounts for around 43% (resp. 17%) of the decrease in worked hours per capita between 2007 and 2010, while the fall in the investment (resp.labor) wedge account for 22% (resp. 17%) of the decrease in investment per capita (see Table 5). After 2010, the U.S. economy recovered (particularly intense in the worked hours per capita), which between 2010 and 2013 was driven by both the investment wedge and the labor wedge, and after 2013, only by the labor wedge (see Figure 7).

CD case. The labor wedge was the main force driving the fall and recovery of worked hours per capita, detrended investment per capita, and detrended output per capita (this last continued falling after 2010, but very slightly). Between 2007 and 2010, the fall in the labor wedge was higher than double the fall in the efficiency wedge or the investment wedge (see Table 4). The ability of the labor wedge to account for the decrease in worked hours, output, and investment between 2007 and 2010 is reflected in the high values taken by its σ-statistics, in Table 6. In particular, its σ-statistic for worked hours per capita is 0.91, for detrended output per capita is 0.49 and for detrended investment per capita 0.32. Between 2007 and 2010, (i) the decline in the labor wedge accounted for around 93% of the fall in worked hours per capita, while the decline in the efficiency and investment wedges only accounted for around 10% and 15%, respectively; (ii) the decline in the labor wedge accounted for around 56% of the fall in detrended output per capita, while the decline in the efficiency and investment wedges accounted for around 44% and 13%, respectively; (iii) the decline in the labor wedge accounted for around 38% of the fall in detrended investment per capita, while the decline in the efficiency and investment wedges accounted for around 24% and 18%, respectively. (see Table 5). Therefore, in the CD case, the efficiency wedge and the investment wedge played a secondary role in accounting for the fall of output, labor and investment during the Great Recession. After 2010, the labor wedge recovered significantly, but the efficiency wedge did not, and the investment wedge recovered slightly (see Figure 7, panel (b)). Therefore, the labor wedge also was the main responsible of recovery after 2010.

VII.2. The 1982 Recession

VES case. The main forces driving the fall in detrended output per capita and detrended investment per capita between 1978 and 1982 were both efficiency wedges (see Figure 8). Between 1978 and 1982, the capital efficiency wedge dropped by 6.58% and the labor efficiency wedge dropped by around 8.95%, while the labor wedge decreased by 2.3% and the investment wedge grew by 1% (see Table 4). The drop in detrended output per capita and investment per capita between 1978 and 1982 was mainly due to the fall of both efficiency wedges (see Figure 8, panel (c) and panel (e)). The combined effect of both efficiency wedges account for around 95% and 74% of the drop in detrended output per capita and detrended investment per capita, respectively (see Table 5). As Table 6 shows, the σ-statistic for output of both efficiency wedges is 0.91 and the σ-statistic for investment is 0.66. The fall in the labor wedge only accounts for around 11% and 14% of the drop in detrended output per capita and detrended investment per capita, respectively, in the period $1978 - 1982$ (see Table 5). However, the joint fall in both efficiency wedges just account for 47% of the drop in worked hours per capita, while the drop in the labor wedge account for 51% (see Table 5). Therefore, the drop in the labor wedge played a secondary role in the fall of detrended investment per capita and detrended output per capita; however, it played a main role in the decrease of worked hours between 1978 and 1982. As Table 3 shows, the σ-statistic for worked hours of the labor wedge is 0.57, while the σ-statistic for worked hours of both efficiency wedges is 0.23. The combined effect of both efficiency wedges accurately account for the evolution of the labor share between 1978 – 1989 (see Figure 8, panel (f)). After 1982, the worked hours per capita, detrended investment per capita, and detrended output per capita recovered. The increase of the labor wedge primarily led the recovery (see Figure 8, panel (c), panel (d), and panel (e)). The investment wedge has not played a significant role in the 1982 recession. The only salient fact is that after 1983, it contributed to slowing the recovery of worked hours per capita, detrended investment per capita, and detrended output per capita (see Figure 8, panel (e) panel (d), and panel (e)).

CD case. Between 1978 and 1982, the fall of the efficiency wedge was about 8.2%, while the fall of the labor wedge only was 0.8%; the investment wedge grew by 2.1% (see Table 4). The fall in the efficiency wedge accounts for most of the fall in detrended output per capita, detrended investment per capita, and worked hours per capita between 1978 and 1982 (see Figure 8, panel (c), panel (d), and panel (e)). As Table 3 shows, the σ-statistic for output of the efficiency wedge is 0.90, for investment is 0.78, and for worked hours 0.37. Moreover, as Table 5 shows, the wedge-alone component of the efficiency wedge accounts for 104% of the drop in detrended output per capita, 74% of the drop in worked hours per capita, and 86% of the drop in detrended investment per capita, while the corresponding percentages accounted by the fall in the labor wedge are 7%, 28%, and 10%. Between 1978 and 1982, the labor wedge only played a significant but secondary role in accounting for the evolution of worked hours per capita. In particular, the σ-statistic for worked hours per capita of the labor wedge is 0.36 (see Table 3). The recovery of these variables after 1982 is mainly driven by the increase in the labor wedge; however, after 1984, the decrease in the investment wedge slowed down the recovery (see Figure 8, panel (c), panel (d), and panel (e)).

Summary of findings

1. In the Great Recession, under the VES specification of the production function, the main force driving the fall in detrended output per capita, detrended investment per capita, and worked hours per capita was the decrease in the capital-efficiency wedge. The investment wedge and the labor wedge had a significant and similar, but

secondary role, in the drop of detrended output per capita, detrended investment per capita, and worked hours per capita. The fall in the investment wedge had a higher contribution to the drop in detrended investment per capita, while the fall in the labor wedge had a higher contribution to the drop in the worked hours per capita and it was about the joint contribution of both (capital and labor) efficiency wedges. The joint evolution of both efficiency wedges accurately account for the evolution of the labor share during the Great Recession.

2. In the Great Recession, under the CD specification of the production function, the main force driving the fall in detrended output per capita, detrended investment per capita, and worked hours per capita between 2007 and 2010 was the decrease in the labor wedge. The contribution of the fall in the efficiency wedge to the drop in detrended output per worker and detrended investment per capita was also significant, but lower. While its contribution to the fall in worked hours per capita was minor. The investment wedge also played a significant, but secondary role in the fall of these variables during the Great Recession.

3. In the 1982 Recession, under the VES specification, the fall in both efficiency wedges account for most of the decrease in detrended output per capita and detrended investment per capita between 1978 and 1982 and almost half the drop in worked hours per capita. The labor wedge played a prominent role in the fall in worked hours per capita; however, it played a minor role in the fall of detrended output per capita and detrended investment per capita. The contribution of the investment wedge to the fall in detrended output per capita, detrended investment per capita, and hours per capita during the 1982′s Recession was not significant, except that its decrease after 1984 slowed down the recovery. The results are similar if a CD production function is specified; however, the role of the labor wedge is lower and that of the efficiency wedge is higher, which means that in the CD the labor wedge plays also a secondary, albeit significant, role in accounting for the fall in worked hours per capita between 1978 and 1982.

4. According to the VES specification, both recessions differ in terms of the role of the labor-efficiency wedge. In particular, in the 1982 Recession, the labor-efficiency wedge worked in the same direction as the capital-efficiency wedge and strengthened the recession; however, in the Great Recession, between 2007 and 2010, the labor-efficiency wedge worked in the opposite direction to the capital-efficiency wedge,

and its increase contributed to reducing the fall in detrended output per capita, detrended investment per capita, and worked hours per capita.

5. Under both the VES and CD specification, the main force driving the recovery of labor, output, and investment after the trough of both recessions was the increase in the labor wedge.

VIII. The Great Recession in the OECD Countries

We calibrate, compute the wedges, and simulate the model for 29 OECD countries using data from the Penn World Table 9.1 (PWT 9.1). We describe the calibration below.[11] The method to compute the wedges is the same as that described above.

For each country, we set δ, γ, η, $\frac{x}{y}$, $\frac{c}{y}$, $\frac{wh}{y}$, and h equal to their annual averages in the sample period. We set $\beta = 0.97721$, $\mu = 1$, $y = 1$, and $\psi = -1.9$ for all countries and $\omega = 0.5$ for most countries. We set higher values of ω for some countries because their reported labor shares by the PWT 9.1 are very low in some years and we need that $s_{h,t} > 1 - \omega$ for all t to have well-defined series for z_t and q_t.We set α such that $\alpha\omega = \frac{wh}{y}$, $\kappa = (1+\eta)(1+\gamma) - (1-\delta)$ and $\phi = 0.25/\kappa$. Solving the equation system (10)-(17), the following variables, parameters, and wedges are calibrated for each country: g, i, k, π_x, π_h, q, z, s, x, c and w. The calibrated parameters that differ across countries are displayed in section III (Table 3) of the Technical Appendix.

To measure the difference between the causes of recession in two countries, j and l, we compute the following statistic for output, and worked hours:

$$\widehat{\sigma}_{j,l}^{m} = \sum_{i} \left(\sigma_i^{m,j} - \sigma_i^{m,l}\right)^2 ,$$

which is the sum of the squared differences between the σ-statistics for variable $m = y, h$ of each wedge $i = g$, π_x, π_h, A, q & z in both countries j and l. A higher value of the statistics means a higher difference between the causes of the change in the variable in each country.

In Table 7, we display the percent change in the observed fall of worked hours per capita and detrended output per capita as well as their wedge-alone components (in

[11]The data used for the United States in our cross-country comparative are different from the data used above and the results obtained are slightly different too. We describe the used data in section IV of the Technical Appendix.

both the VES and CD case) in the United Sates and the other G-7 (UK, Italy, Germany, France, Japan, and Canada) countries between 2007 and the year in which worked hours per capita reached a minimum in each country (2010 in the United States). With these data, we also display the averages of the percent changes for 29 OECD countries and for G-7 countries. The σ-statistics for G-7 countries are also displayed in Table 8. The $\widehat{\sigma}$-statistics for output and worked hours for G-7 countries are displayed in Table 9 and Table 10. The percent change of the observed fall of worked hours per capita and detrended output per capita and their wedge-alone components (in both the VES and CD case) in the OECD countries are displayed in section III of the Technical Appendix. In addition, the σ-statistics for all OECD countries are contained in section III of the Technical Appendix.

In the CD case, the labor wedge is the main force driving the fall of detrended output per capita and worked hours per capita in the United States, while the efficiency wedge is of secondary importance. The wedge-alone component of output due to the labor (resp. efficiency) wedge accounts for 72% (resp. 30%) of the fall in U.S. detrended output per capita between 2007 and 2010 and the wedge-alone component of worked hours due to the labor (resp. efficiency) wedge accounts for 110%. (resp. 6%) of the fall in U.S. worked hours per capita. The U.S. σ-statistics for worked hours of labor wedge and efficiency wedge are 0.94 and 0.02, respectively, and 0.67 and 0.17 for output.

In the CD case, the average of the OECD countries is very different from the United States; on average, the main force driving the fall in worked hours per capita and detrended output per capita was the efficiency wedge. In particular, on average, the wedge-alone component of output due to the efficiency (resp. labor) wedge accounts for 89% (resp. 18%) of the fall in detrended output per capita between 2007 and 2010, and the wedge-alone component of worked hours due to the efficiency (resp. labor) wedge accounts for 68% (resp. 54%) of the fall in worked hours per capita. The average OECD σ-statistics for worked hours of labor wedge and efficiency wedge are 0.31 and 0.48, respectively, and 0.12 and 0.82 for output. Therefore, in the CD case, the $\widehat{\sigma}$-statistics for worked hours and output of the United States and the average of the OECD countries are 0.545 and 0.674, respectively.

However, in the VES case, the experience of the United States is closer to the OECD average. In particular, in the VES case, the wedge-alone component of worked hours due to the labor (resp. efficiency) wedge accounts for 74% (resp. 60%) of the fall in worked hours between 2007 and 2010, while, on average, these percentages are 63% (resp. 62%). In the VES case and regarding detrended output per capita, these percentages are farthest, but closer than in the CD case. In particular, in the VES case, the wedge-alone component of output due to the labor (resp. efficiency) wedge accounts for 45% (resp. 55%) of the fall in detrended output per capita between 2007 and 2010, while, on average, these percentages are 17% (resp. 93%).

In the VES case, the U.S. σ-statistics for worked hours of labor wedge and both efficiency wedges together are 0.79 and 0.13, respectively, and 0.33 and 0.46 for output. The average OECD σ-statistics for worked hours of labor wedge and both efficiency wedges together are 0.71 and 0.17, respectively, and are 0.1 and 0.83 for output. Therefore, in the VES case, the $\widehat{\sigma}$-statistics for worked hours and output of the United States and the average of the OECD countries are 0.208 and 0.169, respectively, lower than the $\widehat{\sigma}$-statistics in the CD, 0.545 and 0.674.

We now focus on G-7. Table 7 shows the results of our simulations for the G-7 (USA, UK, Italy, Germany, France, Japan, and Canada). In the CD case, the United States is an outlier because it is the only country in which the wedge-alone component of output due to the labor wedge accounts for the higher percentage of the fall in detrended output per capita. However, in the VES case, for all countries, including the United States, the main force driving the fall of output is the efficiency wedge. In the VES case, the relative importance of both wedges in the United States is more similar to the G-7 average. In particular, in the CD case, in the United States, the wedge-alone component of output due to the labor wedge accounts for 72% of the fall in detrended output per capita (the average of G-7 is 18%) and the wedge-alone component of output due to the efficiency wedge accounts for 30% (the average of G-7 is 89%). These figures are closer in the VES case; in particular, $44\% - 26\%$ and $54\% - 85\%$.

There is higher variety in the changes in worked hours per capita and its components in the CD case. In the CD case, the labor wedge was the main force driving the fall in worked hours per capita in three countries (USA, UK, and Japan) and the efficiency wedge was the main force in the other four countries. Assuming a VES production function also contributes to homogenize the experience of the G-7 countries during the Great Recession, because in the VES case, the labor wedge was the main force driving the fall in worked hours in all countries. Moreover, in the CD case, the relative effects in the United States of both efficiency and labor wedges on worked hours are far off the average relative effects. However, in the VES case, the relative effects in the United State are closer to the G-7 average relative effects (see Table 7). In particular, in the VES case, the wedge-alone component of worked hours due to the labor wedge accounted for 74% of the fall in worked hours per capita (the G-7 average is 92%) and the wedge-alone component of worked hours due to the efficiency wedge accounts for 44% (the G-7 average is 34%). These figures are more distant in the CD case; in particular, 110% − 60% and 6% − 61%.

Moreover, in the VES (resp. CD) case, the average G-7 σ-statistics for worked hours of labor wedge and both efficiency wedges together are 0.71 and 0.17 (resp. 0.31 and 0.48), respectively, and 0.10 and 0.83 (resp. 0.12 and 0.82) for output. If we compare these figures with the U.S. σ-statistics, in the VES case, the $\widehat{\sigma}$-statistics for worked hours and output of the United States and the average of the G-7 countries are 0.10 and 0.205, respectively, which are lower than the $\widehat{\sigma}$-statistics in the CD, at 0.622 and 0.738.

IX. Conclusion

We performed a growth accounting exercise for the United States using the deterministic version of the neoclassical growth model. In this framework, we developed a method to compute five wedges reflecting distortions in the equilibrium conditions of the model that allow matching theory and data. We apply it to measure the wedges in the U.S. economy for the period 1954 − 2017. The model is simulated to assess the contribution of the wedges to the U.S. post-war economic growth. We have performed the same exercise specifying both VES and CD production functions. Our results reveal that the specification of the production function is important in accounting for some facts of the U.S. post-WWII economic performance.

Our main findings are as follows:

(i) Evolution of U.S. productivity is accurately accounted by the efficiency wedges between 1954 and 2017 and, if a VES production is assumed, the evolution of the U.S. labor share between 1954 and 2017 is also accurately accounted by the evolution of the efficiency wedges. Moreover, under a VES especification of the production function, both the evolution of the U.S. labor share and the U.S. detrended output per worked hour between 1954 and 2017 are mainly accounted by the evolution of the capital-efficiency wedge, and in particular, the fall in the capital-efficiency wedge is primarily responsible for the decline in the U.S. labor share in this century and in the seventies.

(ii) U.S worked hours per capita did not display any significant long-run trend between 1954 and 2017, which according to our model, can be accounted for because two forces were working in opposite directions. On the one hand, the fall of the resource constraint wedge pushed worked hours per capita down. On the other hand, the increase of the labor wedge pushed worked hours per capita up.

(iii) The outstanding growth of the fifties and sixties was mainly driven by the increase of the efficiency wedges. If a VES production function is assumed, mainly by the increase of the labor efficiency wedge.

(iv) If a CD production function is assumed, the labor wedge was the main force driving the fall of output, investment and labor during the Second Growth Slowdown in the first decade of this century. In this period,the efficiency wedge played a significant but secondary role in accounting for the decrease of output, investment and labor. However, during the First Growth Slowdown in the seventies, the main force driving the evolution of output and investment was the efficiency wedge, while the main force driving the fall of of labor was the labor wedge.

(v) If a VES production function is assumed, the decline of output, investment and labor both during the First Growth Slowdown and during the Second Growth Slowdown was driven by the capital-efficiency wedge. In both periods, the labor wedge played a significant but secondary role in accounting for the evolution of output, investment an labor.

(vi) It follows from (iv) and (v) that assuming a VES specification of the production function helps harmonize both periods of growth slowdown. However, there are two differences between both periods. First, the investment wedge played a significant but secondary role in accounting for the fall of output, investment and labor in the Second Growth Slowdown, but it contributed to reduce the decrease of output, investment and labor in the First Growth Slowdown. Second, the efficiency-labor wedge played a negligible role in accounting for the fall of output, investment and labor in the First Growth Slowdown, but it contributed to reduce the fall of output, investment and labor in the Second Growth Slowdown.

(vii) The labor wedge was the main force driving the recovery of growth and worked hours per capita in the eighties and nineties as well as after the Great Recession.

We have applied the methodology to understand the two main economic recessions that the American economy faced after WWII. Our primary finding is that the specification of the production function is crucial for identifying the causes of the crisis. Briefly, if a CD production function is specified, the main force driving the U.S. 1982′*s* recession was the efficiency wedge; however, the main force driving the U.S. Great Recession was the labor wedge. However, if a VES production function is specified, the main force driving both U.S. recessions is the capital-efficiency wedge, even if the labor wedge played a prominent role overall in the fall in worked hours per capita during the U.S. Great Recession. Moreover, if a CD production function is specified, the Great Recession in the United States appears to be different from the Great Recession in the G-7 countries, because only in the U.S. economy did the labor wedge play the main role in accounting for both the growth slowdown of output per capita and the fall in worked hours per capita. However, if a VES production function is specified, the performance of G-7 countries appears to be more homogeneous.

Finally, our analysis has the following implication: to understand the periods of economic rise and recession recovery, we must to understand the factors improving the labor wedge. Similarly, to understand the periods of economic decline and recession, we must first understand the factors worsening the capital efficiency wedge.

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Table 1
Model Parameters and bgp Variables

Model parameters obtained exogenously or estimated.		
Parameter	**Description**	**Value**
η	Population Growth Rate	0.0118
γ	Growth Rate of Output per Worker	0.0163
δ	Depreciation Rate of Capital	0.0640
ψ	Production Function Parameter	-1.900
ω	Production Function Parameter	0.5000
α	Production Function Parameter	0.7200
μ	Relative Value of Leisure	1.0000
Model parameters obtained solving the model.		
β	Discount Factor	0.9772
bgp variables		
q	Capital Efficiency Wedge	0.3296
z	Labor Efficiency Wedge	4.5454
π_x	Investment Wedge	1.1409
π_h	Labor Wedge	0.2732
g	Resource Constraint Wedge	0.10
k	Capital-Output Ratio	3.0338
y	Output per Capita	1.0000
h	Worked Hours per Capita	0.2200
x	Investment Rate	0.2800
c	Consumption to Output Ratio	0.6200
s	Capital-Output Elasticity	0.3600
i	Interest Rate	0.0400

Table 2
Wedge-alone components, growth rate (%).

		VES						CD			
	Data	q	z	q and z	π_x	π_h	g	A	π_x	π_h	g
		The long boom									
h	2.21	3.79	1.76	5.09	-2.10	-2.70	-0.49	5.01	-2.90	-1.49	-1.31
y	26.21	11.85	11.85	25.44	3.71	-2.85	5.09	26.12	1.59	-1.71	4.06
x	34.38	15.62	29.52	45.75	-6.10	-2.85	-2.51	45.43	-6.11	-1.89	-1.72
		The first growth slowdown									
h	-8.10	-3.14	-0.14	-3.36	3.09	-1.64	-3.40	-3.23	5.58	-4.26	-3.48
y	-12.19	-8.67	1.28	-7.48	3.81	-1.89	-2.45	-8.13	6.79	-3.79	-2.40
x	-17.73	-11.60	-0.47	-12.34	11.64	-2.77	-5.10	-16.24	22.76	-7.56	-4.53
		The great moderation									
h	15.16	2.91	-0.03	2.92	-3.78	21.24	-4.41	1.95	-3.66	21.64	-4.55
y	8.51	3.03	-2.04	0.93	-3.13	17.33	-3.78	-0.44	-1.41	17.04	-3.76
x	18.82	11.13	-2.06	9.23	-13.05	23.37	-0.18	5.28	-10.14	25.55	-0.01
		The second growth slowdown									
h	-13.72	-6.45	1.01	-5.01	-3.25	-5.10	1.47	-0.79	-1.23	-11.35	1.51
y	-14.12	-16.00	11.39	-6.43	-4.89	-1.95	1.27	-5.77	-1.67	-6.16	1.30
x	-31.51	-23.32	20.53	-6.64	-12.42	-6.21	-1.56	-7.86	-4.92	-12.94	-1.61
		The great recession recovery									
h	7.21	0.14	-0.68	-1.05	1.70	7.47	-1.45	-1.58	1.27	8.91	-1.51
y	-2.63	-1.96	-5.15	-6.97	0.42	5.09	-1.24	-7.56	0.87	5.10	-1.26
x	4.85	0.07	-11.05	-11.91	7.06	8.50	1.15	-11.81	4.38	10.08	1.13

Table 3

σ-statistics.

	VES									CD			
Variable	q	z	π_x	π_h	g	q and z	π_x	π_h	g	A	π_x	π_h	g
	Entire sample												
h	0.33	0.26	0.20	0.10	0.12	0.43	0.27	0.13	0.17	0.35	0.27	0.24	0.15
y	0.38	0.11	0.25	0.05	0.21	0.62	0.18	0.04	0.16	0.67	0.11	0.06	0.16
y/h	0.36	0.14	0.18	0.17	0.15	0.76	0.08	0.08	0.07	0.89	0.03	0.04	0.04
x	0.29	0.14	0.26	0.10	0.21	0.35	0.30	0.11	0.24	0.52	0.16	0.11	0.21
1-s_k	0.60	0.11	0.09	0.12	0.08	0.80	0.07	0.08	0.05	0.00	0.00	0.00	0.00
	The long boom												
h	0.19	0.13	0.21	0.33	0.15	0.20	0.24	0.38	0.18	0.16	0.24	0.39	0.21
y	0.17	0.45	0.14	0.08	0.16	0.93	0.03	0.02	0.03	0.93	0.02	0.02	0.03
y/h	0.15	0.43	0.16	0.09	0.16	0.84	0.06	0.03	0.06	0.82	0.06	0.04	0.07
x	0.13	0.54	0.10	0.11	0.11	0.73	0.09	0.09	0.09	0.76	0.08	0.07	0.08
1-s_k	0.26	0.17	0.16	0.26	0.15	0.59	0.12	0.19	0.11	0.00	0.00	0.00	0.00
	The first growth slowdown												
h	0.27	0.19	0.12	0.23	0.19	0.32	0.16	0.29	0.23	0.19	0.07	0.57	0.16
y	0.42	0.12	0.09	0.14	0.22	0.62	0.08	0.12	0.19	0.57	0.06	0.17	0.20
y/h	0.30	0.15	0.15	0.25	0.14	0.69	0.09	0.14	0.08	0.76	0.06	0.12	0.06
x	0.18	0.22	0.11	0.21	0.28	0.33	0.12	0.24	0.31	0.32	0.08	0.27	0.33
1-s_k	0.44	0.14	0.13	0.18	0.11	0.72	0.09	0.12	0.07	0.00	0.00	0.00	0.00
	The great moderation												
h	0.16	0.10	0.05	0.61	0.07	0.17	0.06	0.69	0.08	0.17	0.08	0.66	0.10
y	0.25	0.17	0.22	0.14	0.22	0.41	0.23	0.14	0.22	0.30	0.32	0.14	0.23
y/h	0.13	0.37	0.12	0.23	0.15	0.56	0.11	0.20	0.13	0.60	0.07	0.21	0.12
x	0.12	0.26	0.18	0.13	0.31	0.32	0.19	0.15	0.34	0.38	0.21	0.12	0.30
1-s_k	0.27	0.27	0.16	0.17	0.13	0.51	0.17	0.18	0.14	0.00	0.00	0.00	0.00
	The second growth slowdown												
h	0.38	0.10	0.19	0.24	0.09	0.36	0.24	0.29	0.11	0.06	0.06	0.85	0.04
y	0.41	0.04	0.29	0.16	0.10	0.48	0.28	0.15	0.10	0.40	0.17	0.33	0.10
y/h	0.03	0.03	0.33	0.20	0.41	0.58	0.15	0.09	0.18	0.21	0.29	0.10	0.40
x	0.42	0.05	0.24	0.15	0.13	0.29	0.33	0.20	0.18	0.28	0.23	0.30	0.18
1-s_k	0.56	0.20	0.10	0.06	0.08	0.97	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	The great recession recovery												
h	0.02	0.02	0.03	0.91	0.02	0.02	0.03	0.93	0.02	0.05	0.09	0.82	0.05
y	0.30	0.03	0.12	0.02	0.53	0.05	0.17	0.02	0.75	0.04	0.13	0.02	0.80
y/h	0.16	0.43	0.14	0.18	0.10	0.68	0.11	0.14	0.07	0.63	0.08	0.22	0.07
x	0.10	0.02	0.56	0.15	0.17	0.02	0.62	0.17	0.19	0.03	0.63	0.12	0.22
1-s_k	0.26	0.06	0.26	0.12	0.29	0.24	0.29	0.13	0.33	0.00	0.00	0.00	0.00

Table 4
Wedge changes, deviation from peak (hours trough).

			VES						CD			
y	**h**	**x**	q	z	q and z	π_x	π_h	g	A	π_x	π_h	g
			The 1982 Recession									
-9.83	-4.28	-20.94	-6.58	-8.95	-7.57	1.09	-2.29	8.90	-8.18	2.13	-0.82	8.90
			The Great Recession									
-8.22	-7.71	-23.42	-19.72	9.67	-8.98	-2.70	-3.84	29.86	-2.59	-2.14	-7.13	29.86

Table 5
Wedge-alone components, deviation from peak (hours trough).

		VES						CD			
	Data	q	z	q and z	π_x	π_h	g	A	π_x	π_h	g
		The 1982 Recession									
h	-4.28	-1.17	-0.77	-1.99	0.45	-2.17	0.26	-3.17	0.65	-1.21	0.36
y	-9.83	-3.36	-6.08	-9.31	1.61	-1.10	0.14	-10.29	2.34	-0.75	0.24
x	-20.94	-4.51	-11.30	-15.48	1.81	-2.94	-3.78	-18.09	3.93	-2.27	-3.53
		The Great Recession									
h	-7.71	-5.47	0.62	-4.35	-1.31	-3.31	1.51	-0.73	-1.16	-7.18	1.74
y	-8.22	-11.56	6.81	-5.48	-1.83	-1.99	0.97	-3.65	-1.13	-4.68	1.11
x	-23.42	-19.79	11.66	-9.06	-5.28	-4.04	-5.28	-5.63	-4.21	-9.01	-5.00

Table 6

σ-statistics for two recessions.

	VES									CD			
Variable	q	z	π_x	π_h	g	q and z	π_x	π_h	g	A	π_x	π_h	g
	The 1982 Recession												
h	0.16	0.14	0.09	0.52	0.10	0.23	0.10	0.57	0.10	0.37	0.13	0.36	0.14
y	0.20	0.49	0.08	0.13	0.10	0.91	0.02	0.04	0.03	0.90	0.02	0.04	0.03
y/h	0.13	0.69	0.05	0.05	0.07	0.80	0.06	0.06	0.08	0.79	0.06	0.07	0.08
x	0.17	0.40	0.11	0.15	0.17	0.66	0.08	0.12	0.14	0.78	0.05	0.08	0.09
1-s_k	0.06	0.53	0.17	0.14	0.10	0.51	0.21	0.17	0.12	0.00	0.00	0.00	0.00
	The Great Recession												
h	0.48	0.06	0.11	0.30	0.05	0.39	0.14	0.40	0.07	0.03	0.04	0.91	0.02
y	0.37	0.04	0.23	0.26	0.10	0.61	0.15	0.17	0.06	0.27	0.16	0.49	0.08
y/h	0.03	0.04	0.29	0.35	0.29	0.46	0.17	0.21	0.17	0.21	0.32	0.19	0.28
x	0.48	0.04	0.17	0.14	0.17	0.31	0.24	0.21	0.24	0.21	0.24	0.32	0.24
1-s_k	0.53	0.25	0.08	0.05	0.08	0.93	0.02	0.02	0.02	0.00	0.00	0.00	0.00

TABLE 7
THE GREAT RECESSION IN G7 COUNTRIES. WEDGE-ALONE COMPONENTS, DEVIATION (%) FROM PEAK (HOURS TROUGH).

			VES						CD			
		Data	q	z	q and z	π_x	π_h	g	A	π_x	π_h	g
CAN	**y**	-11.54	3.73	-2.55	-9.83	0.95	-2.89	-1.04	-11.47	0.97	-0.19	-1.18
2009	**h**	-4.74	2.30	-1.23	-0.35	0.79	-4.37	-1.15	-4.20	0.57	-0.23	-1.39
DEU	**y**	-10.54	10.51	-3.93	-8.25	-0.71	-1.57	-0.72	-10.43	-0.70	2.33	-0.76
2009	**h**	-1.84	5.94	-1.81	1.34	-0.09	-1.96	-0.59	-3.91	-0.28	4.97	-0.87
FRA	**y**	-15.24	-2.31	-2.30	-15.53	2.39	-2.66	0.28	-15.56	1.66	-1.58	0.36
2016	**h**	-4.25	-1.49	-0.97	-3.51	1.70	-3.07	0.28	-4.79	0.81	-0.60	0.42
GBR	**y**	-9.78	-1.27	-1.74	-7.44	2.61	-6.00	1.10	-7.63	2.33	-5.72	1.25
2011	**h**	-4.49	-0.95	-0.79	-1.60	4.02	-8.91	2.70	-2.23	4.31	-9.10	2.41
ITA	**y**	-23.60	-8.80	-3.93	-22.82	2.97	-5.37	0.83	-22.49	3.32	-5.44	1.20
2014	**h**	-12.64	-2.88	-1.86	-5.57	2.13	-10.19	1.05	-5.97	1.56	-9.72	1.23
JPN	**y**	-13.66	9.04	-6.50	-11.08	-0.58	-1.90	-0.23	-12.72	-0.65	-0.13	-0.16
2009	**h**	-4.91	5.52	-3.04	-0.64	-0.02	-3.51	-0.21	-4.20	-0.24	-0.13	-0.24
USA	**y**	-8.46	-11.19	2.14	-4.65	-1.54	-3.80	1.58	-2.56	-1.27	-6.08	1.75
2010	**h**	-9.09	-5.40	1.10	-4.06	-0.27	-6.72	2.38	-0.57	-0.20	-10.04	2.54
G7	**y**	-13.25	-0.04	-2.68	-11.37	0.86	-3.45	0.25	-11.83	0.80	-2.40	0.35
	h	-5.99	0.43	-1.22	-2.05	1.18	-5.53	0.63	-3.69	0.93	-3.55	0.58
OECD	**y**	-15.12	-6.82	-2.28	-14.17	0.89	-2.57	0.54	-13.93	1.58	-2.77	0.86
	h	-7.00	-3.44	-1.09	-4.37	1.11	-4.45	1.24	-4.78	0.94	-3.78	1.31

In the first column we indicate the year of the trough. The year of the peak is 2007 for all countries.

Table 8
The Great Recession in G7 Countries. σ-statistics for G7 Countries.

		VES									CD			
Country		q	z	π_x	π_h	g	q and z	π_x	π_h	g	A	π_x	π_h	g
CAN	**y**	0.07	0.34	0.14	0.26	0.19	0.87	0.03	0.06	0.04	0.99	0.00	0.00	0.00
	h	0.02	0.08	0.04	0.76	0.10	0.04	0.04	0.81	0.11	0.90	0.02	0.02	0.06
DEU	**y**	0.02	0.72	0.08	0.10	0.08	0.98	0.01	0.01	0.00	0.83	0.06	0.04	0.06
	h	0.00	0.02	0.01	0.96	0.01	0.00	0.01	0.98	0.01	0.20	0.54	0.06	0.20
FRA	**y**	0.18	0.30	0.12	0.23	0.16	0.87	0.03	0.06	0.04	0.88	0.03	0.05	0.04
	h	0.16	0.24	0.08	0.42	0.10	0.42	0.08	0.41	0.09	0.59	0.10	0.20	0.11
GBR	**y**	0.06	0.51	0.06	0.30	0.07	0.75	0.04	0.17	0.04	0.91	0.02	0.06	0.02
	h	0.18	0.49	0.06	0.19	0.08	0.44	0.11	0.32	0.13	0.63	0.04	0.26	0.08
ITA	**y**	0.23	0.31	0.10	0.24	0.12	0.99	0.00	0.00	0.00	0.99	0.00	0.00	0.00
	h	0.06	0.06	0.03	0.81	0.03	0.11	0.03	0.82	0.03	0.24	0.06	0.64	0.06
JPN	**y**	0.03	0.76	0.07	0.09	0.06	0.89	0.03	0.04	0.03	0.98	0.01	0.01	0.01
	h	0.01	0.21	0.04	0.70	0.04	0.07	0.05	0.83	0.05	0.81	0.07	0.07	0.06
USA	**y**	0.58	0.03	0.10	0.24	0.05	0.46	0.14	0.33	0.07	0.17	0.11	0.67	0.06
	h	0.21	0.03	0.04	0.70	0.02	0.13	0.05	0.79	0.03	0.02	0.02	0.94	0.01
Avg.	**y**	0.17	0.43	0.10	0.21	0.10	0.83	0.04	0.10	0.03	0.82	0.03	0.12	0.03
G7	**h**	0.09	0.16	0.04	0.65	0.05	0.17	0.05	0.71	0.06	0.48	0.12	0.31	0.08
Avg.	**y**	0.25	0.29	0.14	0.19	0.14	0.78	0.07	0.08	0.07	0.75	0.08	0.09	0.08
OECD	**h**	0.20	0.24	0.13	0.35	0.08	0.32	0.17	0.40	0.11	0.37	0.19	0.32	0.11

Table 9
The Great Recession in G7 Countries. $\widehat{\sigma}$-statistics for output in G7 countries.

	VES									CD								
	CAN	DEU	FRA	GBR	ITA	JPN	USA	Avg.G7	Avg.OECD	CAN	DEU	FRA	GBR	ITA	JPN	USA	Avg.G7	Avg.OECD
CAN	0.000	0.016	0.000	0.030	0.019	0.001	0.260	0.004	0.011	0.000	0.034	0.017	0.011	0.000	0.000	1.141	0.045	0.078
DEU	0.016	0.000	0.018	0.086	0.000	0.011	0.402	0.033	0.053	0.034	0.000	0.004	0.009	0.034	0.029	0.835	0.008	0.009
FRA	0.000	0.018	0.000	0.028	0.020	0.001	0.254	0.003	0.011	0.017	0.004	0.000	0.001	0.016	0.013	0.903	0.009	0.022
GBR	0.030	0.086	0.028	0.000	0.090	0.038	0.119	0.013	0.010	0.011	0.009	0.001	0.000	0.011	0.008	0.930	0.011	0.033
ITA	0.019	0.000	0.020	0.090	0.000	0.013	0.413	0.036	0.060	0.000	0.034	0.016	0.011	0.000	0.000	1.135	0.043	0.078
JPN	0.001	0.011	0.001	0.038	0.013	0.000	0.285	0.007	0.016	0.000	0.029	0.013	0.008	0.000	0.000	1.111	0.039	0.069
USA	0.260	0.402	0.254	0.119	0.413	0.285	0.000	0.205	0.169	1.141	0.835	0.903	0.930	1.135	1.111	0.000	0.738	0.674
Avg.	0.004	0.033	0.003	0.013	0.036	0.007	0.205	0.000	0.005	0.045	0.008	0.009	0.011	0.043	0.039	0.738	0.000	0.010

Table 10

The Great Recession in G7 Countries. $\widehat{\sigma}$-statistics for hours in G7 countries.

	VES									CD								
	CAN	DEU	FRA	GBR	ITA	JPN	USA	Avg.G7	Avg.OECD	CAN	DEU	FRA	GBR	ITA	JPN	USA	Avg.G7	Avg.OECD
CAN	0.000	0.042	0.312	0.402	0.012	0.006	0.017	0.031	0.263	0.000	0.774	0.136	0.132	0.832	0.013	1.623	0.269	0.402
DEU	0.042	0.000	0.513	0.642	0.036	0.029	0.052	0.106	0.474	0.774	0.000	0.372	0.495	0.599	0.607	1.116	0.334	0.227
FRA	0.312	0.513	0.000	0.009	0.277	0.308	0.238	0.155	0.018	0.136	0.372	0.000	0.011	0.330	0.067	0.892	0.026	0.070
GBR	0.402	0.642	0.009	0.000	0.374	0.406	0.329	0.227	0.024	0.132	0.495	0.011	0.000	0.303	0.069	0.836	0.032	0.094
ITA	0.012	0.036	0.277	0.374	0.000	0.002	0.002	0.019	0.246	0.832	0.599	0.330	0.303	0.000	0.654	0.137	0.176	0.138
JPN	0.006	0.029	0.308	0.406	0.002	0.000	0.006	0.026	0.265	0.013	0.607	0.067	0.069	0.654	0.000	1.376	0.166	0.273
USA	0.017	0.052	0.238	0.329	0.002	0.006	0.000	0.010	0.208	1.623	1.116	0.892	0.836	0.137	1.376	0.000	0.622	0.545
Avg.	0.031	0.106	0.155	0.227	0.019	0.026	0.010	0.000	0.135	0.269	0.334	0.026	0.032	0.176	0.166	0.622	0.000	0.018

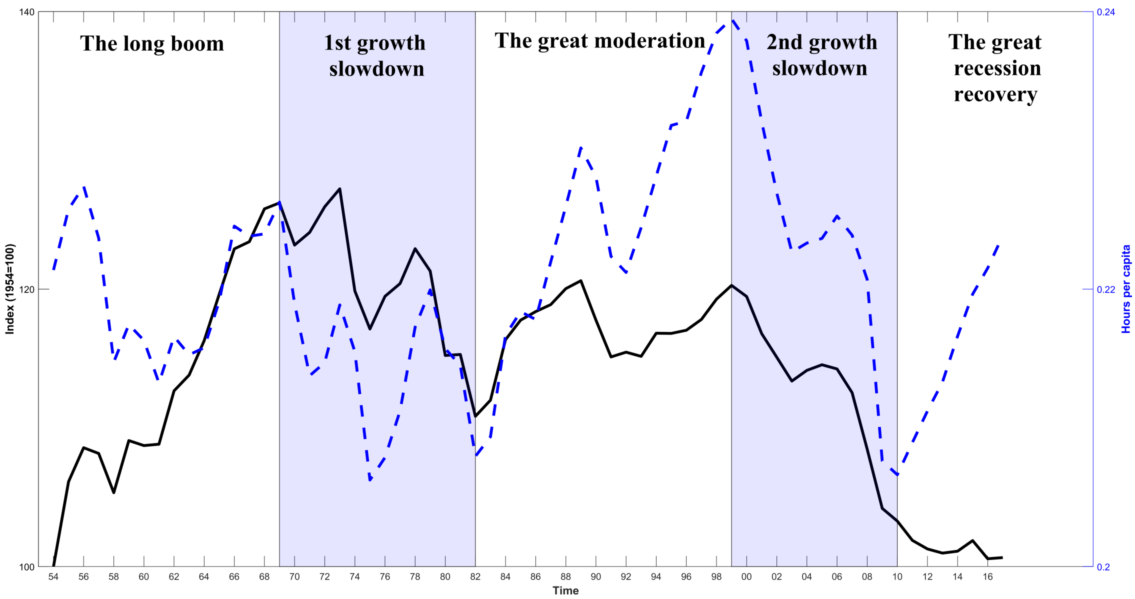
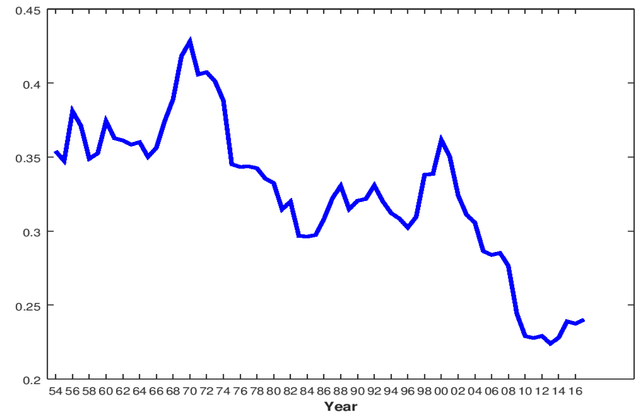
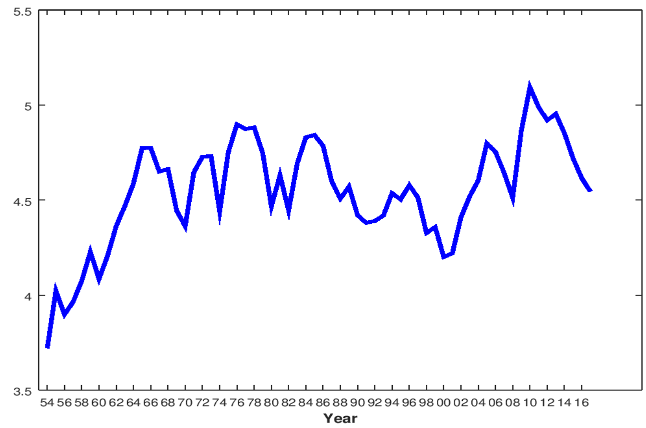


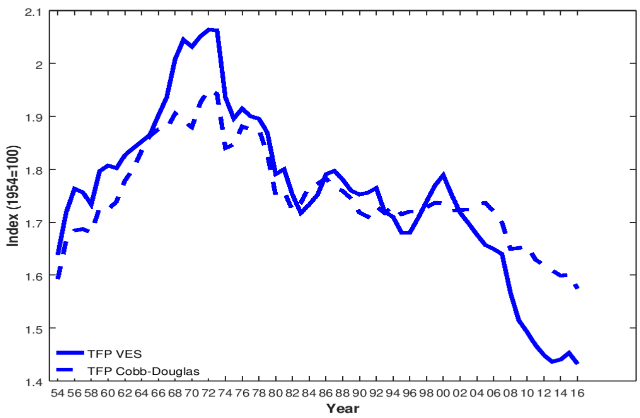
FIGURE 1: U.S. Economic Growth.



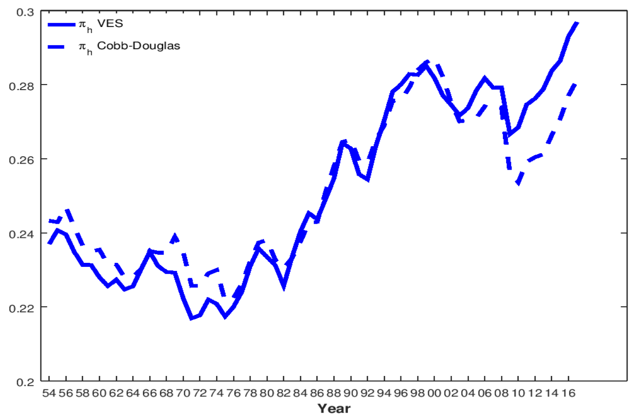
(a) Capital Efficiency (q).



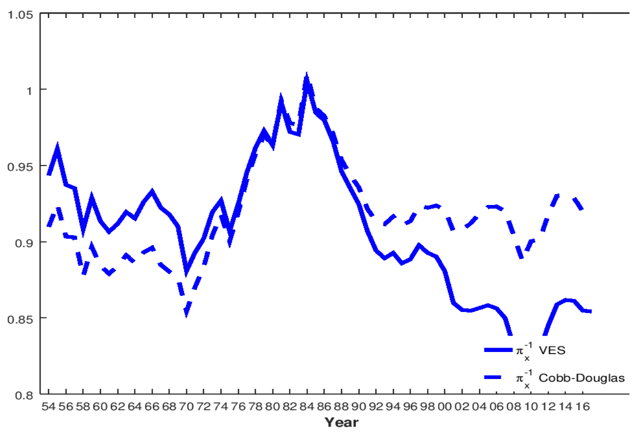
(b) Labor Efficiency (z).



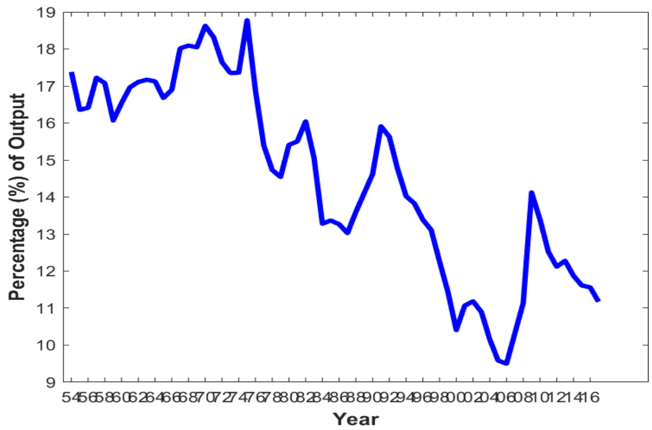
(c) Total Factor Productivity.



(d) Labor Wedge (π_h).

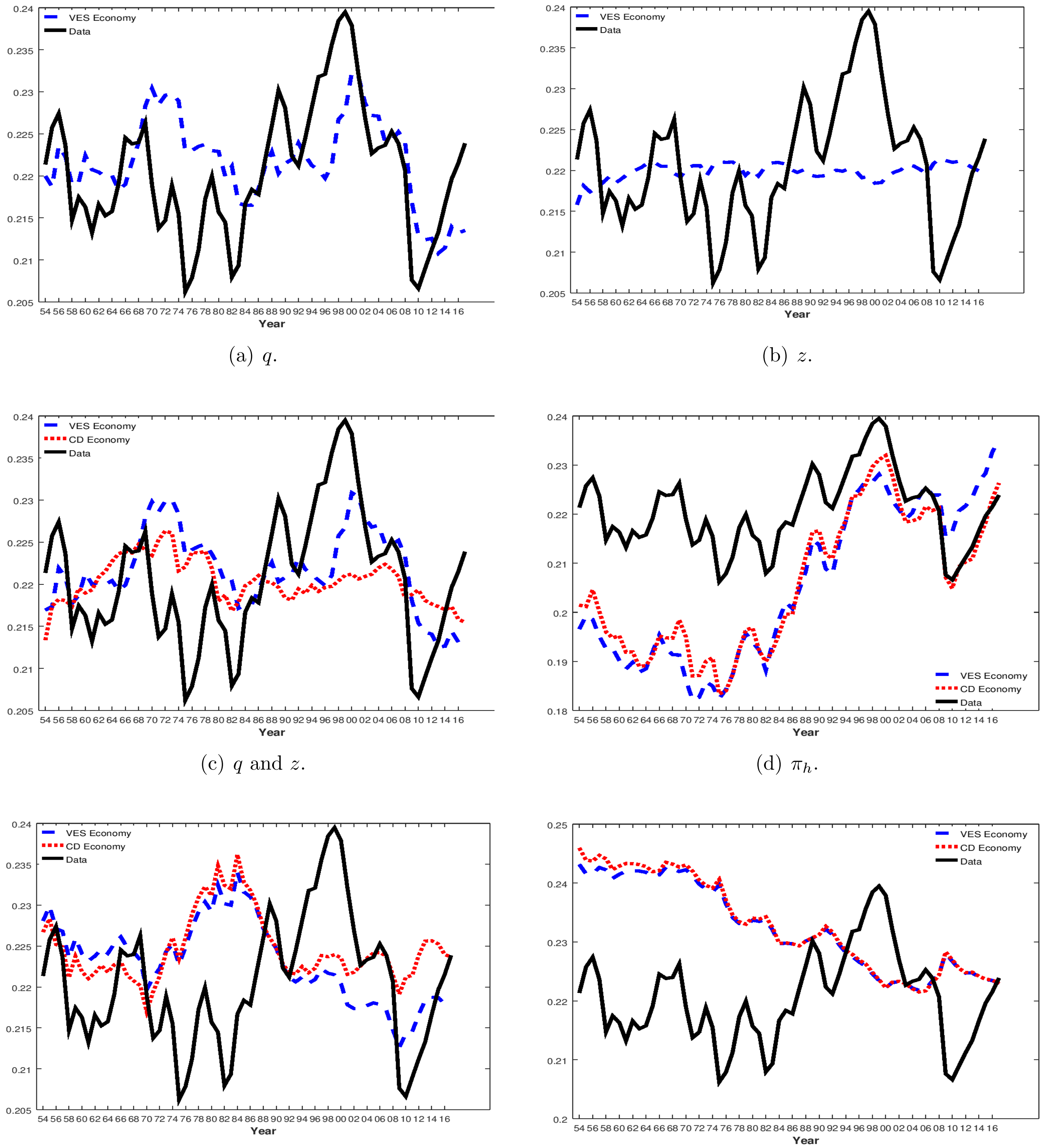


(e) Investment Wedge. (π_x^{-1})



(f) Resources Constraint Wedge.

FIGURE 2: Wedges Paths.

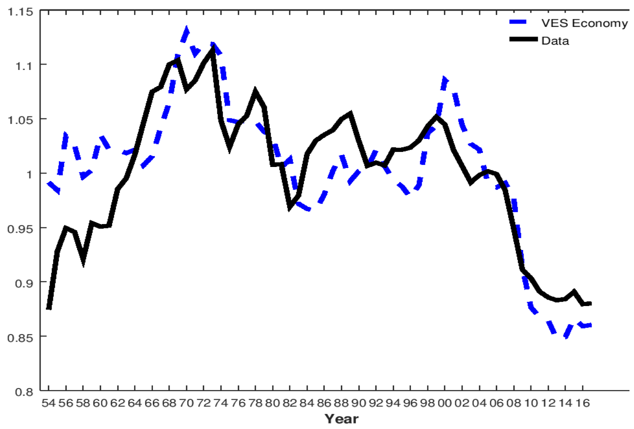


(a) q. (b) z.

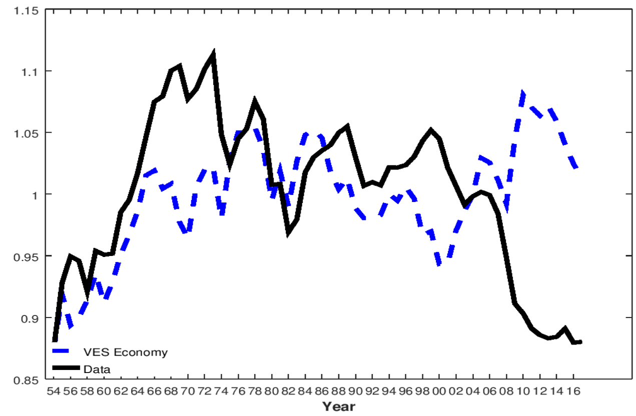
(c) q and z. (d) π_h.

(e) π_x. (f) g.

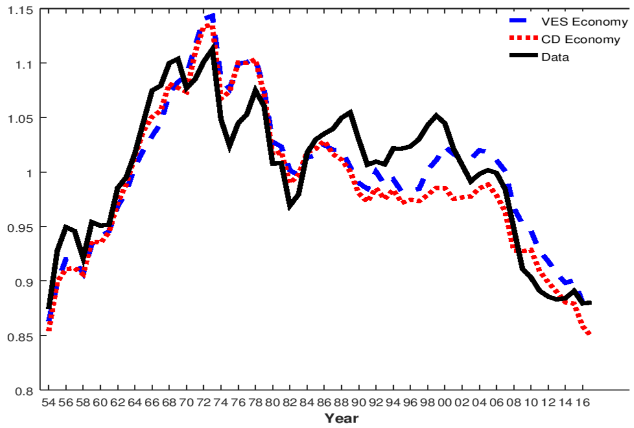
FIGURE 3: The Contribution of Wedges to Worked Hours.



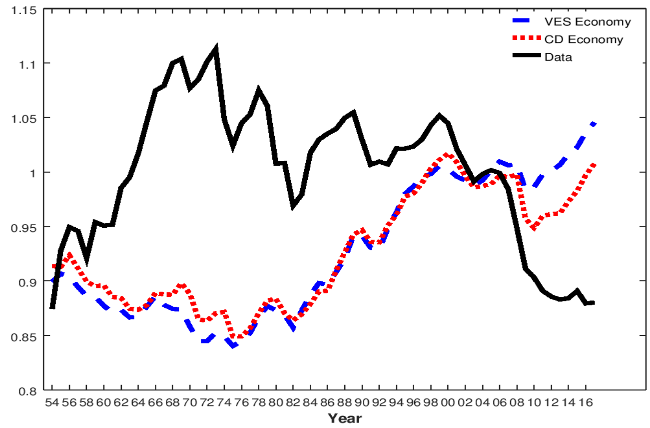
(a) q.



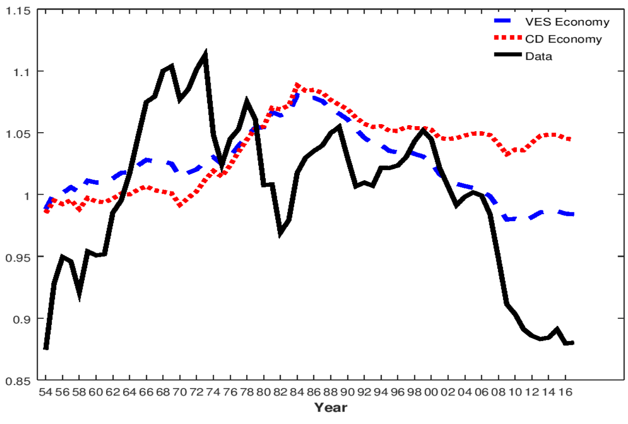
(b) z.



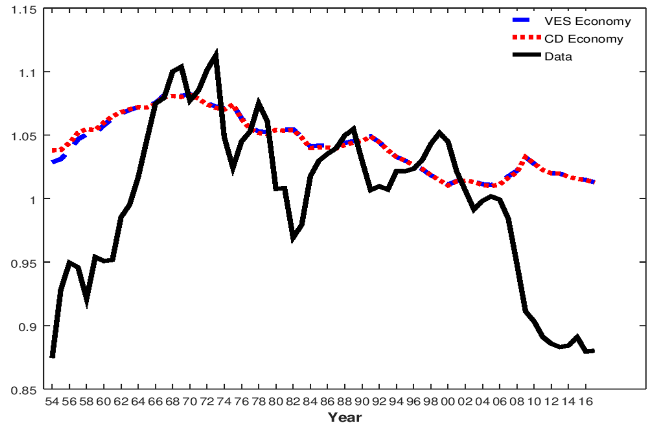
(c) q and z.



(d) π_h.

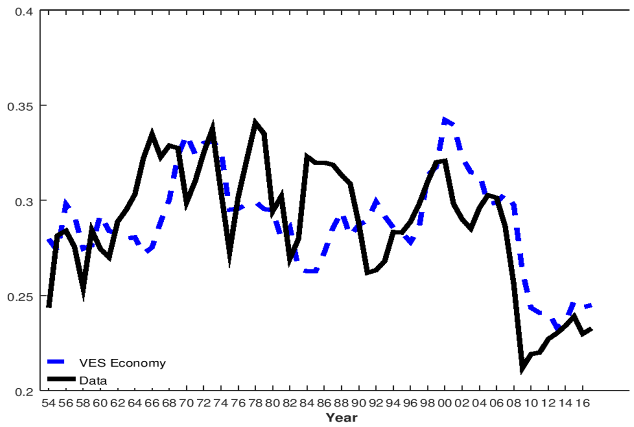


(e) π_x.

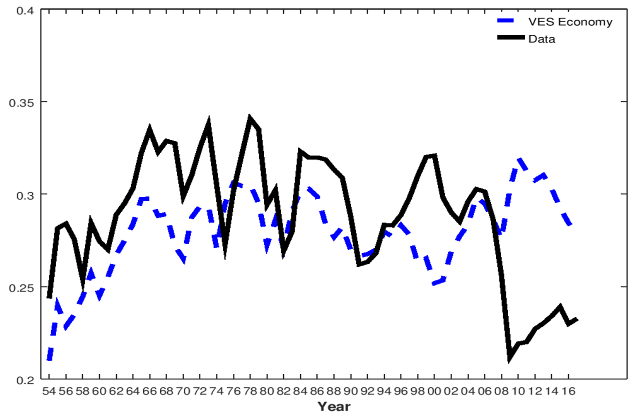


(f) g.

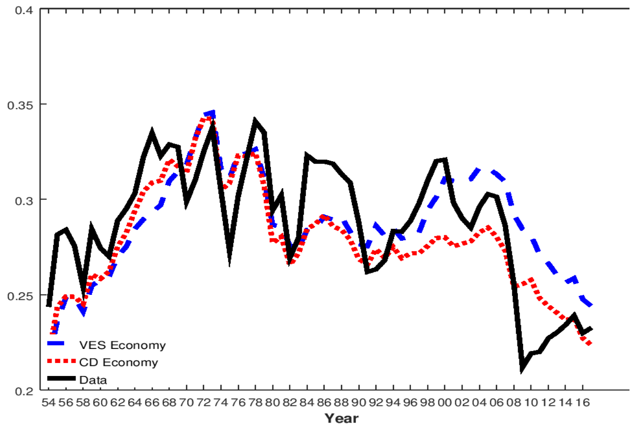
FIGURE 4: The Contribution of Wedges to Output (Detrended).



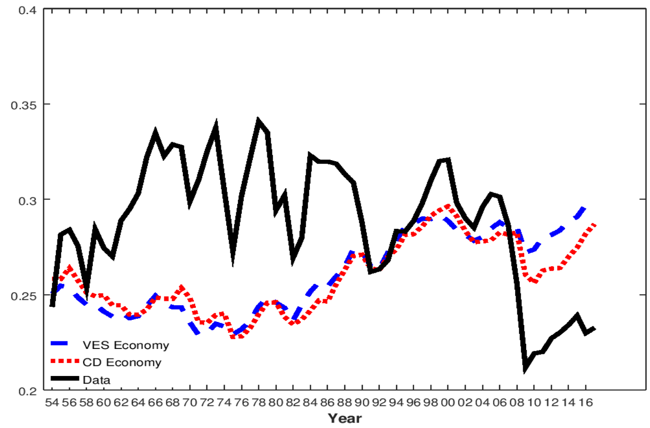
(a) q.



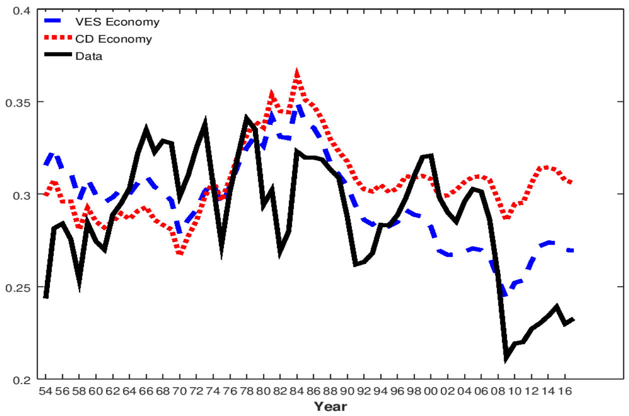
(b) z.



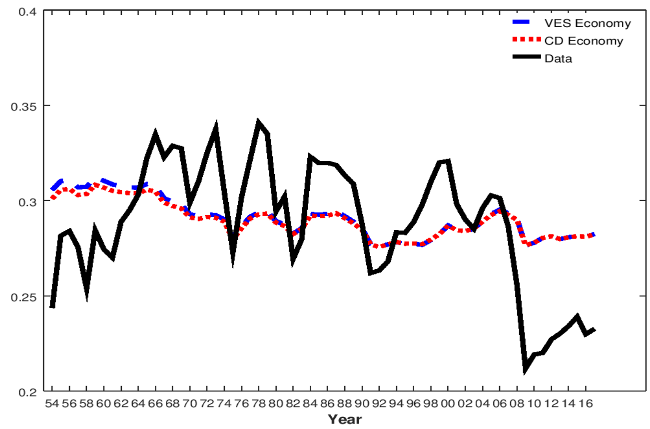
(c) q and z.



(d) π_h.

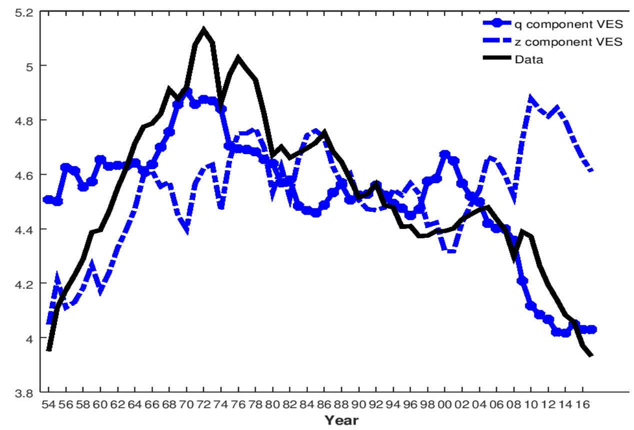


(e) π_x.

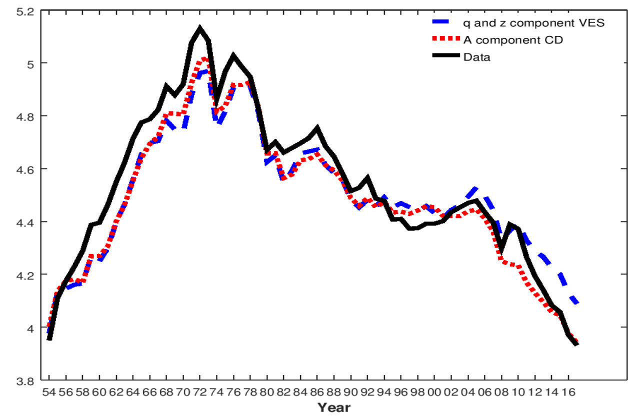


(f) g.

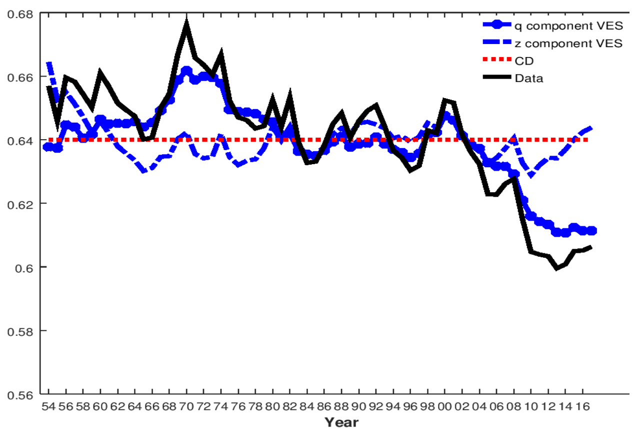
FIGURE 5: The Contribution of Wedges to Investment.



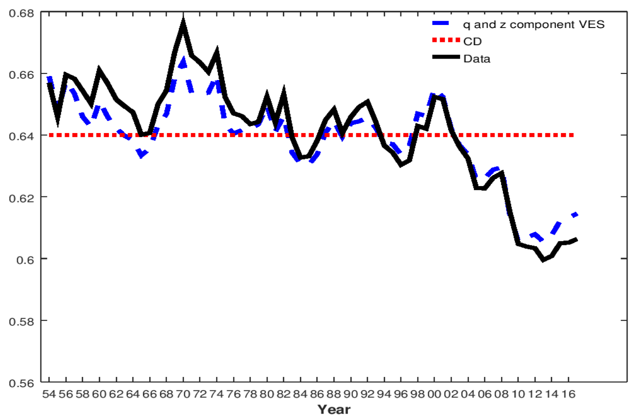
(a) Output per worked hour (Detrended).



(b) Output per worked hour (Detrended).

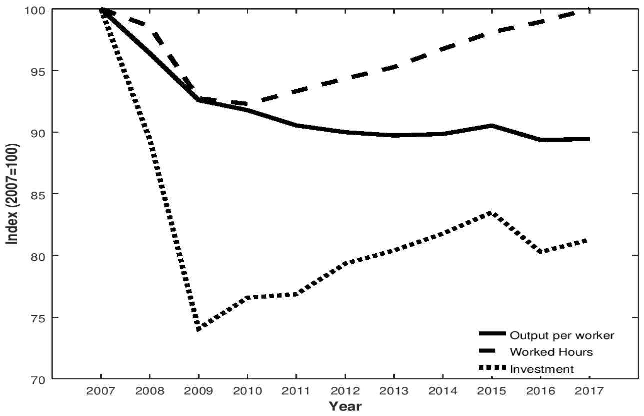


(c) Labor share.

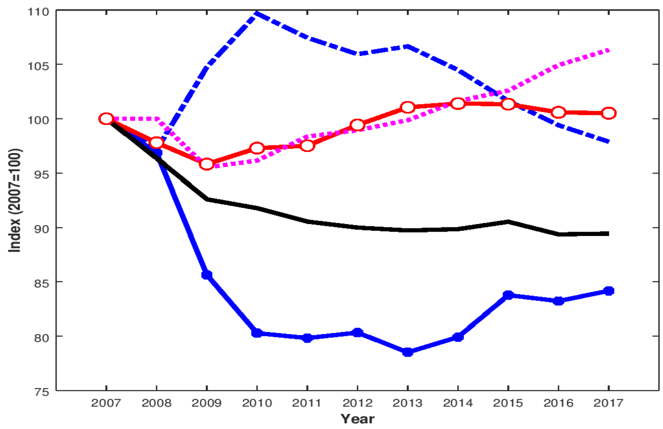


(d) Labor share.

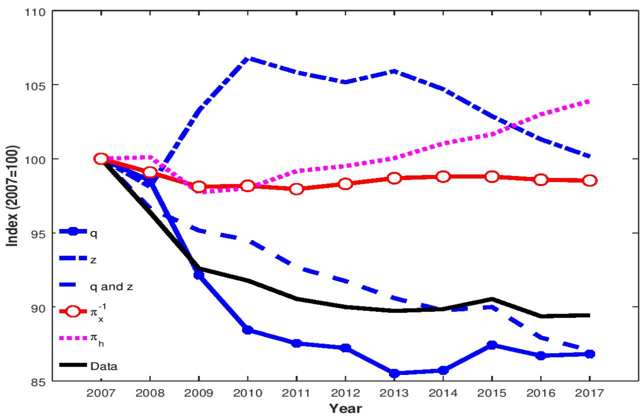
Figure 6: The Contribution of Efficiency Wedges.



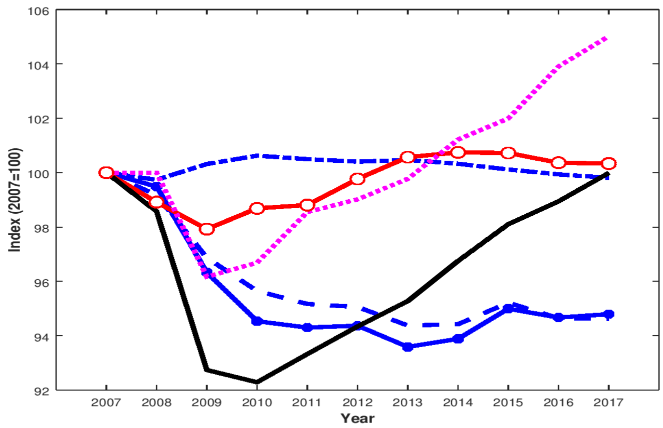
(a) Output per capita, worked hours and investment.



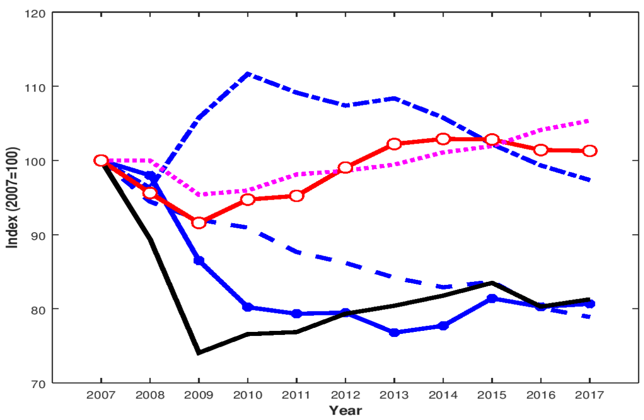
(b) Output per capita and four wedges.



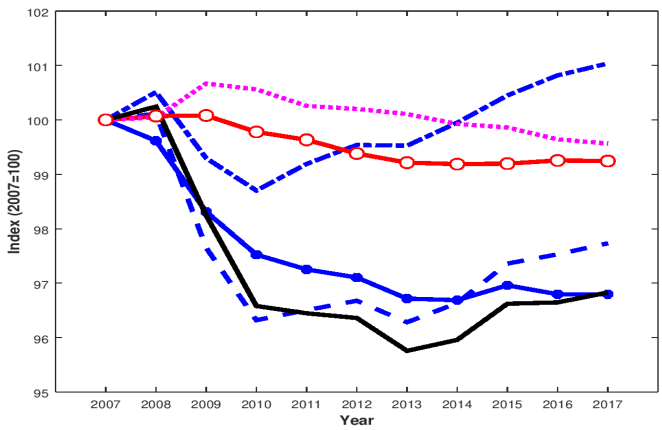
(c) Output per capita and its components.



(d) Worked hours and its components.

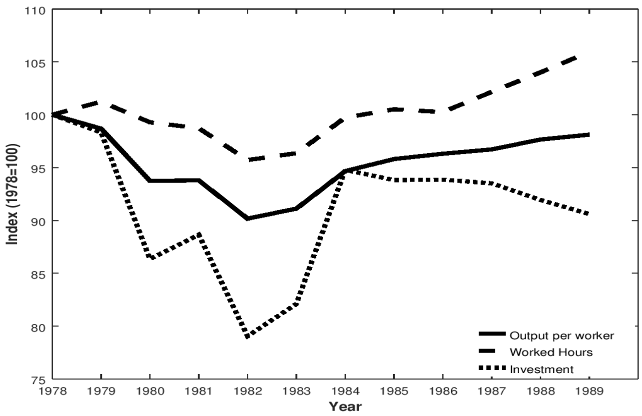


(e) Investment per capita and its components.

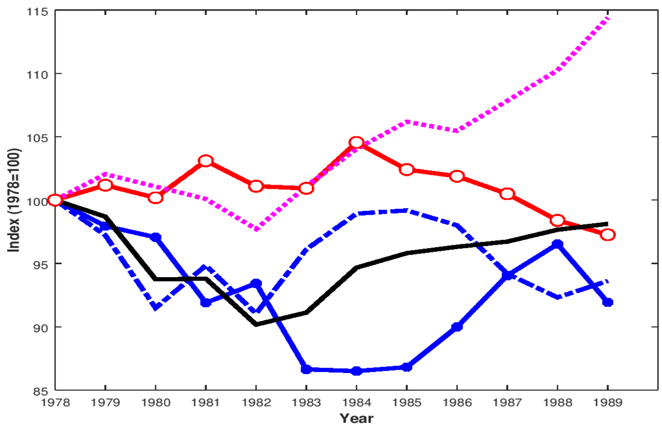


(f) Labor share and its components.

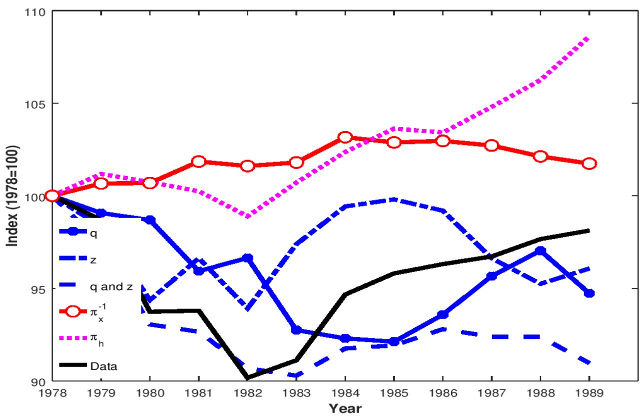
FIGURE 7: The Great Recession with VES production function.



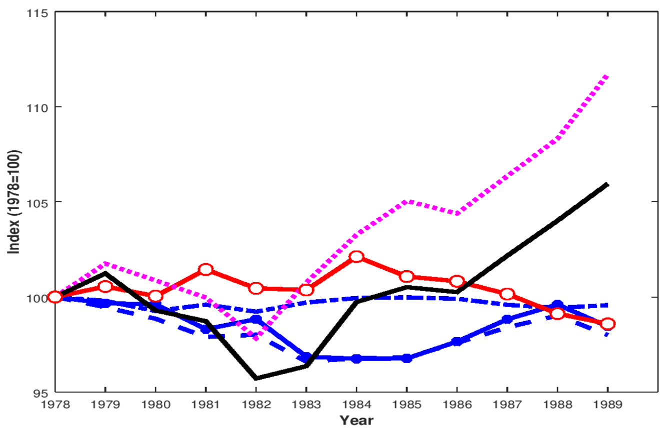
(a) Output per capita, worked hours and investment.



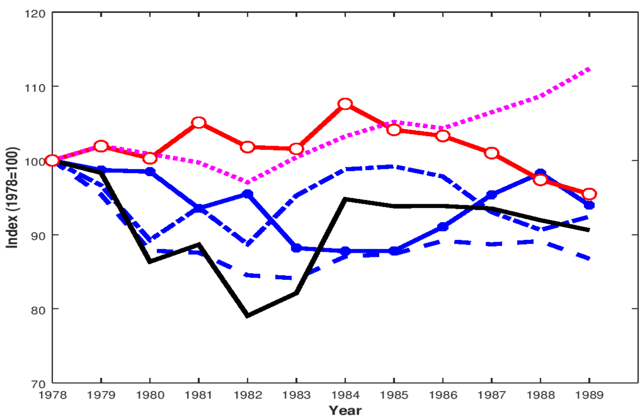
(b) Output per capita and four wedges.



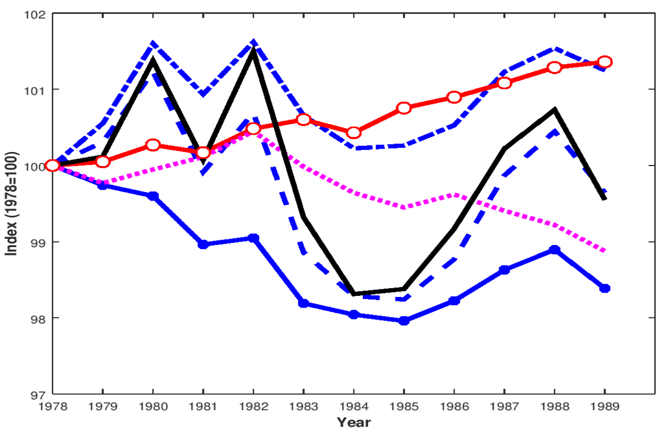
(c) Output per capita and its components.



(d) Worked hours and its components.

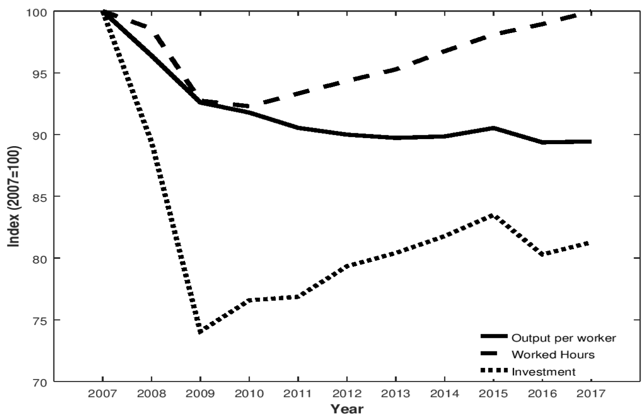


(e) Investment per capita and its components.

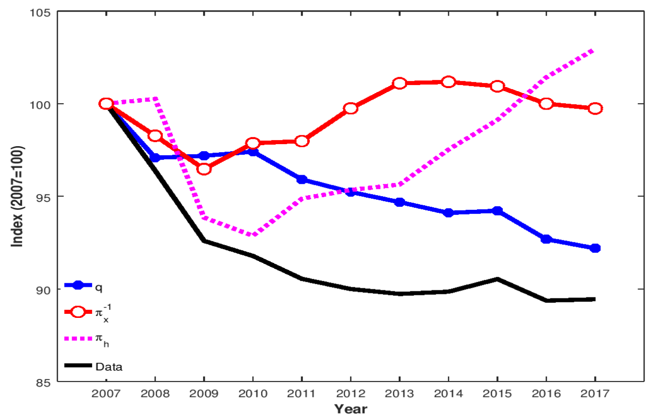


(f) Labor share and its components.

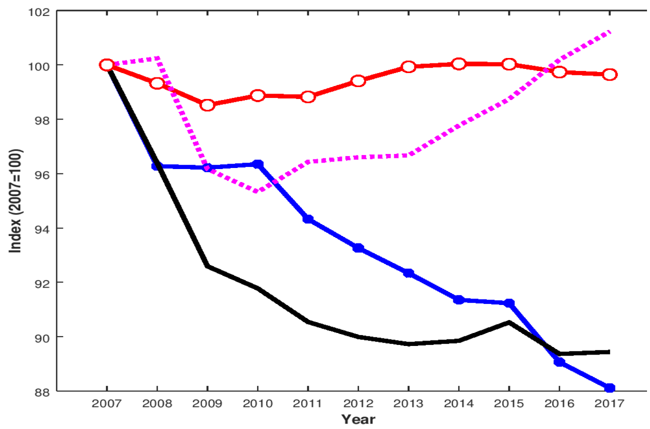
FIGURE 8: The 1982 Recession with VES production function.



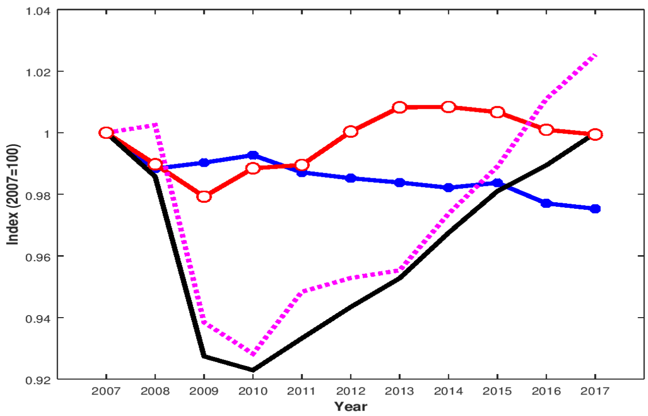
(a)



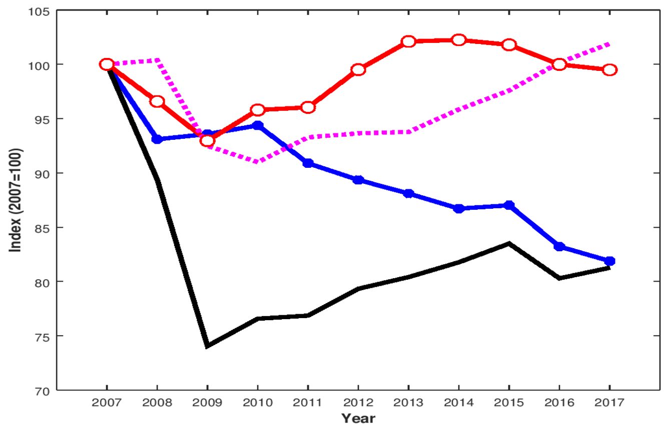
(b) Output per capita and four wedges.



(c) Output per capita and its components.

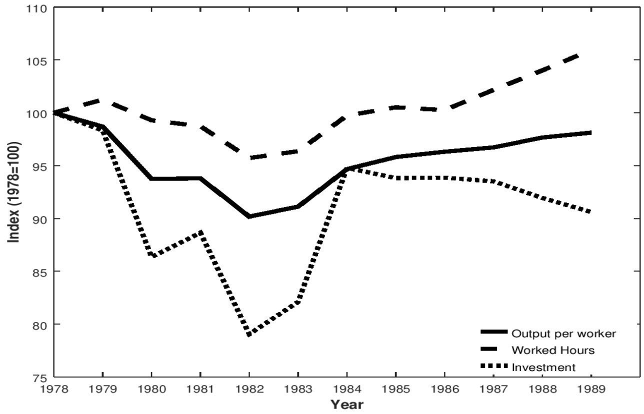


(d) Worked hours and its components.

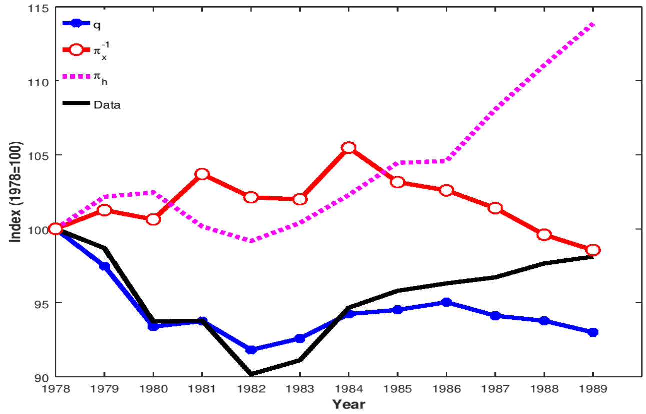


(e) Investment per capita and its components.

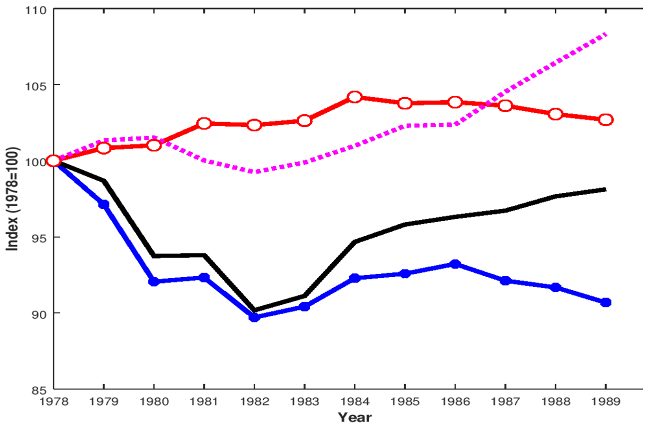
FIGURE 9: The Great Recession with Cobb-Douglas production function.



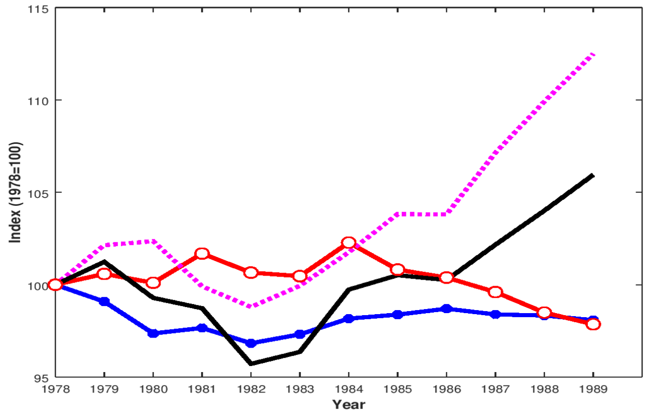
(a) Output per capita, worked hours, and investment.



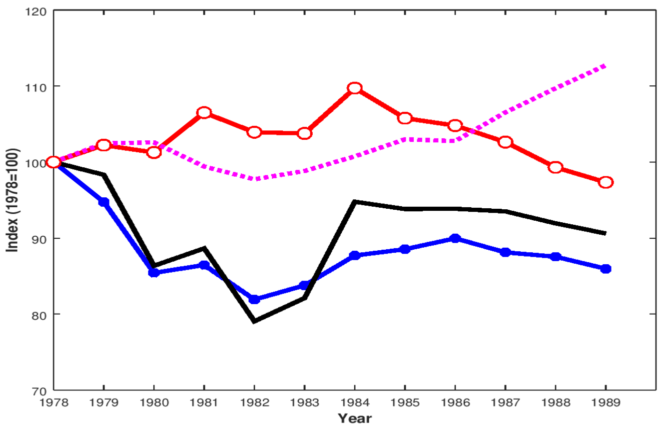
(b) Output per capita and four wedges.



(c) Output per capita and its components.



(d) Worked hours and its components.



(e) Investment per capita and its components.

FIGURE 10: The 1982 Recession with Cobb-Douglas production function.