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TECHNICAL CHANGE, FACTOR SHARES AND FRICTIONS IN THE EURO AREA

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and Alpo Willman

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In 2008 all ECB publications feature a motif taken from the €10 banknote.

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CONTENTS

Abstract

We develop a framework for analyzing "medium-run" departures from balanced growth, and apply it to the economies of continental Europe. A time-varying factor-augmenting production function (mimicking "directed" technical change) with a below-unitary substitution elasticity coupled with supporting short-run factor demands (and price setting) is shown to account for the observed dynamics of factor incomes shares, capital deepening and the capital-output ratio. Based on careful data accounting, we also identify a rising mark-up, which we ascribe to the rise of Services. The balanced growth path emerges as a special (and testable) case of our framework, as do existing strands of medium-run debates.

JEL: C22, E23, E25, O30, O51.
Keywords: Medium Run, Euro Area, Elasticity of Substitution, Factor-Augmenting Technical Progress, Productivity, Income Distribution, Adjustment Costs, Effective Labor Hours.

Non-Technical Summary

The economy of continental Europe (hereafter, the "euro area") has attracted interest because of the puzzling manner in which it has eschewed BGP features: "hump-shaped" labor income shares; persistently high unemployment; decelerated output and productivity growth etc. Given their decades-long persistence, such features can be described as neither short-run nor recognizably long-run features; hence our "medium-run" emphasis.

Regarding the non-constant labor share, many researchers linked differences in the evolution of income shares in the US and Europe (and, in turn, employment and productivity trends) to differences in institutions and adjustment costs (e.g., labor-market features, wage formation); the sequencing of adverse (labor) supply and demand shocks; and the elasticity of factor substitutability.

We develop a framework where dynamic short-run factor demands (and price setting) converge to a medium-run growth path that accounts for observed deviations of factor incomes shares, the mark-up, capital intensity and the capital-output ratio from the balanced growth path. We first consider medium-run supply. The workhorse of growth theory has tended to be the Cobb-Douglas production function whose elasticity of substitution between capital and labor is unity. This property meets the essential condition for balanced growtrh and accords with the stylized facts: the approximate constancy of factor income shares during a steady increase in capital deepening and per-capita income. It follows that under Cobb Douglas the direction of technical change is irrelevant for income distribution. In contrast, pronounced trends in factor income distribution visible in many countries over the "medium run" support the more general Constant Elasticity of Substitution (CES) function and hint at the importance of biases in technical change. In models of biased technical change scarcity generates incentives to invest in factor-saving innovations, i.e., firms reduce the need for scarce factors and increase the use of abundant ones. Acemoglu (2002, 2003) further suggested that while technical progress is necessarily labor-augmenting along the BGP, it may become capital-biased in periods of transition reflecting the interplay of innovation activities, factor intensities and profitability. Given a below-unitary substitution elasticity this pattern promotes the asymptotic stability of income shares while precisely allowing them to fluctuate in the medium run

The intuition for asymptotic labor-augmentation reflects the feature that capital unlike labor may be accumulated limitlessly; thus labor tends to represent the constraining factor, and firms, in order to avoid an explosion of wage income (or labor share), bias and concentrate technical improvements accordingly. However, with persistently high unemployment in the euro area, considering labor as the constraining factor for medium-run growth appears anomalous. This raises the question of whether the implications of balanced growth are fundamentally violated by medium-run developments in the euro area. And in particular - since it is unlikely that relative factor prices are able to completely explain salient euro area features (non-stationary factor income shares, decelerating productivity growth) - whether changes in non-constant factor augmented technical change are part of the explanation.

Arguably much past work muddied the waters by failing to distinguish GDP-income shares and factor-income shares. If the euro area mark-up is time-varying (as we maintain), overlooking this distinction risks mixing structural and technical explanations for medium-run phenomena. For a given substitution elasticity, factor income shares are driven by the dynamics of technical change and the factor price ratio. The mark-up, although not necessarily orthogonal to such matters, may to a first approximation be considered determined by structural factors such as changing sectoral composition. Finally, we argue ignoring financial repression in the 1970s jeopardizes the calculation of capital income, again potentially misdiagnosing the problem.

Our results suggest the elasticity of factor substitution is below unity and that factor augmenting technical change is time-varying ("directed"). We distinguish three growth phases in the euro area from 1970. First, high TFP growth reflecting post-War catch-up. Scarce capital, favorable demographics and financial repression encouraged high capital augmentation. The oil crisis reinforced this: labor's appropriation push gave firms additional incentives to engage in capital augmentation. During the second phase - 1980s-to-early-1990s - financial repression was in retreat and previous constellations of biased technical change curtailed the historically high capital share weakening the need for capital saving. The final phase – from the mid-1990s onwards – were periods of low TFP growth reflecting a particular combination of directed technical change (high capital-, low labor-augmentation) that was the response to the global IT boom and ongoing labor-market deregulation.

Furthermore, these, largely data-based, analyses point to upward trends in the aggregate mark-up. This pure profit component reflects, we argue, structural developments in terms of aggregation across high mark-up/low productivity sectors, on one hand, and low mark-up and high productivity sectors, on the other, with differentiated income elasticities of demand. This is consistent with the rise of Services in the euro area.

Having set up this framework, our attention turns to the corresponding dynamic, short-run factor demands around the medium-run equilibrium and price setting. Much of the medium-run debate is fashioned around accounts of slow real adjustment (e.g., wages and employment) around the first oil shock (e.g., IMF, 1999, Blanchard and Galí, 2007) with rising unemployment and lingering structural rigidities. Accordingly, we allow a careful modeling of factor adjustment costs. Labor participation decisions are modeled along the intensive and extensive margins. In so doing, we introduce the concept of "effective labor hours". An innovative aspect is that the former margin turns out to have a key spillover onto firms' pricing decisions. Thus, in contrast to New-Keynesian models, we model inflation fundamentals (or real marginal costs) not as proportional to labor income share (as under Cobb Douglas) but as factor-augmenting CES real marginal costs, supplemented by an intensive participation margin. This generates the correct inflation fundament with the correct cyclical properties. Capital accumulation reflects time-to-build considerations. The resulting forward-looking, structural dynamic equations have encouragingly good tracking properties (compared to backward-looking rivals), reflecting, we believe, careful modeling of the medium run as much as careful modeling of structural frictions.

"Most of our intuition and most of our models are based on the assumption that technological progress is Harrod-Neutral and that there is a balanced growth path. What happens if not is largely unexplored, but may well be relevant", Blanchard (2006, p13).

"… the fundamental intellectual need is for a common understanding of medium run departures from equilibrium growth", Solow (1987).

1. Introduction

In his survey of macroeconomics, Solow (2000) called for the use of "medium-run" models capable of explaining and reconciling protracted departures from the balanced growth path (BGP). The BGP, the dominant assumption in the theoretical growth literature, suggests that variables such as output, consumption, etc tend to a common, constant growth rate, whilst key underlying ratios (e.g., factor income shares, capital-output ratio) are constant, e.g., Kaldor (1961). The medium run corresponds to the overlap and interaction of this supply-driven BGP with the demand-driven, short run; typical examples, Solow added, include the "lost decade" in Japan, the great US expansion since the early 1990s, and persistent economic divergences in continental Europe.

The economy of continental Europe (hereafter, the "euro area") has attracted interest precisely because of the puzzling manner in which it has eschewed BGP features: "hump-shaped" labor income shares; persistently high unemployment; decelerated output and productivity growth etc. Given their decades-long persistence, such features can be described as neither short-run nor recognizably long-run features; hence our "medium-run" emphasis.

Regarding the non-constant labor share, Bruno and Sachs (1985), Blanchard (1997), and Caballero and Hammour (1998) were among the first to pay serious attention to the issue. They linked differences in the evolution of income shares in the US and Europe (and, in turn, employment and productivity trends) to differences in institutions and adjustment costs (e.g., labor-market features, wage formation); the sequencing of adverse (labor) supply and demand shocks; and the elasticity of factor substitutability.[1] As regards the latter, Caballero and Hammour (1998), Blanchard (1997) and Berthold et al (2002) used models assuming purely labor-augmenting (Harrod-Neutral) technical progress, an above-unity long-run substitution elasticity with short-run putty-clay characteristics. A cost-push shock with sticky real wages would thus lead at first to only a small decline in employment but an increase in the labor share. In the longer run labor is replaced over-proportionally by capital and, with rising capital deepening, the labor-share falls again and unemployment rises.

[1] In a not un-related vein, Krusell et al (2000) suggest that the elasticity of substitution between capital and unskilled labor exceeds that with respect to that of skilled labor. This "capital-skill" complementarity underpins the widening skill premia.

Such explanations have drawbacks. First, the case for an above-unity elasticity appears empirically weak and theoretically anomalous. Besides not being able to explain the secular downward trend in the labor-income share, critics argued that Europe also experienced a decline in capital formation since the 1970's. Declining capital deepening, however, can cause a decline in employment and a rise in the capital income share only if the substitution elasticity does not exceed unity, Rowthorn (1999). Second, given persistently high unemployment it becomes challenging to regard labor availability as the constraining factor for growth (i.e., that technical change is solely Harrod-Neutral). Technical progress may instead be non neutral and time-varying reflecting profit incentives (as suggested by models of directed technical change). Third, the effects of adjustment costs and institutional propagation mechanisms would need to be strong to generate such prolonged dynamics. Finally, the ongoing process of product and labor market reforms in Europe should have diluted the effect of historical employment rigidities.

We develop a framework where dynamic short-run factor demands (and price setting) converge to a medium-run growth path that accounts for observed deviations of factor incomes shares, the mark-up, capital intensity and the capital-output ratio from the BGP. We first consider medium-run supply. The workhorse of growth theory has tended to be the Cobb-Douglas production function whose elasticity of substitution is unity. This property meets the essential condition for a BGP and accords with presumed stylized facts: the approximate constancy of factor income shares during a steady increase in capital deepening and per-capita income. It follows that under Cobb Douglas the direction of technical change is irrelevant for income distribution. In contrast, pronounced trends in factor income distribution visible in many countries over what Blanchard (1997) also called the "medium run" support the more general Constant Elasticity of Substitution (CES) function and hint at the importance of biases in technical change.

In models of biased technical change (e.g., Kennedy, 1964, Samuelson, 1965, Zeira, 1998, Acemoglu, 2002, 2003, Boldrin and Levine, 2002), scarcity generates incentives to invest in factor-saving innovations, i.e., firms reduce the need for scarce factors and increase the use of abundant ones. Acemoglu (2002, 2003) further suggested that while technical progress is necessarily labor-augmenting along the BGP, it may become capital-biased in periods of transition reflecting the interplay of innovation activities, factor intensities and profitability. Given a below-unitary substitution elasticity this pattern promotes the asymptotic stability of income shares while precisely allowing them to fluctuate in the medium run[2]

The intuition for asymptotic labor-augmentation reflects the feature that capital unlike labor may be accumulated limitlessly; thus labor tends to represent the constraining factor, and firms, in order to avoid an explosion of wage income (or labor share), bias and concentrate technical improvements accordingly. However, with persistently high unemployment in the euro area, considering labor as the constraining factor for medium-

[2] Accordingly, capital augmentation, rather than being a nuisance phenomenon, is an equilibrating one: "high" capital income shares generate incentives to save on capital which, in turn, curtails the trend in the capital share.

run growth appears anomalous. This raises the question of whether the implications of balanced growth are fundamentally violated by medium-run developments in the euro area. And in particular - since it is unlikely that relative factor prices are able to completely explain salient euro area features (non-stationary factor income shares, decelerating productivity growth), e.g., Blanchard (2000) - whether changes in non-constant factor augmented technical change are part of the explanation.

Given these debates, we model aggregate supply and factor inputs in a relatively un-restricted manner. Unlike most empirical works, we do not constrain technical progress to evolve at a constant rate but allow for quite general dynamics. This allows us to capture underlying supply in a highly data-driven manner. It also highlights that existing strands of medium-run debates can be nested as special cases. Further, we apply La Grandville (1989)'s "normalization" methodology in a supply-side system, which turns out to be well-suited for analyzing technical biases.

Explaining the medium run in the euro area requires quite careful scrutiny of the data. Arguably much past work muddied the waters by failing to distinguish GDP-income shares and factor-income shares. If the euro area mark-up is time-varying (as we maintain), overlooking this distinction risks mixing structural and technical explanations for medium-run phenomena. For a given substitution elasticity, factor income shares are driven by the dynamics of technical change and the factor price ratio. The mark-up, although not necessarily orthogonal to such matters, may to a first approximation be considered determined by structural factors such as changing sectoral composition. Finally, we argue ignoring financial repression in the 1970s jeopardizes the calculation of capital income, again potentially misdiagnosing the problem.

Our results suggest the elasticity of factor substitution is below unity and that factor augmenting technical change is time-varying ("directed"). We distinguish three growth phases in the euro area from 1970. First, high TFP growth reflecting post-War catch-up. Scarce capital, favorable demographics and financial repression encouraged high capital augmentation. The oil crisis reinforced this: labor's appropriation push gave firms additional incentives to engage in capital augmentation. During the second phase - 1980s-to-early-1990s - financial repression was in retreat and previous constellations of biased technical change curtailed the historically high capital share weakening the need for capital saving. The final phase – from the mid-1990s onwards – were periods of low TFP growth reflecting a particular combination of directed technical change (high capital-, low labor-augmentation) that was the response to the global IT boom and ongoing labor-market deregulation.

Furthermore, these, largely data-based, analyses point to upward trends in the aggregate mark-up. This pure profit component reflects, we argue, structural developments in terms of aggregation across high mark-up/low productivity sectors, on one hand, and low mark-up and high productivity sectors, on the other, with differentiated income elasticities of demand. This is consistent with the rise of Services in the euro area.[3]

[3] The euro area appears to have developed its Services sector later and more unevenly relative to the US, with implications for the smooth transition of employment across industrial phases, Rogerson (2004).

Having set up this framework, our attention turns to the corresponding dynamic, short-run factor demands around the medium-run equilibrium and price setting. Much of the medium-run debate is fashioned around accounts of slow real adjustment (e.g., wages and employment) around the first oil shock (e.g., IMF, 1999, Blanchard and Galí, 2007) with rising unemployment and lingering structural rigidities. Accordingly, we allow a careful modeling of factor adjustment costs. Labor participation decisions are modeled along the intensive and extensive margins. In so doing, we introduce the concept of "effective labor hours". An innovative aspect is that the former margin turns out to have a key spillover onto firms' pricing decisions. Thus, in contrast to New-Keynesian models, we model inflation fundamentals (or real marginal costs) not as proportional to labor income share (as under Cobb Douglas) but as factor-augmenting CES real marginal costs, supplemented by an intensive participation margin. This generates the correct inflation fundament with the correct cyclical properties. Capital accumulation reflects time-to-build considerations. The resulting forward-looking, structural dynamic equations have encouragingly good tracking properties (compared to backward-looking rivals), reflecting, we believe, careful modeling of the medium run as much as careful modeling of structural frictions.

The paper proceeds as follows. The next section offers background on the economy of continental Europe relative to a BGP, as well as a discussion of factor-augmenting production functions. Section 3 outlines the profit-maximization framework, which explicitly captures financial regulation and adjustment cost associated with factor accumulation, whilst section 4 discusses our 'normalized' production function with time-varying, factor-augmenting technical progress. After discussing the euro area dataset, Section 6 present the result of the estimation of medium run supply and relates them to our medium-run theme (Appendix D shows our results are supported at the corresponding country level). Section 7 sets forth specific dynamic adjustment costs in factor accumulation and their estimation. Finally, we summarize what has been learnt about the "medium run" in growth theory as well as medium-run developments in continental Europe.

2. The Euro Area (Balanced and Unbalanced Growth) and Technical Change.

We now motivate our analysis by discussing first recent macroeconomic patterns in the euro area in relation to the BGP (section 2.1) that we seek to explain, followed by the relevant properties of the supporting CES production function with biased technical change (2.2).

2.1 Stylized Features of Euro Area Development and the BGP Benchmark.

A widely-adopted assumption in economics is that the short run can be presented as deviations from the (long-run) BGP. Thus in data spanning some decades the GDP shares of factor income, the mark-up and the capital-output ratio should be stationary (as should unemployment[4]). **Figure 1** shows that the euro area data strongly

[4] Unless interpreted as voluntary (i.e., without any economic implications except for its effect on the available labor force).

violates these requirements. Panel (a) presents the developments of the annual GDP shares of capital (K) and labor (N) income and the mark-up (or pure profit) component residually defined by,

$$1-\frac{WN}{PY}-\left[(r+\delta)\frac{P^{I}}{P}\right]\frac{K}{Y} \qquad (1)$$

where W denotes the aggregate nominal wage, Y aggregate output; P and P^{I}, the aggregate price and investment deflator; r and δ represent the user cost of capital (real long interest rate plus depreciation).[5]

Besides showing, after a hump in the 1970s the well-observed declining labor income share, it also shows an even more dramatic (upward) capital income share, where the latter (for the moment) is calculated using conventionally-defined user cost and capital stock data. The resulting capital income share, however, looks implausibly low in the 1970s (around 10%) with a rapid upward level shift in early 1980s. Thereafter, especially since 1997 it declined. As a mirror image of the GDP share of total factor income, the mark up appeared to follow an inverted-U shape: high in the 1970s, strongly decreasing towards the beginning of 1980s and, thereafter, widening. Panel (c) presents capital and labor not as GDP shares but as shares of total factor income; whilst the capital income share quite closely repeats its GDP-share profile, the labor income share differs dramatically. Labor-to-total factor income share after temporarily absorbing all factor income (following the first oil shock), decreases in the 1970s, levels off in the 1980s and starts rising in the mid-1990s.[6] The capital-output ratio (panel b) also shows a non-stationary pattern: it rises very rapidly until early 1980s, dips until early 1990s and resumes an upward tendency; unemployment (panel d) shows a remarkably similar profile.

Such developments cannot be interpreted in BGP terms. Non-stationary factor income shares and a non-stationary capital-output ratio indicate that production deviated from Cobb-Douglas or Harrod-Neutral CES. Given unemployment developments, it is inconsistent to argue that labor availability has been a constraining factor for growth; consequently, there need be no necessity for medium-run technical change to be purely Harrod-Neutral.

However, technology factors are not able to explain the quite peculiar mark-up indicated in panel (a). Let us first examine apparent level shifts in capital income as shares of total factor-income and GDP as well as in their

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5 Definition (1) slightly simplifies user cost that we used in actual calculations. To better correspond the National Accounting practice we assumed that the rate of return requirement on government sector capital equals the depreciation rate (see Section 6.2)

6 It is often thought that labor shares in the euro area have been secularly falling since the early 1980s. However, as our later discussion of the time-varying markup (as well incorporating the effects of financial regulation on capital share) shall make clear, definitional terms matter. In GDP terms labor share has continued to fall since the early 1980s; in factor income terms it largely stabilized after the early 1980s. This distinction has fundamental implications for explaining factor share developments as well as the sources of TFP growth. Our Figure 2 again presents factor income shares but this time corrected for the effects of financial repression on the user cost. This implies a higher, more plausible capital share in the 1970s and corresponding changes in the labor factor share. It is in terms of these concepts, namely *corrected factor income shares*, that we estimate our supply side system and seek to map technical change developments to factor share dynamics

mirror-images of the factor income share of labor and the GDP-share of implied mark-up. As panels (e) and (g) show these shifts reflect corresponding shifts in the real user-cost and, in turn, the real interest rate. For most of the 1970s the real interest rate was apparently negative which, in perfectly-functioning capital markets, should have offered infinite profit opportunities. However, it is known that financial markets then were far from perfect. Capital movements were controlled and until the mid-1980s most EU banking systems were highly regulated, with distortionary interest-rate regulations and cartel-type agreements (e.g., Vives, 1991, De Ávila, 2003).[7] Likewise, bond rates were affected by interest-rate regulations whose link was fortified by the fact that credit institutions were invariably compelled (coupled with high reserve requirements) to devote some share of their liquid resources to finance public deficits by purchasing bonds. Removals of such regulations coincide well with the level shift in the real interest rate in panel (g).

This raises a serious doubt as to whether in an imperfectly functioning financial market, the observed government bond rate correctly measured firms' marginal cost of financing during this period; there might have been strong incentives for inter-firm credit markets (e.g. in the form of trade credits), where unregulated firms lend to regulated ones in terms negotiated by the participants. This would have raised the required rate of return of investment both for the lending and borrowing firms above the level implied by the observed rate. Consequently, the real user cost (and the GDP-share of capital income) would have been well above that indicated over this period (with the residual markup correspondingly squeezed). Consequently, Figure 1 may paint a distorted picture of the true accounting nature of the data. Our maximization framework will account for this possibility by allowing a binding upper-bound for bank lending and inter-firm credit market in the 1970s and merging these two credit markets upon deregulation.

However, this extension does not help to explain the downward trend in the total factor income and the corresponding upward trend in the mark-up share since (at least) the 1980s. On the BGP, firms and sectors will exhibit some constant share, growth rate and mark-up. Over the medium run, however, sectoral changes in the economy (relating to differing growth rates, technical characteristics, demand) need not be so casually discounted. There is considerable evidence that mark-ups and technical characteristics differ significantly across sectors. Accordingly, we explain this development in terms of aggregation across high mark-up/low productivity sectors, on one hand, and low mark-up and high productivity sectors, on the other, with differentiated income elasticities of demand. Aggregating in this manner introduces an upward trend in the aggregate mark-up, if, due to higher income elasticity, the output-share of share of high-mark-up-firms increase. Furthermore, there is robust evidence that competition and technical progress is lower in (sheltered/regulated) Services sectors relative to the rest of the economy (e.g., Martins et al, 1996, Gouyette and Perelman, 1997, Faini et al, 2003, Alesina et

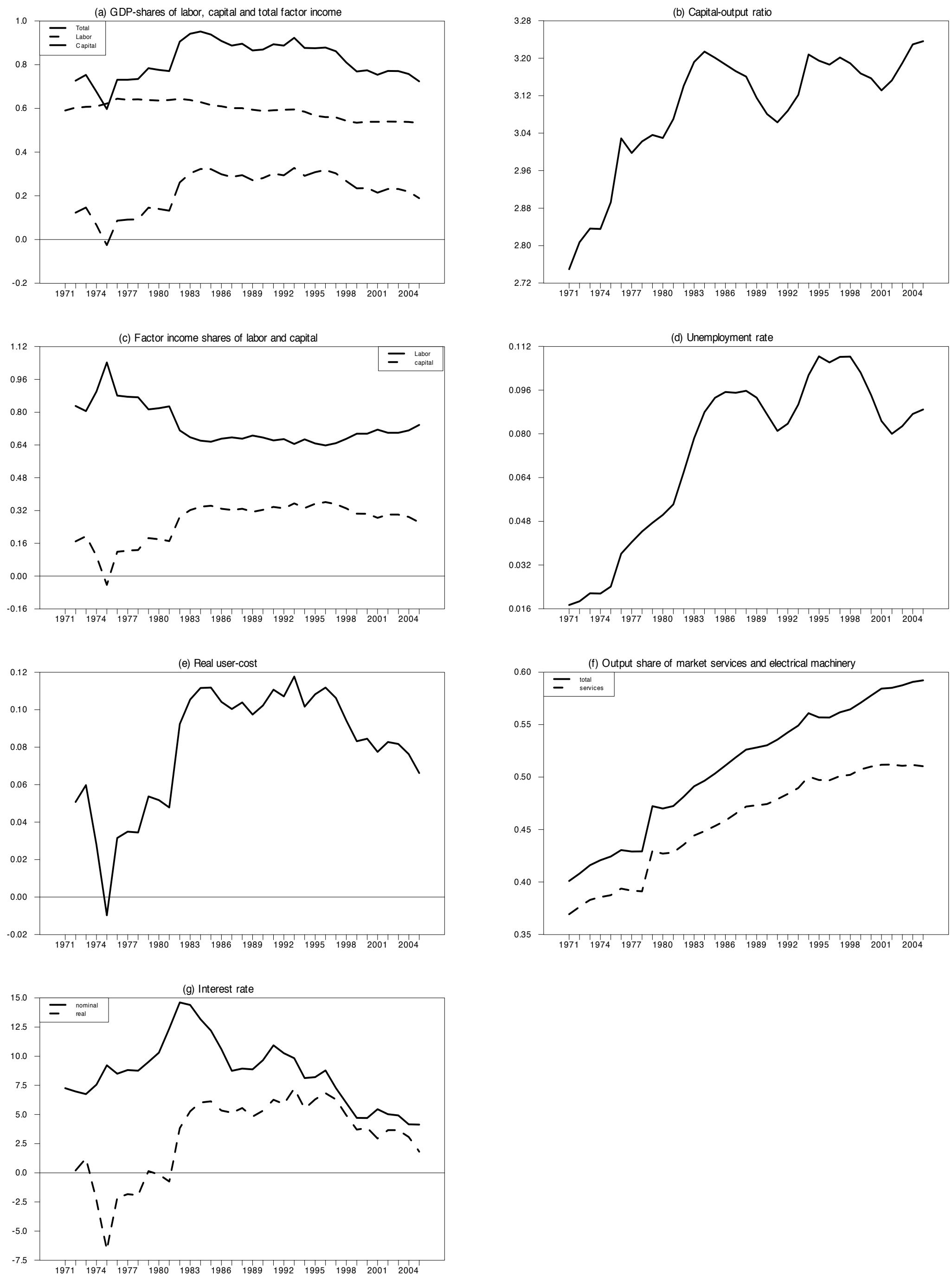
[7] Before 1981 the European Commission also viewed inter-bank rate agreements made under the auspices of national authorities falling in the domain of monetary policy instruments and therefore not subject to the competition articles of the Treaty of Rome.

al, 2005)[8]. As panel (f), based on EU KLEMS data, indicates this has precisely been the case in euro area: over 1970-2004 the output share of market services and electrical machinery have increased around 20 percentage points.

[8] That Services suffer lower productivity and technical levels relative to the aggregate economy is a mainstay of structural economic analysis, e.g., Baumol (2001), Schettkat and Yocarini (2006).

Figure 1 (Annual Data)

Stylised features of euro area development



Finally, **Table 1** shows euro area productivity (relative to the US): post-war, productivity growth was strong in both economic areas, but especially so in Europe. Thanks to this prolonged catching-up period, the large negative productivity gap separating the economies immediately after the War was substantially eroded in a couple of decades. The first oil shock slowed this period of strong productivity growth (in both economies) although Europe continued to perform better on average. Consequently, the catching-up process continued and the productivity (level) gap appeared to close in the first half of the 1990s. Given this favorable trend, a puzzling aspect is the last 10 years, where average labor productivity growth has been about half of that over the previous 15 years, seemingly undergoing some structural break.[9] What makes this especially puzzling is that in the US average labor productivity accelerated (ostensibly as a result of the IT boom). Our results contend that this pattern of high TFP growth in the 1970s, followed by a period of stabilized growth (almost like a BGP) then by a significant drop can be mapped directly to movements in directed technical change conditional on supporting values for the substitution elasticity and factor adjustment costs.

Table 1: Euro Area and US Productivity and Output Growth.

	1971-1980	1981-1990	1991-1995	1996-2005
Euro Area				
Growth of Average Labor Productivity, %	2.9	1.8	1.8	0.9
Average per capita (*) Output Growth, %	2.5	1.5	1.2	1.1
US				
Growth of Average Labor Productivity, %	1.1	1.4	1.4	2.1
Average per capita (*) Output Growth, %	0.9	1.6	1.4	2.1

Source: Authors' own calculations from Area-Wide Model database (see section 5), and from NIPA sources.
Notes: (*) In terms of labor force.

2.2 The CES Function and Factor Augmenting Technical Change

The CES production function takes the form:

$$F\left(\Gamma_t^K K_t, \Gamma_t^N N_t\right) = \left[\pi\left(\Gamma_t^K K_t\right)^{\frac{\sigma-1}{\sigma}} + (1-\pi)\left(\Gamma_t^N N_t\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{2}$$

[9] This "structural break" becomes evident in our later supply-side estimations where we allow the nature of factor-augmenting technical progress to differ in the pre- and post-1997 periods. We have also verified this break using the Bai-Perron (2003) flexible structural break procedures where the average spans of the various break points found were 1996-1998. Details available. A structural break at this time in euro area labor productivity has been confirmed elsewhere, e.g., Gomez-Salvador et al (2006).

where distribution parameter $\pi \in (0,1)$ reflects capital intensity in production and the elasticity of substitution (σ) between capital and labor is given by the percentage change in factor proportions due to a change in the marginal products (equivalently, factor price ratio), $\sigma \in (0,\infty) = -\dfrac{d\log(\mathrm{K/N})}{d\log(\mathrm{F_K/F_N})}$.

Equation (2) nests Cobb-Douglas when $\sigma = 1$; the Leontief function (i.e., fixed factor proportions) when $\sigma = 0$; and a linear production function (i.e., perfect factor substitutes) when $\sigma \to \infty$. Finally, when $\sigma < 1$, factors are gross compliments in production and gross substitutes when $\sigma > 1$.

Terms Γ_t^K and Γ_t^N capture capital- and labor-augmenting technical progress. To circumvent problems related to Diamond et al's (1978) impossibility theorem, researchers usually assume specific functional forms for technical progress, e.g., $\Gamma_t^K = \Gamma_0^K e^{\gamma_K \cdot t}, \Gamma_t^N = \Gamma_0^N e^{\gamma_N \cdot t}$ where γ_i denotes growth in technical progress associated with factor *i*, *t* represents a time trend, and where $\gamma_K = \gamma_N > 0$ denotes Hicks-Neutral technical progress; $\gamma_K > 0, \gamma_N = 0$ yields Solow-Neutrality; $\gamma_K = 0, \gamma_N > 0$ represents Harrod-Neutrality; and $\gamma_K > 0 \neq \gamma_N > 0$ indicates general factor-augmenting technical progress.

As La Grandville (2007, ch. 3) reiterates, the prime motive of introducing the concept of factor substitution was to account for the evolution of income distribution. To illustrate, if factors are paid their marginal products, relative factor shares and relative marginal products are given by (dropping time subscripts):

$$\frac{qK}{wN} \equiv sh^{K/N} = \frac{\pi}{1-\pi}\left(\frac{\Gamma^K}{\Gamma^N}\cdot\frac{K}{N}\right)^{\frac{\sigma-1}{\sigma}} \quad (3)$$

$$\frac{F_K}{F_N} = \frac{\pi}{1-\pi}\left[\left(\frac{K}{N}\right)^{-\frac{1}{\sigma}}\left(\frac{\Gamma^K}{\Gamma^N}\right)^{\frac{\sigma-1}{\sigma}}\right] \quad (4)$$

Thus, capital deepening assuming gross complements (gross substitutes) reduces (increases) capital's income share:

$$\frac{\partial\left(sh^{K/N}\right)}{\partial(K/N)} \left.\begin{matrix} <0 \text{ for } \sigma<1 \\ =0 \text{ for } \sigma=1 \\ >0 \text{ for } \sigma>1 \end{matrix}\right\} \quad (5)$$

and reduces its relative marginal product:

$$\frac{\partial(F_K/F_N)}{\partial(K/N)} < 0, \forall \sigma . \quad (6)$$

Condition (5) demonstrates that if inputs are gross complements, factor abundance diminishes factor income share.

Likewise, a relative increase in, say, capital-augmentation assuming gross compliments (gross substitutes) decreases (increases) its relative marginal product and factor share:

$$\frac{\partial(F_K / F_N), \partial\left(sh^{K/N}\right)}{\partial\left(\Gamma^K / \Gamma^N\right)} \left.\begin{matrix} < 0 \text{ for } \sigma < 1 \\ = 0 \text{ for } \sigma = 1 \\ > 0 \text{ for } \sigma > 1 \end{matrix}\right\} \tag{7}$$

Accordingly, we may conclude (e.g., Acemoglu, 2002) that it is only in the gross-substitutes case that, for instance, capital augmenting technical progress implies capital-biased technical progress (i.e., in terms of (7), raising its relative marginal product for given factor proportions). Naturally, as can verified from (5) and (7), the relations between the substitution elasticity, technical bias and factor shares evaporates under Cobb-Douglas.

To illustrate, it is widely (and correctly) assumed that labor share rose after first oil crisis, setting aside adjustment costs, and concentrating on the gross-complements case, the conditions for a rise (fall) in the labor (capital) factor income share rests on the following margins:

a) $\dot{K} / K > \dot{N} / N$: Capital deepening increases (equivalently, capital becomes the relatively more abundant factor).

b) $\gamma_K > \gamma_N$: Technical progress becomes relatively more capital saving.

Whether the labor share continues to rise, falls or stabilizes depends on the ongoing evolution of these two inequalities. Manipulating the standard first-order conditions (foc) of profit maximization, we further know that capital deepening (part a) is a function of relative factor prices and technical bias:

$$\log\left(\frac{K_t}{N_t}\right) = \varphi + \sigma \log\left(\frac{w_t}{q_t}\right) + \left(\gamma_N - \gamma_K\right) \cdot (1-\sigma) \cdot t$$

where $\varphi = \sigma \log(\pi/(1-\pi))$. Capital deepening occurs if real wages rise relative to the user cost (i.e., factor prices favor capital accumulation) and, assuming gross complements, if technical change is directed towards labor.

Biased technical change (part b) may be exogenous or map to a complex function of firms' profit maximizing incentives and innovation possibilities. Given these conceptual uncertainties, we follow an agnostic approach by modeling time-varying technical progress in a flexible, data-oriented manner.

3. The Model

In the following we derive the inter-temporal maximization conditions of the firm. To mimic bank centered financial markets in Europe, the only sources of external financing are bank loans and, if the bank lending rate is regulated, unregulated inter-firm credit market. Profit maximization accounts for adjustment costs associated with capital and labor inputs in a framework where wage contracts are fashioned in terms of normal working hours with a pre-set overtime premium. Thereafter, for estimation purposes, we decompose the system into the static part, which defines the medium-run system of aggregate supply, and the dynamic part, which defines the short-run adjustment to that medium-run path.

3.1 Maximization Problem of the Firm

The firm maximizes its expected discounted stream of dividends, V_t; bank loans and net borrowing from inter-firm credit markets are assumed the only forms of external financing. The output of a firm, Y, is defined by its production function $F(K_t, H_t, t)$, where K is capital stock, and labor input is measured in terms of 'effective' labor hours H_t defined by the identity $H_t = N_t h_t$ (N is the number of employees, h 'effective' working hours per employee), and t is time. (Section 7.1 explains these effective concepts more fully). Accounting for adjustment costs associated with changes in both employment margins (heads and hours) as well as with capital, real dividend (D_t) in terms of investment deflator can be defined as,

$$D_t = P_t Y_t - W_t\left[H_t + A_H(N_t, H_t) + A_N(N_t, N_{t-1})\right] - I_t - A_K(K_t, K_{t-1}, K_{t-2}) + B_t - (1 + r_{t-1})B_{t-1} + S_t - (1 + r_t + \kappa_t)S_{t-1} \quad (8)$$

Where B_t is bank loans, S_t is net borrowing from inter-firm credit market deflated by investment prices, r_t is the real interest rate and $\kappa_t \geq 0$ is an interest premium, which, as will be shown, exceeds zero when regulation is binding, P_t and W_t are aggregate relative output price and the real straight-time wage rate, respectively, in terms of investment prices. $A_H(\cdot)$ accounts for the cost effects of overtime wage premium and variations in work intensity. By assuming, as in Shapiro (1986) and Bils (1987), that all workers in the firm - and even more so across firms and industries - do not work the same number of hours nor at the same intensity, function $A_H(\cdot)$ can be treated as continuously differentiable, although for an individual employee the wage rate may jump up discontinuously when hired hours exceed normal hours $h - \bar{h} > 0$. Functions $A_N(\cdot)$ and $A_K(\cdot)$ represent adjustment cost functions for labor and capital, whose exact form, as well as that of $A_H(\cdot)$, will be defined later. Note, that for capital, we assume that adjustment costs can additionally accommodate changes in the rate of capital stock accumulation; this extra cost essentially reflects time-to-build considerations in investment formation, and is empirically supported.

Applying constraints $Y_t = F(K_t, H_t, t)$ and $B_t \leq \bar{B}_t$ (where $\bar{B}_t$ defines the upper bound of bank lending) the maximization of the present discounted value of the real dividend stream gives:

$$Max\, V_t = E_t \sum_{i=0}^{\infty}\left[\prod_{j=0}^{i}\beta_j\right]\left\{D_{t+i} + \Lambda^F_{t+i}\left[F(K_{t+i}, H_{t+i}, t+i) - Y_{t+i}\right] + \Lambda^B_{t+i}\left(\bar{B}_{t+i} - B_{t+i}\right)\right\} \quad (9)$$

where β refers to the subjective discount factor and Λ^F and Λ^B are Lagrangean multipliers. In maximizing (9) with respect to Output, Effective Labor Hours, Labor, Capital, borrowings (B and S) and Λ^F. We apply the downward-sloping demand function, $P_t = P(Y_t)$, and the law of motion for capital, $K_t = (1-\delta)K_{t-1} + I_t$. Disregarding, for notational simplicity, the expectation operator, we obtain,

$$\frac{\partial V_t}{\partial Y_t} = P_t\left(1+\frac{\partial P/\partial Y}{P/Y}\right) - \Lambda_t^F = 0 \tag{10}$$

$$\frac{\partial V_t}{\partial H_t} = -W_t\left[1+\frac{\partial A_H(K_t,H_t)}{\partial H_t}\right] + \Lambda_t^F \frac{\partial F(K_t,H_t,t)}{\partial H_t} = 0 \tag{11}$$

$$\frac{\partial V_t}{\partial N_t} = -W_t\left[-\frac{\partial A_H(K_t,H_t)}{\partial N_t} + \frac{\partial A_N(N_t,N_{t-1})}{\partial N_t}\right] - E_t\beta_{t+1}W_{t+1}\frac{\partial A_N(N_{t+1},N_t)}{\partial N_t} = 0 \tag{12}$$

$$\begin{aligned}\frac{\partial V_t}{\partial K_t} &= P_t(1+\frac{\partial P/\partial Y}{P/Y})\frac{\partial F(K_t,H_t,t)}{\partial K_t} - \frac{\partial A_K(K_t,K_{t-1},K_{t-2})}{\partial K_t} - 1 \\ &+ E_t\beta_{t+1}\left\{-\frac{\partial A(K_{t+1},K_t,K_{t-1})}{\partial K_t} + (1-\delta)\right\} \\ &+ E_t\beta_{t+1}\beta_{t+2}\left\{-\frac{\partial A(K_{t+2},K_{t+1},K_t)}{\partial K_t}\right\} = 0\end{aligned} \tag{13}$$

$$\frac{\partial V_t}{\partial B_t} = 1 - \Lambda_t^B - \beta_{t+1}(1+r_t) = 0 \tag{14}$$

$$\frac{\partial V_t}{\partial S_t} = 1 - \beta_{t+1}(1+r_t+\kappa_t) = 0 \tag{15}$$

$$\frac{\partial V_t}{\partial \Lambda_t^F} = F(K_t,H_t,t) - Y_t = 0 \tag{16}$$

where the mark-up is given by $1+\mu = \left(1+\frac{\partial P/\partial Y}{P/Y}\right)^{-1}$. Condition (10) implies,

$$\Lambda_t^F = \frac{P_t}{1+\mu} \tag{17}$$

Foc (15) defines the discount factor in terms of marginal cost of financing and (14)-(15) relates Λ_t^B to the interest rate premium κ_t:

$$\beta_{t+1} = \frac{1}{1+r_t+\kappa_t} \tag{18}$$

$$\Lambda_t^B = \frac{\kappa_t}{1+r_t+\kappa_t} \tag{19}$$

Condition (19) equalizes the shadow price of bank loans and the price of inter-firm credits, when the bank loan ceiling is binding; when not binding, i.e. $\Lambda_t^B = 0$, then no premium exists, $\kappa_t = 0$.

With Λ^F defined by (17) and β_{t+1} by (18), system (11)-(13) and (16) determines optimal price setting (11), the number of employees (12), capital inputs (13) and effective hours (16) conditional on the expected development of real wages and explicit functional forms for demand, the production function, and the (three) adjustment-cost functions,.

3.2 The Medium-Run Supply-Side System

To proceed it is useful to re-present the system neglecting (albeit temporarily) adjustment costs, $A_t = 0$; thus, (12) reduces to $H_t = N_t$, (i.e., $h_t = \bar{h} = 1$ and, hence, normal working hours N_t equals 'effective' hours H_t), and system (10)-(16) can be re-expressed as: [10]

$$\frac{W_t N_t}{W_t N_t + q_t K_t} = \frac{N_t}{Y_t} \frac{\partial F}{\partial N_t} \tag{20}$$

$$\frac{q_t K_t}{W_t N_t + q_t K_t} = \frac{K_t}{Y_t} \frac{\partial F}{\partial K_t} \tag{21}$$

$$Y_t = F\left(K_t, N_t, t\right) \tag{22}$$

where $q_t = r_t + \kappa_t + \delta$ is the user cost of capital. The benefit of estimating the supply side in this manner (i.e., factoring out the mark-up) is that we isolate the effects of time-varying technical changes, capital deepening and relative factor prices from the evolution of the (time-varying) mark-up. The latter naturally reemerges in the context of the economy's frictionless price (section 7.1).

4. "Normalized" CES Production with Time-Varying Factor Augmenting Technical Progress.

4.1 Normalization of Production functions

In estimating system (20-22), our technology assumption is the "normalized" CES function allowing for time-varying factor-augmenting technical progress. The importance of explicitly normalizing CES functions was discovered by La Grandville (1989) and first implemented empirically by Klump, McAdam and Willman (2007). Normalization starts from the observation that a family of CES functions whose members are distinguished only by different substitution elasticities need a common benchmark point. Since the elasticity of substitution is defined as a point elasticity, one needs to fix benchmark values for the level of production, factor inputs and marginal rate of substitution, or equivalently for per-capita production, capital deepening and factor income shares.

Normalization is crucial when dealing with CES functions: (a) It is necessary for identifying in an economically meaningful way the constants of integration which appear in the solution to the differential equation from which the CES production function is derived. (b) it is necessary for securing the property of a strictly positive relationship between the elasticity of substitution and output, (c) it is (implicitly or explicitly)

[10] Recalling that, by definition, the mark-up $(1+\mu)$ equals $PY/(WN+qK)$ equations (20) and (21) correspond to the conventional first-order conditions of profit maximization $\partial F/\partial N = (1+\mu)W/P$ and $\partial F/\partial K = (1+\mu)q/P$

employed in all empirical studies of CES functions, (d) it is convenient when biases in technical progress are to be empirically determined (as here). The normalized production function is given by[11],

$$\frac{Y_t}{Y_0} = \left\{ \pi_0 \left[\Gamma_K(t,t_0)\frac{K_t}{K_0} \right]^{\frac{\sigma-1}{\sigma}} + (1-\pi_0)\left[\Gamma_N(t,t_0)\frac{N_t}{N_0} \right]^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}} \tag{22'}$$

where π_0 is the capital share evaluated at the normalization point (subscript 0) and $\Gamma_i(t,t_0)$ define the (indexed) level of technical progress associated to factor *i* (with $\Gamma_i(t_0,t_0)=1$).

4.2 Flexible Modeling of Technical Progress

Neo-classical growth theory (Uzawa, 1961) suggests that, for an economy to posses a steady state with positive growth and constant factor income shares, the elasticity of substitution must be unitary (i.e., Cobb Douglas) or technical change must exhibit labor-augmentation (i.e., Harrod Neutrality). Under Cobb Douglas, the direction of technical change is irrelevant for income distribution. In contrast, pronounced trends in factor-income distribution witnessed in many industrialized countries support the more general CES function and raise the importance of biases in technical progress. For CES, though, a steady state with constant factor income shares is only possible if technical progress is purely labor augmenting. Acemoglu (2003) was able to derive this same result in a model with endogenous innovative activities but demonstrated that, over significant periods of transition, capital-augmenting progress can be expected resulting from endogenous changes in the direction of innovations.

Earlier work on CES functions tended to assume constant technical growth. However, following recent debates about directed technical change, it is not obvious that growth rates should always be constant; accordingly, we follow an agnostic approach and model technical progress drawing on a well-known flexible, functional form (Box and Cox, 1964):

$$\log[\Gamma_i(t,t_0,\gamma_i,\lambda_i)] = \frac{\gamma_i t_0}{\lambda_i}\left[\left(\frac{t}{t_0}\right)^{\lambda_i} - 1\right] \tag{23}$$

where $i = N, K$. The log level of technical progress, $\Gamma_i(\bullet)$ is, therefore, a function of time, *t* (around its normalization point, t_o), a curvature parameter, λ_i, and has a growth rate of γ_i at the representative point of normalization.[12] When λ_i =1 (=0) [<0], technical progress displays linear (log-linear) [hyperbolic] dynamics:

[11] Leon-Ledesma, McAdam and Willman (2007) discuss and evaluate normalization more extensively.

[12] Note we scaled the Box-Cox specification by t_0 to interpret γ_N and γ_K as the rates of labor- and capital-augmenting technical change at the fixed (i.e., representative) point.

$$\log \Gamma_i(\mathrm{t}) \Rightarrow \begin{cases} \lim\limits_{t\to\infty}[\log \Gamma_i(\mathrm{t})] = \infty & \text{if } \lambda_i \geq 0 \\ \lim\limits_{t\to\infty}[\log \Gamma_i(\mathrm{t})] = -\dfrac{\gamma_i t_0}{\lambda_i} > 0 & \text{if } \lambda_i < 0 \end{cases} \tag{24a}$$

$$\frac{\partial \log \Gamma_i(\mathrm{t})}{\partial \mathrm{t}} = \gamma_i (t/t_0)^{\lambda_i - 1} \Rightarrow \begin{cases} = \gamma_i (t/t_0)^{\lambda_i - 1} > 0;\ \lim\limits_{t\to\infty} \dfrac{\partial \log \Gamma_i(\mathrm{t})}{\partial \mathrm{t}} = \infty & \text{if } \lambda_i > 1 \\ = \gamma_i, \forall t & \text{if } \lambda_i = 1 \\ \geq 0;\ \lim\limits_{t\to\infty} \dfrac{\partial \log \Gamma_i(\mathrm{t})}{\partial \mathrm{t}} = 0 & \text{if } \lambda_i < 1 \end{cases} \tag{24b}$$

Thus, if $\lambda_i \geq 0$, the level of technical progress accruing from factor *i* tends to infinity but is bounded otherwise, (24a). If $\lambda_i = 1$ the factor growth of technical progress is constant (i.e., the "text-book" case) but asymptotes to zero from above for any $\lambda_i < 1$, (24b). This set up has three advantages.

First, flexible (Box-Cox) modeling of technical progress allows the data to decide on the presence and dynamics of factor-augmenting technical change rather than being imposed a priori by the researcher. If, for example, the data support an asymptotic steady state, this will arise naturally from the dynamics of these curvature functions (i.e., labor-augmenting technical progress becomes dominant, that of capital absent or decaying).

Second, it allows us to nest existing strands of medium-run debates as special cases. For instance, the combination,

$$\gamma_N > 0, \lambda_N = 1; \gamma_K = \lambda_K = 0 \tag{25}$$

coupled with the assumption of $\sigma >> 1$, corresponds to that drawn upon by Caballero and Hammour (1997), Blanchard (1997), Berthold et al (2002) in explaining the decline in the labor income share in continental Europe. Notwithstanding, the case for an above-unity elasticity appears both empirically weak and theoretically anomalous. Regarding theory, an above-unity elasticity generates perpetual growth (even without technical progress) since scarce labor can be completely substituted by capital implying that the marginal product of capital remains asymptotically bounded above zero, Solow (1956). Furthermore, if, for a given technology level, the economy's output is a positive function of this elasticity (e.g., Klump and Preißler, 2000), then we would expect, somewhat counterfactually, either per-capita living standards or the per-capita growth rate in continental Europe to exceed those of the US (since most studies suggest a below-unity elasticity for the US, e.g., Klump, McAdam and Willman, 2004, Table 1).

Another combination embedded in (23), which we speculatively term "Acemoglu-Augmented" Technical Progress, can be nested as,

$$\gamma_N, \gamma_K > 0; \lambda_N = 1, \lambda_K < 1 \tag{26}$$

where $\sigma < 1$ is natural. Consider two cases within (26). A "weak" variant, $\lambda_K < 0$, implies that the contribution of capital augmentation to TFP is bounded with its growth component returning rapidly to zero;

whilst in the "strong" case, $0 < \lambda_K < 1$, capital imparts a highly persistent contribution with (relatively slower convergence to) a zero growth rate. Both cases are asymptotically consistent with a BGP, where TFP growth converges to that of labor-augmenting technical progress, γ_N. However, empirically capturing the co-existence and interplay of these (level and curvature) terms is an attractive channel for medium run stories.

A final advantage of representing factor-augmenting time-varying technical progress following (23) is that we are not tied to any theoretical construct underlying directed technical change; condition (23) may therefore be seen as a reduced-form to some more specific aggregate innovations possibilities frontier (which in the aggregate would necessarily be difficult to identify).

5. Data [13]

Following Smets and Wouters (2003), Coenen, McAdam and Straub (2007) and others, we model interactions in continental Europe using aggregate euro-area data (from 1970q1-2005q3) from the current version of the Area Wide Model (AWM) database of the European Central Bank (Fagan et al, 2001). However, our euro-area capital stock is based on Eurostat harmonized net capital stock data which is directly related to underlying country data. This capital stock data is annual and covers 1970-1999 so we interpolated into quarterly frequency using quarterly gross investment and depreciation rate data, after the latter was, through interpolation, transformed to a quarterly frequency. Thereafter, as the somewhat rising trend of the depreciation rate had stabilized by 1999, the capital stock series was continued by perpetual inventory method keeping the depreciation rate fixed at its 1999 level.

5.1 Factor Incomes

Regarding labor income, at the area-wide level, no data on the income of self-employed workers are available. Therefore as in e.g. Blanchard (1997), Gollin (2002) and McAdam and Willman (2004) we used the aggregate wage rate as a shadow wage rate also for the labor income component of self-employed workers. We also accounted for the fact that a part of the self-employed was unpaid family workers, whose share has continuously decreased.[14] Hence, labor income was calculated using:

$$W_t N_t = \left(1 + \mathrm{SOSR}_t + \frac{N_t^S - N_t^{UP}}{N_t^E}\right) W_t^E \cdot N_t^E$$

where SOSR is the employers' social security payment rate, N^S, N^{UP} and N^E are the numbers of self-employed workers, unpaid workers and employees and W^E is the wage rate per employee. (or wage and salary income per employee).

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[13] Our data set and estimation files are available upon request.

[14] Since information of on unpaid family workers (Source: OECD Labor Force Statistics) did not cover the full sample we used backward extrapolation in evaluating the labor share development in 1970:1-1976:4.

Capital income is calculated as the product of nominal user cost and the volume of the capital stock. The interest rate measure is the long term nominal interest rate of the AWM data. To retain compatibility with the National Accounting practices, which assumes no net operating surplus in government sector, the rate of return requirement on government sector capital was assumed to equal the depreciation rate. Accordingly, we calculated capital income as:[15]

$$qK = \mathrm{P}^1\left[\frac{K^P}{K}\cdot\left(i-\pi+\underbrace{\kappa\cdot Dum_t}_{\kappa_t}\right)+\delta\right]K$$

where K^P/K is the private-to-total capital stock ratio, i is the long-term nominal interest rate, π denotes the inflation rate. To account for the possibility that regulated euro-area interest rates did not correctly measure the marginal cost of financing in the 1970s, a freely-determined level-shift dummy was constructed to correct the interest rate (upwards) during this period. This corrected interest rate could be interpreted as the shadow rate of bank loans or the rate equilibrating the unregulated inter-firm credit market, i^m, measuring the marginal (nominal) cost of financing[16], $i_t^m = i_t + \kappa_t \equiv i_t + \kappa\cdot\mathrm{Dum}_t$, where Dum_t is a smooth, hyperbolic level-shift dummy calibrated to unity in the early 1970s but which converges to zero around the mid 1980s[17] (with the major part of the level shift concentrated in 1978-1982), after which in practice $i^m \to i$.

5.2 Data for the big four euro area countries

In estimating the supply-side system for Germany, France, Italy and Spain our main data source is annual EU KLEMS database (March 2007 vintage) covering 1970-2004. As this database does not contain capital stock data, we use Eurostat harmonized net capital stock data that after 1999 was updated in the same way as euro area aggregate capital stock. Long-term interest rate data come from OECD sources.

[15] Our user cost formulation does not capture possible tax effects. This need not be a major defect, if (a) depreciations for tax purposes are strongly front loaded and/or (b) there were no major changes in corporate taxation during our sample period. In the latter case there may be some downward bias in our user cost estimate, but the time profile is largely correct.

[16] This would presuppose the existence of a rather well functioning "grey" financial market. Then, when regulation is binding, the marginal cost of financing can be markedly above the average cost of financing, which the interest rate measures. After deregulation, under the Modigliani-Miller (1958) theorem, as our user cost definition assumes, the marginal and average costs of financing are equal.

[17] We observe two levels in the *ex post* real interest rate in the euro area, France, Italy and Spain; a negative level covering most of 1970s and a shift in the late 1970s and early 1980s to a markedly higher (positive) level covering the rest of the sample. Only in Germany the real interest rate remained positive trough the whole ample period, which is in line with the fact that Germany liberalized capital flows already in 1967, which must have markedly increased the interdependency of German and international financial markets. However, Germany did not abandon interest rate regulation before 1981 (Gual, 1999).

6 Estimation Results of Medium Run Supply

6.1 The Medium Run Supply-Side System.

Table 2 shows parameter estimates for supply-side system (20-22): technical parameters ($\zeta;\gamma_N;\gamma_K;\sigma$), factor-augmenting Box-Cox curvature parameters ($\lambda_N;\lambda_K$), and marginal financing parameter (κ).[18] (The precise specification of supply-side system incorporating "normalization" (section 4.1) and time-varying factor-augmenting technical progress (section 4.2) is shown in Appendix A, equations A1-A3). Thereafter, we report TFP growth evaluated at the fixed point;[19] residual stationarity tests; the system metric (the log determinant); and, where applicable, tests for conventional neutrality. To generate meaningful TFP estimates in the presence of *biased* technical progress we use not the (Hicks-Neutral) Solow Residual, but we generalize the "Kmenta (1967) Approximation" to the factor augmenting case, see Appendix B. As can be seen, most parameters are significant at 1%.

The substitution elasticity appears well below unity (around 0.7)[20]; TFP growth (in the point of normalization) is just over 1% per year and the importance of financial regulation, κ, is confirmed.[21] By and large, most forms of neutrality conventional used to motivate long or medium run growth patterns are rejected.

The first column (showing full-sample estimation) suggests Solow Neutrality: $\gamma_K = 0.008; \gamma_N = 0$, with essentially linear capital curvature, $\lambda_K \approx 1$[22]. Further examination, however, reveals the production-function residual exhibits non-stationarity, and that the parameters are unstable. In particular, the strong capital-augmenting technical progress seems to be coupled with developments towards the end of the sample; when incrementally dropping years from the sample end-point, λ_K decreased and λ_N strengthened.

This can be gauged from column 2 where, consistent with our earlier discussion of structural breaks (recall Table 1), we estimate until 1997:4. System residual stationarity and log-determinant results improve. The quarterly growth rates of labor and capital augmenting technical progress (evaluated at the point of normalization) are, respectively, 0.3 and 0.2. Moreover, the dynamics of factor-augmenting technical progress are such that labor augmentation dominates (i.e., $\lambda_{N1} \approx 1$) whilst the contribution of capital decays relatively slowly over time (i.e., $\lambda_{K1} < 1$). In terms of (26), this resembles the "strong" capital curvature case, where there is additionally approximate (but not strict[23]) convergence to the Harrod-Neutral BGP.

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[18] We estimated the system using non-linear SUR. Since the estimation of non-linear systems can be sensitive to initial parameter conditions (e.g., McAdam and Hughes-Hallett, 1999), we varied parameters individually and jointly around plausible supports to ensure global results (details available).
[19] TFP at the normalization point ($t=t_0$) is zero by definition, we therefore take the derivative at that point which in discrete time means calculating TFP($t=t_0+1$) - TFP($t=t_0$).
[20] Recursive estimation did not reveal any statistically significant drift in the substitution elasticity over time. Accordingly, explanations of labor share dynamics based on discrete elasticity shifts over time (e.g., Caballero and Hammour, 1998) are not part of our explanation.
[21] Although the exact size and time profile of this effect should be treated with caution, its inclusion is indispensable, firstly, to construct reasonable data for capital income (excluding mark-up) and, secondly, to have both in economic and econometric terms a satisfactory explanation for euro-area developments starting from 1970s.
[22] Naturally, when $\gamma_N = 0$, λ_N cannot be interpreted.
[23] In other words, λ_{N1} is close to but significantly different from unity at the 5% level.

In column 3 we utilize the full sample but allow for structural breaks in the growth rates of both augmented technical progress components from in 1997:4[24]. Estimation of factor curvature in the second regime is data constrained, so we calibrated on the basis of economically-reasonable priors (i.e., centered on the unit interval): $\lambda_{N,t>1997} = \lambda_{K,t>1997} = 0.5$ [25]. The parameters of technical progress and curvature in the pre-break sample (i.e., $\gamma_{N1}, \lambda_{N1}; \gamma_{K1}, \lambda_{K1}$) and the substitution elasticity remain essentially unchanged compared to sub-sample results (column 2) with labor augmentation being the dominant contributor to TFP growth. Note, however that the growth rate of labor-augmenting technical change falls from γ_{N1}=0.0036 (until end-1997) to $\gamma_{N,t>1997}$=-0.0080 in the second sub-sample, whilst that of capital increases from γ_{K1}=0.0014 to $\gamma_{K,t>1997}$=0.0103. 1997 onwards is therefore associated with a reversal of the factor contribution to TFP growth. Although the upward shift in capital augmentation exceeds the drop in labor augmenting progress, TFP growth decelerates due to lower income share of capital relative to labor in its derivation (see equations B2-B3). This time-varying pattern is graphed in the next section and matched up against the historical outcomes.

[24] Note, we incorporated an abrupt break; smoother forms are likely but may be difficult to identify from the available data. The abrupt break may bias upwards the jump in capital augmentation, but qualitatively the shift to higher capital augmentation in the last 1990s appears a robust one.

[25] To have the curvature parameters exceeding unity would not only be incompatible with balanced growth (which, after all, is our natural prior) but would also imply that the detected productivity slowdown and technical-progress break is permanent (an extremely strong assumption and largely at odds with the relevant time-series literature). Likewise, setting them marginally below unity (e.g., 0.99) would imply exceptionally persistent dynamics following the break in factor augmentation. Note, however, the other parameters values in the system appeared highly robust to different trial values for $\lambda_{N,t>1997}$ and $\lambda_{K,t>1997}$; details available.

Table 2: Supply-Side Estimates

	1970:1-2005:3	1970:1-1997:4	1970:1-2005:3
ζ	1.0098 (0.0014)	1.0000 (0.0015)	1.0078 (0.0013)
γ_{N1}	0.0000 (0.0000)	0.0031 (0.0002)	0.0036 (0.0001)
λ_{N1}	-5.9057 (0.4044)	1.4579 (0.0995)	1.3644 (0.0778)
$\gamma_{N,t>1997}$	–	–	-0.0081 (0.0006)
$\lambda_{N,t>1997}$	–	–	0.5000 (–)
γ_{K1}	0.0082 (0.0001)	0.0020 (0.0004)	0.0014 (0.0003)
λ_{K1}	0.9723 (0.0317)	0.1649 (0.1614)	0.0363 (0.1464)
$\gamma_{K,t>1997}$	–	–	0.0103 (0.0011)
$\lambda_{K,t>1997}$	–	–	0.5000 (–)
σ	0.7889 (0.0060)	0.6804 (0.0095)	0.6542 (0.0108)
κ	0.0281 (0.0004)	0.0302 (0.0004)	0.0281 (0.0004)
TFP Growth	0.00263	0.00276	0.00293
π_0	0.320	0.341	0.320
	Parameter Restrictions		
$\lambda_N = 1$	[0.0000]	[0.0000]	[0.0000]
$\lambda_K \approx 0$ (a)	[0.0000]	[0.2787]	[0.7599]
$\lambda_N = 1, \lambda_K \approx 0$	[0.0000]	[0.0000]	[0.0000]
	Conventional Neutrality Assumptions		
Harrod: $\gamma_K = \lambda_K = 0, \lambda_N = 1$	[0.0000]	[0.0000]	–
Hicks: $\gamma_N = \gamma_K, \lambda_N = \lambda_K = 1$	[0.0000]	[0.0000]	–
Hicks Modified $\gamma_N = \gamma_K, \lambda_N = \lambda_K$	[0.0000]	[0.0000]	–
Solow: $\gamma_N = \lambda_N = 0, \lambda_K = 1$	[0.1984]	[0.0000]	–
	Stationarity		
ADF_p	-4.3188	-5.2848	-5.4599
$ADF_{ck/wn}$	-4.2458	-5.0000	-5.1493
$ADF_{Y/N}$	-2.7139	-3.4229	-3.8857
Log Determinant	-24.2738	-25.4409	-25.0530

Notes: Standard errors in parenthesis, p-values in squared brackets, "-" denotes non-applicable. (a) Wald test of the restriction $\lambda_K = -0.01$ which, within our sample, approximated closely enough a logarithmic function since $\lambda_K = 0$ strictly renders the equation indeterminate. TFP growth at the point corresponding to the sample averages (the fixed point). Parameter ζ is explained in Appendix A.

6.2 A Graphical Analysis: How Well Do Our Supply Results Fit The Data?

Figures 2 plots results corresponding to our preferred case (Column 3, Table 2). Three left-hand panels present the factor-income shares of labor and capital and the capital-output ratio with their fitted values. The right-hand panels present the estimated dynamics of TFP growth (factor components and total[26]), capital deepening in actual/efficiency units and two measures of the real user cost.

Note, the first two row graphs in column 1 of Figures 2 present corrected versions of panel (c) in Figure 1 with capital user costs (and by implication capital income) corrected for financial regulation and the factor income shares of labor and capital accordingly recalculated. The bottom right panel shows the imputed effect of the financial regulation on the user cost defined jointly by the hyperbolic level shift dummy and $\hat{\kappa}$. Instead of being around zero as the observed measure of marginal financing would imply, results suggest a marked upward premium. Accordingly, the average real user cost in the 1970s, instead of being markedly below, exceeded somewhat its 1980s level. Although the exact size and time profile of this premia should be treated with caution, we conclude that its inclusion is indispensable first, to construct reasonable capital income (excluding mark-up) data and, second, to have a satisfactory explanation for euro area development starting from the 1970s.

The three left-hand panels show the estimated system tracks the underlying medium-run developments of factor income shares and the capital-output ratio pretty well. Moreover, the ADF-t-test statistics of Table 1 indicate that the deviations of these variables from their medium-run histories are stationary.[27] Contrary to balanced growth, these three variables contain time-varying trend components: the labor- (capital) income share and the capital-output ratio increase (decreases) rather strongly, largely stabilize in the 1980s and 1990s and resume their rise (decrease) in the late 1990s.

We explain the first two row graphs in column 1 of Figures 2 by those of column 2. The top right panel shows the co-existence of labor and capital augmenting technical progress in the 1970s (with the latter dominating) and, accordingly, buoyant TFP growth. In line with Acemoglu's (2002, 2003) framework, this latter component decays over time leaving TFP growth converging on labor-augmenting growth. From 1997 onwards, though, there is a reversal of the factor content of TFP growth: although the upward shift in capital augmentation exceeds the drop in labor augmentation, TFP growth decelerates due to their different weights. Equation (3') recalls how technical change maps to income shares:

$$\Delta \log\left(\frac{qK}{wN}\right) = \frac{\sigma - 1}{\sigma}\{[\Delta \log(\Gamma_K) + \Delta \log(K)] - [\Delta \log(\Gamma_N) + \Delta \log(N)]\} \tag{3'}$$

[26] The individual factor growth components are calculated according to (24b) and overall TFP growth from (B2-B3).

[27] Of course, the fit is not perfect. This reflects that the estimated system is derived under assumption $\boldsymbol{h}(\boldsymbol{t}) = 1$ and the estimated fits define (in our case) the medium-run path corresponding to this hypothetical situation. The essential point is that the deviations of from these equilibrium paths, i.e., the residuals, should be stationary. That is the case in all cases as the Table 1 ADF-t-tests indicate. Hence, our estimation results pass the statistical requirements of successful estimation (which is not the case if we use a Cobb-Douglas based system, details available). On the other hand, one can envisage improvements, e.g. allowing labor (capital) share to decrease (increase) in early 1990s and, thereafter, resume rising (decreasing) 1-2 years earlier. However, the decrease in the labor income share can be reduced to cyclical factors, which first very sharply decreased labor demand around 1991-1993 (our dynamic labor demand equation tracks that well see our later Figure 4) and thereafter transmitted into exceptionally low growth of real wage rates in 1993-1998 (negative on the average). Tracking the cyclical behavior of wages is outside our scope.

If the substitution elasticity lies below unity, as our estimates suggests, an increase in capital deepening increases the labor factor income share (and decreases capital share); net capital-saving ($\gamma_K - \gamma_N > 0 | \sigma < 1$) does likewise. Capital deepening (recall Section 2.2) occurs if the factor price ratio favors capital accumulation and technology is net labor-saving. Over the sample as a whole, the latter condition holds, and throughout the sample real user cost (though initially high) declines. Capital deepening in efficiency units exceeded actual units in the first half of the sample and (dramatically so) from 1997 onwards. Accordingly, given (3') the link between capital deepening in efficiency units and the labor factor income share is apparent (as is the mirror image in capital share). The downward trend in the capital income share is matched by that in real user cost[28]; this decline has not been compensated by the rise in capital deepening and the capital-output ratio (the fit of which is particularly good, bottom left panel).[29]

To sum up: directed technical changes map well to factor income share movements in the euro area. Using the terminology of Section 2.2, technical change was labor-biased (i.e., $\gamma_K > \gamma_N, \sigma < 1$) in the 1970s and in the late 1990s but capital-biased (i.e., $\gamma_K < \gamma_N, \sigma < 1$) in between. These developments translate directly into TFP growth; comparing Figures 2 (upper right panel) with Table 1 is particularly instructive in terms of understanding the three phases of euro area TFP growth.

How can we rationalize this pattern of directed technical change? A plausible explanation may be that, after the War, capital was at a low level: partly destroyed by the war, partly obsolete. There was an urgent need to increase and modernize the capital stock to catch-up the gap with the US created by the War. At the same time, there was also a heavily regulated financial market and capital controls restrained financing from abroad. The demand for domestic finance clearly exceeded supply and the de facto user cost exceeded regulated rates over the 1970s. The shadow price of capital (and in turn its income share) was therefore high, generating strong incentives for capital-saving.[30] Moreover, the rapid growth of available labor in end-1960s/early-1970s (e.g., large generations born post-war entered the labor market; part of labor force was under-utilized (especially in agriculture) and migrated to other industries; increase in female participation etc) may have made labor notionally abundant, necessitating a relatively lower level of labor saving. Moreover, labor's successful appropriation push following the first oil crisis gave firms additional incentives to engage in capital augmentation.

During the second phase (1980s-to-early-1990s), financial deregulation was in full swing and previous constellations of technical change curtailed the historically high capital share. This weakened capital-saving incentives. Thus, TFP settles down to BGP-like characteristics being dominated by labor augmentation.

This pattern was stable until the late 1990s, when there appeared to be a structural break in TFP growth and directed technical change in favor of capital. This sheds light on the puzzle of why the euro area "missed out" on

[28] Is the downward trend in real user cost fact or artifact? Regarding the 1970s, we repeat earlier reservations concerning the marginal financing premia κ. However, since the mid-1980s the correspondence between the observed data and the underlying theoretic concept should be close. A caveat is that our user cost does not include corporate taxation. However, this omission is largely neutral since (to our knowledge) no major corporate tax revisions have been implemented and the general tone of the discussion on corporate taxation, and taxation in general, has been in favor of lightening, especially, during the latter half of our sample.

[29] Note, capital growth fell substantially until the mid-1980s (see Figure 4 above), which is itself presumably indirect evidence of quality improvements.

[30] Note the general applicability here. With its huge urban and rural population, China is presumably not limited to Harrod-Neutral technical innovations. And with substantial financial repression and limited external financing, its current economic catching-up may be underpinned by aggressive capital augmentation.

the global IT boom: although the upward shift in capital augmentation is higher than the drop in labor augmenting progress, TFP growth decelerates due to the relatively lower income share of capital in TFP. In the US the IT revolution appeared to take the more standard labor-augmenting form (with a corresponding acceleration in TFP) reflecting that in the medium run US labor availability remained a constraining factor for growth, indicated by the low, roughly constant unemployment rate and the fact that factor income shares were essentially stable suggesting that the profitability of capital augmenting progress did not increase over time. Evidence for the relative scarcity of capital in the euro area which then induced capital-augmenting technical progress then also comes from an inspection of the growth rate of real wages, which since about 1976 have remained continuously below the growth rate of labor productivity (not shown). This cumulative decrease of unit labor costs may have made capital augmenting technical progress a profitable alternative to that of labor. By the same token, firms made use of abundant labor and unemployment dropped (from ≈12% to 8%) despite low growth in output and TFP.[31] Parenthetically, the late 1990s were known to be periods of enhanced employment opportunities for the low skilled (low quality) employees.

6.3 Does this pattern hold for other euro area countries?

These are dramatic results and raise the question of country-level correspondence. We repeated estimations for the four largest euro area countries: Germany, France, Italy and Spain (see Appendix D).

As with the euro-area estimation, full sample estimation without a structural break in the late 1990s favored quasi-Solow neutral technical change. Similarly, the ADF-t-test statistics of production function residuals indicate non-stationarity in all cases. A closer examination reveals a structural break in factor augmenting technical changes in three of the four: France, Italy and Spain. There the inclusion of the break improved overall fit as well as ADF-t-test statistic markedly. France and Spain followed quite closely the euro area pattern: a distinct acceleration (deceleration) in capital (labor) augmenting technical change in 1996 (one year earlier than in the area wide estimation). As before, given their relative weights, TFP growth decelerated. In Italy a downward shift in the TFP growth was identified, but included an equal downward shift in both capital and labor augmenting technical change. An initially high level of capital augmentation was also detected.

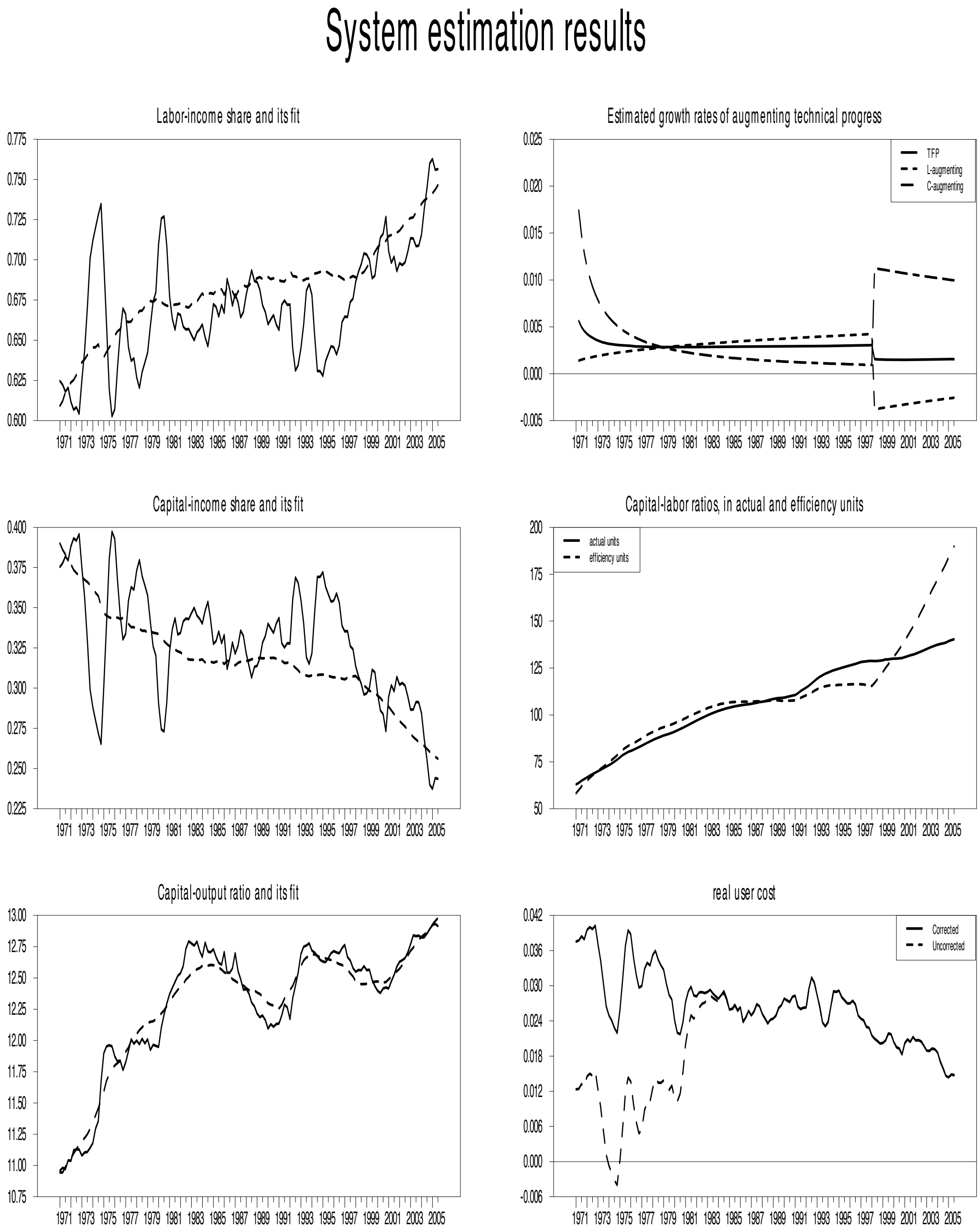
Germany was the only case where no structural break in technical change was statistically identified. Although free estimation of augmenting technical change, on the basis of statistical criteria, supported the constraint of pure capital augmenting technical change, we estimated the German supply-side system also under the constraint of labor augmenting technical change (German table, column 3, Appendix D). In the light of statistical criteria, this alternative is only marginally worse than the capital augmenting alternative (2nd column), but in economic terms much more reasonable. A slightly below unity (0.9) curvature parameter of the labor augmenting technical change implies a slow but a continuous deceleration of the technical change reflecting the observable deceleration of average labor productivity in the data.

Regarding the pre-structural break period, the Italian pattern of technical progress most closely resembled that of the euro area. Technical change contained both labor and capital augmenting components, i.e. a close to constant labor augmentation and decaying capital augmentation. France and Spain showed only substantial labor

[31] Low output growth and high employment growth defies Okun's Law. Recent literature (inter alia, Perman and Tavera, 2005) has responded by examining parameter instability issues. However, it should be recalled that Okun's Law is predicated on Harrod-Neutrality.

augmenting technical change until the 1996. All these results can be seen in the third column of the respective tables of Appendix D. Substitution elasticities were 0.73 (France); 0.52 (Italy); 0.55 (Spain); and for Germany 0.56 (labor augmenting case) and 0.88 (capital augmenting case). These are compatible with the area-wide elasticity estimate of 0.65.[32]

Figures 2



[32] The weighted average of substitution elasticity was 0.59 (0.71), if the German estimate of 0.56 (0.88) is used in calculation.

A final common feature between these country and euro area estimations concerns the role of the marginal financing dummy. Its inclusion strongly improved the general fit of the estimations and the sizes of the estimated corrections reflect well differences in measured ex post interest rates across countries in the 1970s. The estimates of the financing premia were highest in countries (Spain and Italy) where the measured real interest rate were the most negative in the 1970s. The corresponding estimate for France was around the same as that for the euro area, reflecting the fact that there the real interest rates was quite close to the euro area average. In the German case, this estimate was smaller than in other countries, but statistically significant in spite of the fact that Germany had already started liberalizing her financial markets by the beginning of 1970s. However, financial regulation continued until 1981, which may have constrained, especially, small and medium sized firms' financing at the regulated rate.

7. Taking the "Medium Run" Seriously: Optimal Price Setting and Dynamic Factor Demands

The medium run, as a conceptual macro-economic framework, necessarily extends beyond capturing potential output and optimal factor demands. Consider some cases in point. Dynamic Stochastic General Equilibrium models, for instance, typically embody adjustments costs fashioned around BGP closures, with (arguably) little reflection as to supporting data coherence. Likewise, the fit of much forward-looking dynamic specification is known to be poor despite their attractive structural (as opposed to ad-hoc) features.

The following sections carry some of these ideas forward and tries to develop an appreciation for medium-run modeling. In New-Keynesian models of inflation determination, real marginal costs (typically Cobb-Douglas inspired labor share) are (known to be) counter-cyclical rather than pro-cyclical (Rotemberg and Woodford, 1999). Real Marginal cost in the medium run world cannot be modeled as Cobb-Douglas. However, leaving aside the capturing of fluctuation income shares, both CES and Cobb-Douglas are likely to generate counter-cyclical real unit labor costs, Thus medium-run inflation determination requires correct real costs measures supplemented by some employment margins which supply net pro-cyclicality in a way grounded in our original medium-run framework (i.e. the general framework of section 3). This is achieved in our concept of effective hours.

A final case relates to the merits of structural modeling. Theory-based dynamic equations offer a structurally attractive perspective relative to ad-hoc backward-looking alternatives, but their data congruence appears the relatively poorer. Accordingly, if we could show that correct modeling of the medium run is sufficient to challenge this outcome, this would represent a major advance. We re-examine this in the context of investment dynamics (sections 7.4-7.5).

Thus far, we derived the estimated form of medium-run supply (20-22). This enables us to solve the dynamic system (10-16) of the foc of profit maximization for optimal price setting and optimal factor inputs conditional on the production function parameter estimates. Specifically, conditional on these first-stage estimates, the marginal productivity of capital and the optimal number of employees can be defined, leaving only adjustment parameters to be estimated. It is worth noting that as our optimization framework contains no adjustment costs or constraints for price setting, the implied optimal price-setting is perfectly flexible. Although this feature constraints the applicability of our framework for short-run inflation analysis, our main interest here is to present an interesting link from costs related to the deviation of effective hours from normal working hours onto optimal price setting.

Let us now, however, return to system (10)-(13) and (19) which determines price setting, the dual labor margins, and capital inputs. First, we consider the relationship between 'effective' labor hours and the pricing decision.

7.1 Effective Labor Hours and Pricing

Typically, around two-thirds of the variation in total hired hours originates from employment; the rest from changes in hours per worker, e.g., Kyland (1995), Hart (2004), Schwerdt and Turunen (2006).[33] The relatively small proportion of the variation of paid hours per worker is explained by the fact that labor contracts are typically framed in terms of "normal" working hours. Therefore, it is difficult for firms to reduce hired hours per worker below that norm and problematic to increase them above without increasing marginal costs. Under these conditions it may be optimal for firms to allow the intensity at which hired labor is utilized to vary in response to shocks. Hired hours may therefore underestimate the true variation of the utilized labor input over the business cycle and "effective hours" would be the correct measure of labor input in production. An empirical difficulty with effective hours is that they are not directly observable (although we demonstrate that effective hours can be expressed in terms of observables).

As before, assume that output is defined by production function, $F(K_t, H_t, t)$, where H is effective labor hours ($H_t \equiv N_t h_t$: N is the number of employees, h effective working hours per employee). To illustrate the concept, assume an employee is paid for, say, 8 "normal" hours, even though there may be periods when he works below "full" intensity (being equivalent, say, to only 5 hours work with "full" intensity). From the production-function standpoint, the logically correct measure of the labor input is 5 hours (i.e., the *effective* labor input) which implies that for effective labor hours the identity $H_t \equiv N_t h_t$ must hold.

Further, in the spirit of indivisible labor (e.g., Kinoshita, 1987, Trejo, 1991, Rogerson, 1998) assume that contracts are drawn up in terms of fixed (or normal) working hours per employee, normalized to unity: $\bar{h} = 1$. In general, effective hours in excess of normal hours attract a premium. Conversely, employers have limited possibilities to decrease paid hours when effective hours fall below normal ones. Hence, total wage costs, recalling equation (8), can be presented as a convex function of the deviation of effective hours from normal hours.[34] Using a variant of the "fixed-wage" model of Trejo (1991) for overtime pay, the following function gives an approximation of this relation in the neighborhood of effective hours equaling normal hours: [35]

---

[33] Our analysis based on Schwerdt and Turunen (2006), suggest that the split is 70:30 for the euro area, at least since 1980.

[34] Whilst, the overtime pay schedule of a single worker takes a kinked form, this is not so at a firm level, if there are simultaneously employees working at less than full intensity and those working overtime at full intensity (see the discussion in Bils, 1987).

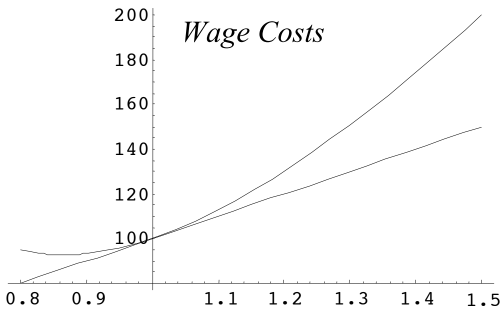
[35] Trejo's (1991) focus was in overtime hours and, therefore, he did not distinguish between effective and paid hours. Hence, our formulation is compatible with his when $h_t \geq \bar{h}$ and effective and paid hours are equal. However, our formulation also accounts for the possibility that effective hours are below normal (i.e. paid) hours.

$$W_t\left[H_t + A_H\left(N_t, H_t\right)\right] \equiv W_t\left[H_t + \frac{a_h}{2}\frac{\left(H_t - \bar{h}N_t\right)^2}{H_t}\right];\; a_h \geq 0 \qquad (27)$$

where W_t is the real straight-time wage rate which each firm takes as given. Conditional on the contracted straight-time wage rate and the overtime wage premium function, effective hours are completely demand determined. Firms can also freely (but not costlessly) determine the allocation of total effective hours into effective hours per employee and the number of employees.

Setting the number of employees, N, to 100 and W=1, the linear schedule in **Figure 3**, illustrates the dependency of total wage costs if deviations of effective hours from normal hours attract no premium, i.e. $a_h = 0$. Convex curvature in wage costs results for $a_h > 0$, and the greater the curvature, the greater is the incentive to adjust total effective hours, H, by changing the number of employees. Indeed, if changing the number of employees is costless, all adjustment is done via this margin and, independently from the size of a_h, effective hours H equals N for all periods. However, in reality, changes in the number of employees are known to be associated with non-trivial costs.

Figure 3: Wage Costs and Effective Hours



h ($\bar{h}$ = 1) , *Effective Labor Hours per Employee*

Furthermore, in the dynamic setting $\partial F / N_t = h_t\, \partial F / \partial H_t$ and effective total working hours can be solved from the inverted production function implied by condition (16),

$$H_t = F^{-1}\left(K_t, Y_t, t\right) \qquad (28)$$

Utilizing these relations, equations (10) and (11) yield the following rule for (log) optimal pricing,

$$\log P_t = \log\left(\frac{(1+\mu)\cdot W_t}{\partial F/\partial N_t}\right) + \log\left(\frac{F^{-1}\left(K_t, Y_t, t\right)}{N_t}\right) + \log\left\{1 + a_h\left[1 - \left(\frac{F^{-1}\left(K_t, Y_t, t\right)}{N_t}\right)^{-2}\right]\right\} \qquad (29)$$

where μ is the mark-up of the firm implied by the price elasticity of the demand function. Before estimating (29), consider two issues.

First, W_t is the straight-time wage rate, while the compensation per employee $\widetilde{W}_t$, observable in our aggregate euro-area data, accounts for both normal time and overtime compensations. However, on the basis of (27) with $\bar{h} = 1$ the relation between these two concepts is defined by: $\widetilde{W}_t = W_t\left[h_t + \frac{a_h}{2}(h_t - 1)^2\right]$.[36]

Second, although the mark-up was not an explicit feature of our supply-side system, it re-emerges naturally in the context of the economy's frictionless price level. As panel (a) of Figure 1 and our subsequent discussion in section 2.1 showed the euro area mark-up trends upwards over time. To account for this we observe that the aggregate mark-up need not be constant (or stationary) even if industry level mark-ups are. If competition, as well as the income elasticities of demand, deviate across industries, then, in a growing economy, aggregation across sectors introduces a deterministic trend into the aggregate mark-up. This reasoning resonates with the (quite dramatic) sectoral developments in the euro area. Panel (f) of Figure 1 shows that increase in the share of market services and electrical machinery out of total production of marketable goods rose dramatically over 1970-2004 (41%-59%). In addition, evidence suggests that, besides competition, in (sheltered) Services sectors, technical progress is also lower relative to the rest of the economy (e.g., Martins et al, 1996, Gouyette and Perelman, 1997). This would logically strengthen a positive trend in the aggregate mark-up. Appendix C elaborates on the foundations for such a trend in the mark-up arising from aggregation.

Unless one incorporates a trend, co-integration between the optimal and actual price, even controlling for traditional determinants of the price level (such as employment margins) is not attainable. Accordingly, and collecting the two latter terms on the right hand-side of (29), we derive:

$$\log P_t = \log\left(\frac{\widetilde{W}_t}{\partial F/\partial N_t}\right) + a_h \log\left(\frac{F^{-1}(K_t, Y_t, t)}{N_t}\right) + \underbrace{\mu_A + \psi(t - \bar{t})}_{\mu_t} \qquad (29')$$

where the aggregate mark-up, μ_t, now has a constant and time-varying component, where μ_A is the weighted average of constant firm or sectoral level mark-up in the mid-point of the sample. The time-dependent component, in turn, reflects changes in production shares of high and low mark-up industries.

Lastly, to repeat, note the deviation of effective working hours from normal hours has a spill-over to pricing when $a_h \neq 0$. Therefore, despite the fact that equation (29') is a static relationship, it is affected, via parameter a_h and the effective-to-normal hours gap, by the adjustment dynamics of labor and capital inputs.

[36] We see that, if h_t is pro-cyclical, then $\widetilde{W}_t / W_t$ is also pro-cyclical. Hence, even without renegotiating the straight-time wage rate, the average wage rate per employee or per hour is pro-cyclical.

7.2 Employment and Capital

Dynamic labor demand (12) can be re-written as,

$$\frac{\partial A_N(N_t, N_{t-1})}{\partial N_t} + \frac{E_t(W_{t+1})}{W_t(1+r_t+\kappa_t)} \frac{\partial A_N(N_{t+1}, N_t)}{\partial N_t} = a_h \left(1 - \frac{N_t}{F^{-1}(K_t, Y_t, t)}\right) \tag{30}$$

Whilst, condition (13) can be re-written as:

$$\frac{\partial A_K(K_t, K_{t-1}, K_{t-2})}{\partial K_t} + E_t(1+r_t+\kappa_t)^{-1}\left\{\frac{\partial A_K(K_{t+1}, K_t, K_{t-1})}{\partial K_t}\right\}$$
$$+ E_t[(1+r_t+\kappa_t)(1+r_{t+1}+\kappa_{t+1})]^{-1}\left\{\frac{\partial A_K(K_{t+2}, K_{t+1}, K_t)}{\partial K_t}\right\} = \frac{P_t}{(1+\mu)}\frac{\partial F(K_t, H_t, t)}{\partial K_t} - \frac{r_t+\kappa_t+\delta}{1+r_t+\kappa_t}, \tag{31}$$

where, as before, P_t is the relative GDP-to-Investment deflator. With function F known, effective total hours as well as the marginal product of capital are defined. However, for estimation we must define explicit functional forms for adjustment cost functions A_N, A_K. Where relations between variables are multiplicative, as here, quasi-quadratic adjustment costs result in particularly elegant results, Willman et al (1999). The adjustment cost functions, and for comparison, their quadratic counterparts are then,

$$A_N(N_t, N_{t-1}) = \frac{a_N}{2}\cdot \Delta N_t \Delta n_t \approx \frac{a_N}{2}\cdot\frac{(\Delta N_t)^2}{N_{t-1}} \tag{32}$$

$$A(K_t, K_{t-1}, K_{t-2}) = \frac{a_K}{2}\cdot\Delta K_t \Delta k_t + \frac{a_K b_K^2}{2}\cdot \Delta K_{t-1}\Delta k_{t-1} - a_K b_K \cdot \Delta K_t \Delta k_{t-1} \approx \frac{a_K}{2}\cdot\frac{(\Delta K_t - b_K \Delta K_{t-1})^2}{K_{t-1}} \tag{33}$$

where lower case denotes logs and $b_K \in [0,1]$. Substituting these conditions (and their derivatives) into (30) and (31) and utilizing the relation $\widetilde{W}_t = W_t\left[h_t + \frac{a_h}{2}(h_t - 1)^2\right]$, we derive our final dynamic (estimable) factor demands,

$$\Delta n_t - \frac{\widetilde{W}_{t+1}}{(1+r_t+\kappa_t)\widetilde{W}_t}\cdot\frac{\left(1+\log\left(\frac{F_t^{-1}}{N_t}\right)+a_h\left(\log\left(\frac{F_t^{-1}}{N_t}\right)\right)^2\right)}{\left(1+\log\left(\frac{F_{t+1}^{-1}}{N_{t+1}}\right)+a_h\left(\log\left(\frac{F_{t+1}^{-1}}{N_{t+1}}\right)\right)^2\right)}\cdot\Delta n_{t+1} = \frac{a_h}{a_N}\log\left(\frac{F_t^{-1}}{N_t}\right) \tag{34}$$

$$\frac{b_K}{(1+r_t+\kappa_t)(1+r_{t+1}+\kappa_{t+1})}\Delta k_{t+2}-\left(\frac{b_K^2}{(1+r_t+\kappa_t)(1+r_{t+1}+\kappa_{t+1})}+\frac{(1+b_K)}{(1+r_t+\kappa_t)}\right)\Delta k_{t+1}+\left(\frac{b_K(1+b_K)}{(1+r_t+\kappa_t)}+1\right)\Delta k_t-b_K\Delta k_{t-1}$$

$$=\frac{1}{a_K}\left(\frac{P_t}{(1+\mu)}\frac{\partial F}{\partial K_t}-\frac{r_t+\kappa_t+\delta}{1+r_t+\kappa_t}\right) \tag{35}$$

If $r_t+\kappa_t$ and $r_{t+1}+\kappa_{t+1}$ are replaced by their steady-state value, $\bar{r}$, then equation (35) has one stable and two unstable roots – $b_K, \frac{1+\bar{r}}{b_K}$ and $1+\bar{r}$ – implying saddle-path stability. The dominant lead root equals the inverse of the average discount factor which being only slightly above unity, implies highly forward-looking behavior. The importance of the past depends on the size of adjustment-cost parameter b_K: if $b_K=0$, the net investment level can be changed costlessly. Similarly, it can be shown that with $F_t^{-1}=N_t$ and constant wage growth (34) has one unstable and one stable root (see Table 4).

7.3 Estimation of Dynamic Factor Demands and Price Equations

Tables 3-5 give the estimates for the dynamic investment (35) and labor (34) equations and the static price relationship (29'). In all cases, parameters are significant at 1% and the roots and over-identifying restrictions are in line.

Consistent with our theoretical specification, adjustment costs of the labor input have strong spillover effects on prices: $a_h = 0.48$. Further, as the Durbin-Watson statistic shows, the residual of the price equation, although stationary, is highly auto-correlated and consistent with the consensus view that there is considerable stickiness in price setting.

Likewise, adjusting the number of employees is associated with significant costs (reflected by the roots, 0.84 and 1.21). The investment costs-of-adjustment parameter, b_k (the backward-looking root), is estimated to be quite high 0.57 which implies that, in addition to costs associated with changing the level of the capital stock, it is not costless either to change the level of investment.[37]

[37] This idea, though once controversial, is becoming increasingly popular in investment modeling. Christiano et al. (2005), for instance, allow the flow of investment to be costly to adjust. As Svensson and Tetlow (2005) comment, this is equivalent to having higher-order adjustment costs for the capital stock.

Table 3: Price Equation Estimates (eq, 29')

μ_A	0.0373 (0.0014)
ψ	0.0024 (0.0000)
a_h	0.4831 (0.0984)
DW	0.1170

Table 4: Dynamic Labor Demand Estimates (eq, 34)

a_h	0.4831 (0.0984)
a_N	14.1624 (3.1414)
Characteristic Roots	1.2100 ; 0.8357
J-Test	[0.9192]

Note: Instruments used: lags of employment and output growth, of deviation of actual efficient hours, of capacity utilization, and growth of real wages (in terms of the investment deflator).

Table 5: Dynamic Capital Demand Estimates (eq, 35)

$1/a_K$	0.0081 (0.0027)
b_K	0.5738 (0.0598)
Characteristic Roots	1.7680; 1.0144; 0.5738
J-Test	[0.8861]

Note: Instruments used: own lags of capital and output growth, of real user cost, marginal productivity of capital, of the difference between GDP and investment deflator, long and short-term nominal interest rate, investment deflator inflation and TFP growth.

7.4 A Graphical Analysis: How Well Do Our Dynamic Results Fit The Data?

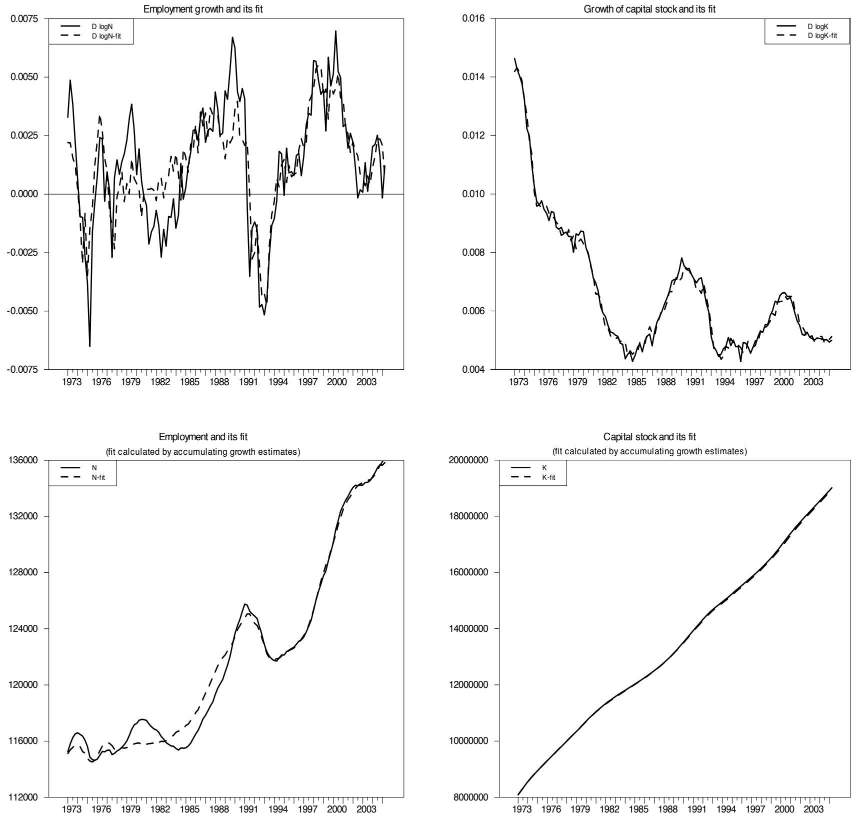
In **Figures 4**, we show the corresponding fit of the dynamic equations which have the medium-run trajectories as their fundament. The tracking properties are extremely encouraging: with the long decline in the growth of capital formation and the rising trend in employment in the euro area captured very well. This is a particularly attractive outcome given that these dynamic equations embody purely structural dynamics, eschewing ad-hoc backward-looking frictions. It is often considered that such specifications compromise data compatibility. This is not the case here and in the next section we propose a formal comparison between backward-looking and forward-looking investment.

Overall, these results would suggest that the issue of deriving theoretically-well founded and empirically supported equations lies not only in the careful and plausible modeling of adjustment costs but also equally careful attention to medium-run dynamics.

Figure 4

Growth rates and levels of employment (N) and capital stock (K)

(in calculating fits forward variables are instrumented)



7.5 Investment Tracking: An Aside.

One issue is how well these factor input equations, especially capital demand, track the data; the empirical performance of highly theoretical factor demand specifications (compared to, say, ad-hoc or backward-looking equivalents) has long been an issue, e.g., Oliner et al (1995). For the transparency of comparison, we can derive a backward-looking investment equation which is, except for the expectations formation, based on the same theoretic framework. With extrapolative expectations the backward-looking counterpart of (35) is

$$\Delta k_t = \lambda_1 \Delta k_{t-1} + \frac{1}{\lambda_2 - \lambda_3}\left(\left(\frac{\lambda_3}{\lambda_3 - 1} \right) - \left(\frac{\lambda_2}{\lambda_2 - 1} \right) \right) \left(\frac{P_t}{(1+\mu)} \frac{\partial F}{\partial K_t} - \frac{r_t + \delta}{1 + r_t} \right) \tag{35'}$$

where $\lambda_i \ (i = 1,2,3)$ are the roots of (35) with $\lambda_1 < 1$ and $\lambda_3 > \lambda_2 > 1$. Freely estimating the above yields,

$$\Delta k_t = \underset{(0.0116)}{0.9417} \Delta k_{t-1} + \underset{(0.0054)}{0.0094} \left(\frac{P_t}{(1+\mu)} \frac{\partial F}{\partial K_t} - \frac{r_t + \delta}{1 + r_t} \right) + \underset{(0.0001)}{0.0003}, \ \overline{R}^2 = 0.986; DW = 1.57, SE = 2.7e-4$$

The resulting fit is quite satisfactory: all parameters are significant and correctly signed. It is worth noting that the estimate for the stable root (λ_1) implied by the estimated backward-looking equation is much higher (0.94) than that implied by the estimated forward-looking equation (at 0.57). As the growth of capital stock is highly auto-correlated, this may reflect the omitted-variable problem; lagged growth of the capital stock may capture part of the effect of the leaded growth of capital stock on current period growth in backward-looking estimation. To have a comparable goodness of fit measure for our forward looking equation we normalized it with respect to current period net investment and calculated the standard error (SE) of its implied residual which was 2e-4. That is 25% smaller than that of the estimated backward-looking equation and, in the light of this measure, our forward looking equation outperforms its freely estimated backward looking counterpart.

8 Conclusions

This paper set itself two aims. First, to establish a framework for capturing medium-run growth dynamics. Second, against that background, to account for the particular medium-run features of continental Europe.

The "medium run" corresponds to the overlap of the long run (where supply factors govern events) and the short run (where demand presides). As regards the former, we estimated a normalized supply-side side incorporating time-varying technical progress. The elasticity of substitution (a key parameter in "medium-run" debates) was estimated below unity. Accordingly, factor augmentation plays a central role in accounting for non-stationary factor income shares and enriching our analysis of the factor content of TFP growth. Directed technical change offers attractive explanations for the high-TFP catch up period and labor appropriation phase of the early 1970s and sheds light on the puzzle of why, in the midst of the recent global IT boom, euro-area productivity growth decelerated.[38] Based on close scrutiny of the data, we further detected the importance of financial regulations in determining capital income share in the 1970s and a generally upward trend in the pure profit component (whose development we ascribed to the shift towards higher mark-up, less efficient Service sectors).

Our medium-run outcomes were then fashioned around theoretically well-founded adjustment cost functions. Regarding labor, a special feature was to decompose such costs into dual participation margins. This extension introduces the deviation of effective labor hours from normal paid hours into pricing behavior, which proved empirically significant. Regarding capital, besides adjustment costs in its level (as standard), we also introduced costs associated with the level of investment. Besides being theoretically well grounded, these dynamic specifications appear data-congruent; reflecting, we believe, careful modeling of medium-run growth trends as much as careful modeling of structural frictions.

To sum up, we tried to model the main planks of the "medium-run" debate in Continental Europe – fluctuating factor incomes, decelerating productivity, non-stationary mark-ups, the role of the substitution elasticity, technical biases, sectoral changes etc – in a manner consistent with nested asymptotic growth theory. Naturally, we do not claim our approach incorporates all perspectives. However, what we do claim (recalling Blanchard's opening quote) is that departures from balanced growth are important, interesting and, with due care,

[38] This pattern may help resolve, at least for the euro area, a latter-day 'Solow Paradox': "You can see the computer age everywhere but in the productivity statistics", New York Review of Books, July, 1987.

un-coverable from the data. Moreover, we do not exclude the compatibility of our explanations with traditional ones. Rising mark-ups and directed technical change as against the interaction between shocks and institutions may be different sides of the same coin: if the success of labor's appropriation push reflected labor-sheltering institutions, this would precisely strengthen the case for firms manipulating technical biases to compensate.

A number of directions for future research are suggested by this study. At the outset, we hope that flexible estimation of production technology and supply-side systems will become common in CES estimation and that our medium-run framework may be usefully applied to other countries, sectoral studies and perhaps in a cross-country panel context. Other promising extensions include formally endogenizing technical progress and distinguishing between different skill varieties in the labor input. From the standpoint of short-run adjustment dynamics with monetary policy implications, it might be interesting to implement our pricing relationship into New-Keynesian models of inflation determination to account for price stickiness. Finally, although we have largely separated structural (sectoral) changes and directed technical change explanations for medium-run episodes, the interplay between these developments also appears a promising research avenue.[39]

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[39] Several studies have suggested the rise of the sheltered Services sector in the euro area impeded the adoption and diffusion of new technology, e.g., Conway and Nicoletti (2006), Alesina et al. (2005), Nicoletti and Scarpetta (2003).

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A: Precise Form of Supply-Side Estimation

The estimated form corresponding to system (13-15) becomes:

$$\log\left(\frac{w_t N_t}{w_t N_t + q_t K_t}\right) - \log(1-\bar{\pi}) + \frac{1-\sigma}{\sigma}\left[\log\left(\frac{Y_t/\bar{Y}}{N_t/\bar{N}}\right) - \log\zeta - \frac{\bar{t}\gamma_N}{\lambda_N}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_N} - 1\right)\right] = 0 \qquad \text{(A1)}$$

$$\log\left(\frac{q_t K_t}{w_t N_t + p_t k_t}\right) - \log(\bar{\pi}) + \frac{1-\sigma}{\sigma}\left[\log\left(\frac{Y_t/\bar{Y}}{K_t/\bar{K}}\right) - \log\zeta - \frac{\bar{t}\gamma_K}{\lambda_K}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_K} - 1\right)\right] = 0 \qquad \text{(A2)}$$

$$\log\left(\frac{Y_t/\bar{Y}}{N_t/\bar{N}}\right) - \log(\zeta) - \frac{\bar{t}\gamma_N}{\lambda_N}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_N} - 1\right) + \frac{\sigma}{1-\sigma}\log\left[\bar{\pi} e^{\frac{1-\sigma}{\sigma}\left[\frac{\bar{t}\gamma_N}{\lambda_N}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_N}-1\right) - \frac{\bar{t}\gamma_K}{\lambda_K}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_K}-1\right)\right]}\left(\frac{K_t/\bar{K}}{N_t/\bar{N}}\right)^{\frac{\sigma-1}{\sigma}} + (1-\bar{\pi})\right] = 0 \qquad \text{(A3)}$$

where $\bar{\pi} = \dfrac{\bar{q}\bar{K}}{\bar{w}\bar{N} + \bar{q}\bar{K}}$ is the capital share evaluated at the fixed point (sample mean).

We suggest normalization points should be calculated from sample averages (denoted by a bar). However, due to the non-linearity of the CES function, sample averages (arithmetic or geometric) need not exactly coincide with the implied fixed point of the underlying CES function. That would be the case only if the functional form is log-linear i.e. Cobb-Douglas with constant technical growth. Therefore, we capture and measure the possible emergence of such a problem by introducing an additional parameter, ζ, which should be close to unity. This allows us to express the fixed point in terms of the geometric sample averages of output and inputs, $Y_0 = \zeta \cdot \bar{Y}, K_0 = \bar{K}, N_0 = \bar{N}$, and the arithmetic sample averages of capital income share and time: $\pi_0 = \bar{\pi}, t_0 = \bar{t}$. Distribution parameter $\bar{\pi}$ can be calculated directly from the data or it can be estimated jointly with the other parameters of the model. We apply the former approach, however, modified so that the implied factor income share is conditional on the estimated level correction on the real marginal cost of financing (parameter κ).

B: Factor-Augmenting TFP Identification using the Kmenta Approximation.

It is well known that the log of the TFP is separable from the production function, only under Hicks neutrality, $\gamma_N = \gamma_K$. However, it would be useful to calculate TFP in the context of *factor augmenting* technical change. By drawing on the Kmenta (1967) approximation, production function (22’) can be re-presented as:

$$\log(Y_t/Y_0) = \frac{\sigma}{\sigma-1}\log\left\{(1-\pi_0)(N_t/N_0)^{\frac{\sigma-1}{\sigma}} + \pi_0(K_t/K_0)^{\frac{\sigma-1}{\sigma}}\right\}$$
$$\underbrace{+\pi_0\left[1-\frac{1-\sigma}{\sigma}(1-\pi_0)\log\left(\frac{K_t/K_0}{N_t/N_0}\right)\right]\gamma_K(t)+(1-\pi_0)\left[1+\frac{1-\sigma}{\sigma}\pi_0\log\left(\frac{K_t/K_0}{N_t/N_0}\right)\right]\gamma_N(t)-\frac{1-\sigma}{\sigma}\frac{\pi_0(1-\pi_0)}{2}[\gamma_N(t)-\gamma_K(t)]^2}_{\text{Log TFP}} \tag{B1}$$

In the neighborhood of $K_t = K_0$ and $N_t = N_0$ the TFP component can be further approximated by:

$$\log(Y_t/Y_0) = \frac{\sigma}{\sigma-1}\log\left\{(1-\pi_0)(N_t/N_0)^{\frac{\sigma-1}{\sigma}} + \pi_0(K_t/K_0)^{\frac{\sigma-1}{\sigma}}\right\}$$
$$\underbrace{+\pi_0\gamma_K(t)+(1-\pi_0)\gamma_N(t)-\frac{1-\sigma}{\sigma}\frac{\pi_0(1-\pi_0)}{2}[\gamma_N(t)-\gamma_K(t)]^2}_{\text{Log TFP}} \tag{B2}$$

where

$$\text{TFP Growth} = \text{Log(TFP/TFP}(-1)) \tag{B3}$$

C: Aggregation and the Time-Varying Mark-Up

Assume that there are *m* sectors and n_j firms in each sector. The economy-wide aggregates are determined by the identities:

$$X \equiv \sum_{j=1}^{m} X^j \equiv \sum_{j=1}^{m}\sum_{i=1}^{n_j} X_i^j \tag{C1}$$

where $X_i^j = Y_i^j, K_i^j, N_i^j$

$$PY = \sum_{j=1}^{m} P^j Y^j = \sum_{j=1}^{m}\sum_{i=1}^{n_j} P_i^j Y_i^j \tag{C2}$$

Hence, denoting by *k* the capital-to-labor ratio, aggregated production (or labor demand) and the profit maximizing price in sector *j* are determined by:

$$\frac{Y^j}{N^j} = f(k)A^j e^{\gamma_j t} \tag{C3}$$

$$P^j = (1+\mu^j)\left[\frac{w}{A^j e^{\gamma^j t}\left(f(k)-kf'(k)\right)}\right] \tag{C4}$$

Equation (3) defines that the per-capita production function $f(k)$ is same for all sectors, which can contain a common augmented technical component, However, if sectoral production functions allow the separation of a non-zero Hicks-neutral technical progress component as a multiplicand of the function, then that component can differ across sectors.

Aggregation across sectors, as defined by identity (C1), implies that the aggregate level supply-system, corresponding to the firm level supply system (20)-(22), can be written as,

$$\frac{Y}{N} = f(k)\left[\sum_{j=1}^{m} s_t^j \left(A^j\right)^{-1} e^{-\gamma^j t}\right]^{-1} \tag{C5}$$

$$\frac{q\left[f(k) - kf'(k)\right]}{wf'(k)} = 1 \tag{C6}$$

$$P = \sum_{j=1}^{m} s_t^j P^j = \frac{w}{f(k) - kf'(k)} \sum_{j=1}^{m} s_t^j \left(1+\mu^j\right)\left(A^j\right)^{-1} e^{-\gamma^j t} \tag{C7}$$

where $s_t^j = \frac{Y_t^j}{Y_t}$. Equations (C5) and (C6) become more transparent after transforming them into logarithmic form and then linearizing the logarithms of the summation terms around the values $s_t^j = s_0^j$ and *t=0*:

$$\log\frac{Y}{N} = \log f(k) + \log A + \gamma_A \cdot t - \sum_{j=1}^{m} A\left(A^j\right)^{-1}\left(s_t^j - s_0^j\right) \tag{C8}$$

$$\log P = \log w - \underbrace{\left\{\log\left[f(k) - k \cdot f'(k)\right] + \log A + \gamma_A \cdot t - \sum_{j=0}^{m} A\left(A^j\right)^{-1}\left(s_t^j - s_0^j\right)\right\}}_{\text{Log of the Marginal Product of Labor}}$$
$$\underbrace{+\log\left(1+\mu_A\right) + \sum_{j=1}^{m} \frac{A\left(A^j\right)^{-1}\left(\mu^j - \mu_A\right)}{1+\mu_A}\left(s_t^j - s_0^j\right) - \sum_{j=1}^{m} b^j\left(\gamma^j - \gamma_A\right) \cdot t}_{\text{Log of the mark-up}} \tag{C9}$$

Assume next that the demand for sector *j* goods is determined by the demand system,

$$\frac{Y^j}{Y} = s_t^j = s_0^j + \xi^j \log\left(\frac{Y/Y_0}{N/N_0}\right) \text{, where } \sum_{j=1}^{m} s_t^j = 1 \text{ and } \sum_{j=1}^{m} \xi^j = 0 \tag{C10}$$

Hence, if the demand elasticity with respect to per capita income (or average aggregate productivity) in sector *j* is above (below) unity then along with growing per capita income the output share of sector *j* increase (decreases). Denoting the trend component of average aggregate productivity by $TREND_{Y/N}$ (C10) can be presented as follows,

$$s_t^j - s_0^j = \xi^j TREND_{Y/N} + \xi^j \left[\underbrace{\log\left(\frac{Y/Y_0}{N/N_0}\right) - TREND_{Y/N}}_{u_t}\right] = \xi^j TREND_{Y/N} + \xi^j u_t \tag{C11}$$

where u_t can be assumed stationary around zero and, accordingly, the trend in aggregate mark-up can be reduced to the trend component of average aggregate productivity as well as to sectoral deviations in Hicks neutral productivity growth rates.

D: Country Results

Germany	1971-2004	1971-2004	1971-2004
	General factor augmenting	Capital augmenting	Labor augmenting
ζ	1.0022 (0.0004)	1.0025 (0.0076)	1.0010 (0.0068)
γ_{N1}	0.0022 (0.0029)	–	0.0152 (0.0006)
λ_{N1}	1.6444 (1.6552)	–	0.9018 (0.1043)
γ_{K1}	0.0334 (0.0077)	0.0397 (0.0016)	–
λ_{K1}	0.8973 (0.1990)	1.0025 (0.1200)	–
σ	0.8713 (0.0119)	0.8835 (0.0112)	0.5556 (0.0049)
κ	0.0124 (0.0005)	0.0124 (0.0009)	0.0119 (0.0010)
TFP Growth	0.0109	0.0111	0.0109
π_0	0.279	0.279	0.278
	Stationarity		
ADF_p	-3.7534	-3.6757	-3.7247
$ADF_{ck/wn}$	-3.6596	-3.5759	-3.9149
$ADF_{Y/N}$	-2.1446	-2.1803	-2.1468
Log Determinant	-25.3324	-25.3288	-25.0964

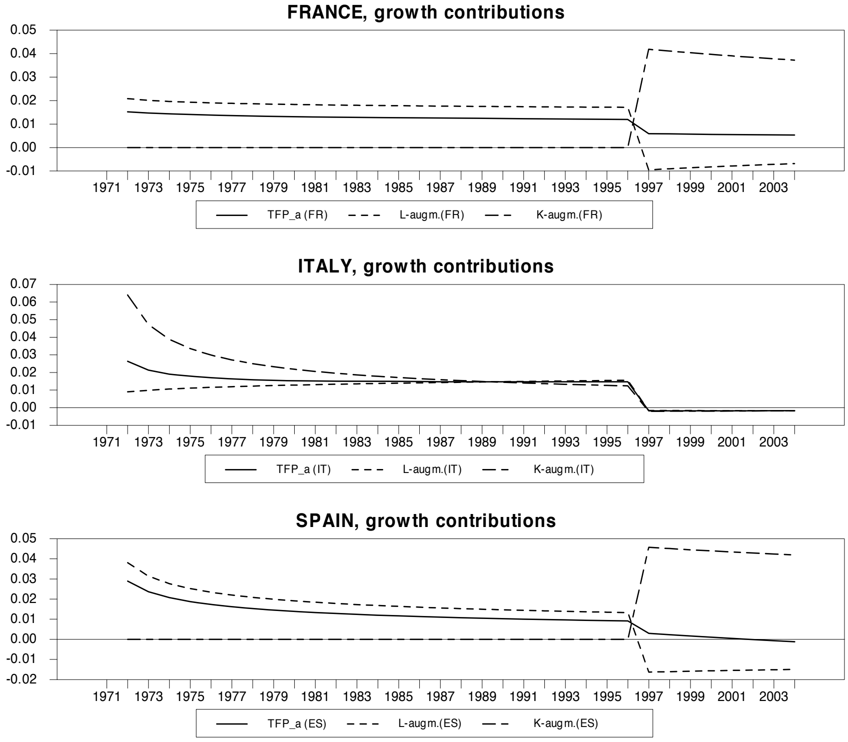
France	1971-2004	1971-1996	1971-2004
	Full-sample	Sub-sample	Full-sample
ζ	1.0113 (0.0036)	1.0002 (0.0031)	1.0009 (0.0028)
γ_{N1}	-0.0000 (0.0000)	0.0180 (0.0004)	0.0179 (0.0004)
λ_{N1}	-15.1161 (0.0740)	0.9733 (0.0723)	0.9311 (0.0556)
$\gamma_{N,t>1996}$	–	–	-0.0268 (0.0005)
$\lambda_{N,t>1996}$	–	–	0.5000 (–)
γ_{K1}	0.0406 (0.0011)	–	–
λ_{K1}	0.8064 (0.0742)	–	–
$\gamma_{K,t>1996}$	–	–	0.0423 (0.0053)
$\lambda_{K,t>1996}$	–	–	0.5000 (–)
σ	0.9095 (0.0119)	0.7953 (0.0181)	0.7322 (0.0131)
κ	0.0319 (0.0010)	0.0325 (0.0004)	0.0304 (0.0004)
TFP Growth	0.0111	0.0128	0.0127
π_0	0.276	0.287	0.286
	Stationarity		
ADF_p	-3.2688	-3.3433	-3.6656
$ADF_{ck/wn}$	-3.4034	-3.5315	-3.7770
$ADF_{Y/N}$	-2.0208	-1.9670	-2.9173
Log Determinant	-26.1151	-26.7113	-27.0156

Italy	1971-2004	1971-1996	1971-2004
	Full-sample	Sub-sample	Full-sample
ζ	1.0296 (0.0040)	1.0055 (0.0037)	1.0074 (0.0037)
γ_{N1}	-0.0000 (0.0000)	0.0149 (0.0012)	0.0138 (0.0012)
λ_{N1}	-3.0000 (–)	1.1854 (0.1439)	1.1930 (0.1522)
$\gamma_{N,t>1996}$	–	–	-0.0172 (0.0040)
$\lambda_{N,t>1996}$	–	–	1.1930 (0.1522)
γ_{K1}	0.04263 (0.0016)	0.01559 (0.0034)	0.0178 (0.0032)
λ_{K1}	0.5047 (0.0566)	0.3834 (0.1825)	0.4266 (0.1544)
$\gamma_{K,t>1996}$	–	–	-0.1433 (0.0123)
$\lambda_{K,t>1996}$	–	–	0.4266 (0.1544)
σ	0.7492 (0.0152)	0.4898 (0.0195)	0.5199 (0.0199)
κ	0.0357 (0.0015)	0.0390 (0.0018)	0.0379 (0.0017)
TFP Growth	0.0115	0.0151	0.0149
π_0	0.276	0.301	0.300
	Stationarity		
ADF_p	-3.2856	-2.8743	-3.2795
$ADF_{ck/wn}$	-3.9852	-3.3767	-3.9463
$ADF_{Y/N}$	-2.6333	-2.6525	-3.4869
Log Determinant	-21.1427	-21.9475	-22.2743

Spain	1971-2004	1971-1996	1971-2004-
	Full-sample	Sub-sample	Full-sample
ζ	1.0177 (0.0047)	1.0115 (0.0038)	1.0121 (0.0033)
γ_{N1}	0.0055 (0.0017)	0.0162 (0.0006)	0.0168 (0.0005)
λ_{N1}	1.2246 (0.5490)	0.6905 (0.0836)	0.6319 (0.0585)
$\gamma_{N,t>1996}$	–	–	-0.0296 (0.0028)
$\lambda_{N,t>1996}$	–	–	0.6319 (0.0585)
γ_{K1}	0.0173 (0.0041)	–	–
λ_{K1}	0.3519 (0.1502)	–	–
$\gamma_{K,t>1996}$	–	–	0.0461 (0.0077)
$\lambda_{K,t>1996}$	–	–	0.6319 (0.0585)
σ	0.6125 (0.0285)	0.6820 (0.0353)	0.5527 (0.0250)
κ	0.0432 (0.0020)	0.0428 (0.0017)	0.0246 (0.0019)
TFP Growth	0.0084	0.0113	0.0118
π_0	0.255	0.296	0.285
	Stationarity		
ADF_p	-5.7381	-6.2553	-5.8065
$ADF_{ck/wn}$	-2.4037	-3.2730	-3.0292
$1ADF_{Y/N}$	-1.3527	-2.7072	-2.7747
Log Determinant	-19.8593	-22.0412	-23.1975

Figure 1D

Factor augmenting technical progress



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