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ARTICLES

# MEDIUM RUN REDUX

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We develop a framework for measuring and analyzing medium-run departures from balanced growth, and apply it to developments in the euro area. A time-varying factor-augmenting production function (mimicking directed technical change) with below-unitary substitution elasticity is shown to account for the observed dynamics of factor incomes shares, TFP growth, and its components. Based on careful data accounting, we also identify a rising markup and the importance of financial-market regulations in the 1970s. The balanced growth path emerges as a special (and testable) case of our framework, as do existing strands of medium-run debates.

**Keywords:** Medium Run, Euro Area, Elasticity of Substitution, Directed Technical Change, Productivity, Income Distribution, Okun's Law

> 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)

> . . . 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).[1] The BGP, the dominant assumption in the

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theoretical growth literature, suggests that variables such as output and consumption tend to a common growth rate, whereas key underlying ratios (e.g., factor income shares, capital–output ratio) are constant [Kaldor (1961)]. In that respect, the economy of continental Europe (the "euro area") has attracted particular interest: hump-shaped labor income shares, persistently high unemployment, decelerated productivity growth, etc. Given their persistence, such features can be described as neither short-run nor recognizably long-run features.[2]

Our contribution to this topic is, first, to establish a framework for capturing medium-run growth features in a supply context and, second, against that background, to account for the particular medium-run features of continental Europe. Our focus is on the role of directed technical change and factor substitution, with some lesser but supporting emphasis on financial repression and aggregate markup dynamics. Our framework, though, nests the BGP as a special (and therefore testable) case.

The medium-run features of European development have generated a prominent literature. Regarding the nonconstant labor share, Bruno and Sachs (1985), Blanchard (1997), and Caballero and Hammour (1998) linked differences in the evolution of income shares in the United States and Europe (and, in turn, employment and productivity) 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. On the latter, Blanchard (1997) and Caballero and Hammour (1998) used models assuming purely labor-augmenting technical progress and an above-unity long-run substitution elasticity (SE) with short-run putty-clay characteristics.

These explanations proved influential, but they have drawbacks. First, the case for above-unity elasticity appears empirically weak and theoretically anomalous (as discussed later). Besides its not being able to explain the downward trend in the labor share, Europe also experienced a decline in capital formation since the 1970s. Declining capital deepening can cause a decline in employment and a rise in the capital income share only if the SE 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 labor augmenting or Harrod-neutral). Technical progress may instead be *nonneutral* (as emphasized by models of directed technical change).

Much of economics assumes unitary-elasticity Cobb–Douglas (CD) production. Under CD the direction (or bias) 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 put biases in technical change centre stage.

In models of biased technical change [e.g., Kennedy (1964), Samuelson (1965), Acemoglu (2002a)], scarcity, reflected by relative factor prices, generates incentives to invest in factor-saving innovations; i.e., firms reduce the need for scarce factors and increase the use of abundant ones.[3] Acemoglu (2002a) further suggested that although technical progress is labor-augmenting along the BGP, it may become capital-biased in transition. Given a below-unitary SE this pattern promotes the asymptotic stability of income shares while allowing nonstationary developments in the medium run.

The intuition for asymptotic labor augmentation reflects the feature that capital, unlike labor, may be accumulated limitlessly; thus labor represents the constraining factor, and, to avoid an explosion of wage income, firms bias technical improvements accordingly. With persistently high European unemployment, however, considering labor as constraining medium-run growth appears anomalous. In contrast, the repressive financial regime in the 1970s may instead have made *capital* the scarce factor of production.[4]

Explaining the medium run in the euro area requires careful data scrutiny. Arguably much past work muddied the waters by failing to distinguish between "GDP-income shares" and "factor-income shares." Output may be divided between returns to labor, returns to capital, and a pure profit component. If all firms are perfectly competitive (i.e., their price elasticity is infinite, or they have zero markup), the latter component is zero. Otherwise, there will be a distinction between GDP income shares and factor income shares. To illustrate, labor income (wages times heads) may be defined as a share of GDP income or GDP minus pure profit (i.e., in terms of factor income share). If the aggregate markup is time-varying, as the European data strongly indicate over our sample, overlooking this distinction risks mixing structural and technical explanations for medium-run phenomena. For instance, it is often stated that euro-area labor shares have been secularly falling since the early 1980s. But definitions matter. In GDP terms labor share *has* continued to fall since the early 1980s; in factor income terms, though, it largely stabilized after the early 1980s (and started to rise in the mid-1990s).

Making and understanding this distinction is essential for explaining factor share and total factor productivity (TFP) developments. For a given SE, factor income shares are driven by technical biases, capital deepening, and factor prices. The aggregate markup, in contrast, is largely determined by structural factors, e.g., changing sectoral compositions, reflecting, for instance, differing income elasticities of demand. We suggest that the substantial output-share shift from manufacturing to service industries over our sample [the latter typically characterized by lower productivity and higher markups, as in Nicoletti and Scarpetta (2003)], has (almost as a tautology) induced an upward component into the aggregate euro-area markup (a behavioral explanation is that the income elasticity of services has been well above unity).

Our results suggest that the elasticity of factor substitution in the euro area is well below unity, that the aggregate GDP-share markup has risen over time, and that non–constant growth ("directed") technical change is a key component underpinning euro-area medium-run phenomena. To the best of our knowledge, this study offers the most comprehensive and rigorous analysis of medium-run trends in the euro area and is the first to highlight the role of directed technical change in those developments. Our results account for both the high-TFP growth period of the 1970s and its well-documented slump since the 1990s (Europe's lost "IT boom"), as well as attendant movements in factor income shares and in key ratios. The elements that we propose (nonconstant growth in technical progress; below-unitary SE; time-varying markup; financial repression) are taken to the data in an incremental, transparent manner.

Lest they be considered merely historical revisionism, we stress the importance of our results. First, despite renewed interest in models of biased technical change, the corresponding empirical effort to identify (i.e., *measure*) episodes from macro data has been lacking.

Second, from a modeling point of view, the same movements in factor income shares may be generated in distinct ways. For example, a rise in the labor share may be the result of an increase in labor-augmenting technical progress (for an above-unity SE) or an increase in capital-augmenting technical progress (for a below-unity SE). A causal observer may be indifferent to the reasons behind a given income share movement, but the implications of each—e.g., in terms of growth accounting, inequality, and policy recommendations—are profoundly different. In short, discriminating between explanations is important.[5]

The paper proceeds as follows. Next we offer background on the euro-area economy relative to the BGP and on the directed–technical change literature and then discuss factor-augmenting production functions. Section 3 outlines the model. After a discussion of the euro area data set, Section 5 describes our estimates of medium-run supply. Finally, we conclude.

## 2. THE EURO AREA: (UN)BALANCED GROWTH AND TECHNICAL CHANGE

We motivate our analysis by discussing recent patterns in the euro area in relation to the BGP (Section 2.1), then briefly discuss biased technical change explanations of endogenous growth (Section 2.2), and then the properties of the "normalized" CES production function with biased technical change (Section 2.3). Our analysis is based on the euro area data set of Fagan et al. (2001); see Section 4.

### 2.1. Stylized Features of Euro-Area Development and the Balanced Growth Path Benchmark

A widely adopted assumption is that the short run can be presented as deviations from the (long-run) BGP. Thus in data spanning several decades, income shares, the markup (i.e., the gap between prices and costs), and the capital–output ratio should be stationary (as should involuntary unemployment). Figure 1 (Panel A) presents the development of the GDP shares of capital ($K$) and labor ($N$) income (we use aggregated euro area data from the 1970s; see Section 4 and the note that follows Figure 1).

Besides showing the declining labor income share after a hump in the 1970s, Figure 1 also shows an (even more dramatic) upward shift in capital income share.

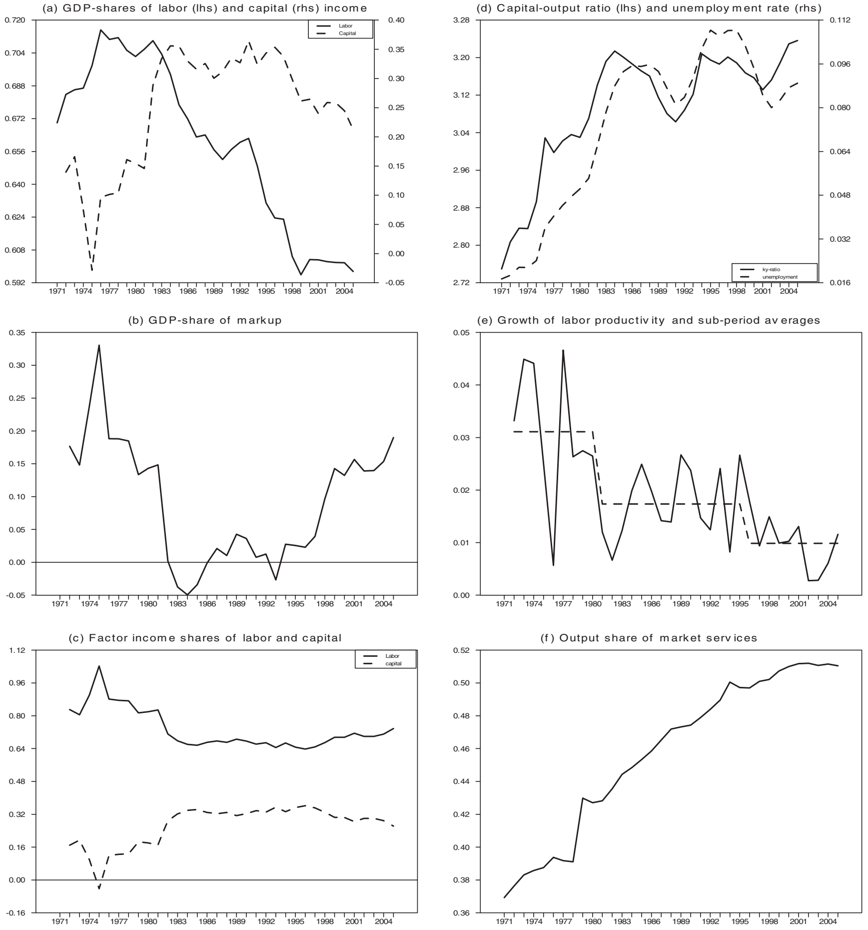


**FIGURE 1.** Stylized features of euro-area development. *Notes:* Components in panels (a) and (b) sum to unity; panel (c) components sum to unity. Capital income $= qK$, where $K$ is the capital stock and $q$ is the marginal product (or *user cost* or *opportunity cost*) of a unit of capital (e.g., some measure of the real interest rate plus depreciation). Labor income $=$ $wN$: average compensation per employee times number of employees. Labor's GDP income share and factor income share are, respectively, $w_tN_t/p_tY_t$ and $w_tN_t/(w_tN_t+q_tK_t)$, where $p_tY_t = (1+\mu_t)[w_tN_t + q_tK_t]$, and equivalently for capital.

The capital share appears implausibly low through the whole 1970s ($\approx$10%), even being temporarily negative around the first oil shock, with a striking upward level shift in early 1980s. Thereafter, especially since 1997, it has declined (this odd dynamic, as we shall see, reflects measurement errors associated with the interest rate used to define capital income).

Almost as a mirror image of the GDP share of capital income, the profit share (or the GDP share of the markup) (Panel B)[6] (i.e., nominal income minus "labor share" minus "capital share" divided by nominal income: see Sections 3.1 and 4 for further details on data concepts, as well as the note after Figure 1) appeared to follow a U shape: high in the 1970s, strongly decreasing toward the beginning of the 1980s, and then widening again.[7]

In contrast, Panel C presents capital and labor not as GDP shares but as shares of total factor income (again see the note after Figure 1 for definitions). Although the capital income share resembles its GDP-share profile, that of labor differs dramatically. The labor share of total factor income, after temporarily absorbing all factor income (following the first oil shock), decreases in the 1970s, levels off in the 1980s, and starts rising moderately in the mid-1990s.

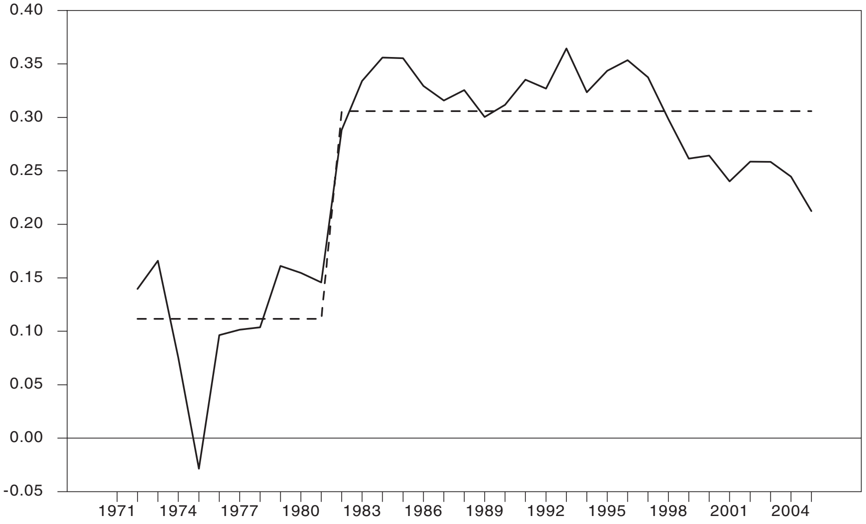
The more straightforward capital–output ratio, Panel D, also shows a nonstationary pattern: it rises rapidly until the early 1980s, dips in the early 1990s, and then increases again. Unemployment shows a remarkably similar profile.

Panel E shows the well-known [e.g., Gomez-Salvador et al. (2006)] progressive deterioration of euro-area productivity, with sizable regime shifts in the early 1980s and mid-1990s. Of particular interest is the late 1990s, when many other countries—e.g., the United States—by stark contrast enjoyed a productivity boom.

In general, unbalanced growth represents a situation in which economic growth is faster in some segments of the economy than in others. Indeed, Panel F shows that through the sample the production structure of the euro-area economy was changing from more competitive manufacturing sectors toward less competitive services.[8]

As regards the apparent level shifts in capital income, as Figure 2 indicates, they reflect corresponding shifts in the real interest rate. For most of the 1970s, the real rate was apparently negative, which, in perfectly functioning capital markets, should have offered considerable profit opportunities. However, it is well known that financial markets then were heavily regulated.[9] Removal of those regulations (from the early 1980s) coincides extremely well with the level shift in the real interest rate.

This casts doubt on whether, in an imperfectly functioning financial market, the observed government bond rate [as conventionally utilized in the calculation of firms' financing costs, e.g., Jorgensen and Yun (1991)] correctly captured firms' marginal financing cost during this period; there might have been strong incentives for interfirm credit markets, where (in the bank lending markets) unconstrained firms lend to constrained ones. This would in practice have *raised* the required rate of return of investment above the observed rate both for the lending and for the borrowing firms. Consequently, the real observed "user cost" (and the GDP share of capital income) would have been above that indicated—where a simple measure of the user (or opportunity) cost of capital is the real interest plus depreciation. With an accordingly higher capital share in the 1970s, the "true" markup would instead follow an *upward* trend since the 1970s, instead of a U-shape. Such a


(a) GDP-share of capital income (reprod. from Fig. 1a) and sub-period averages

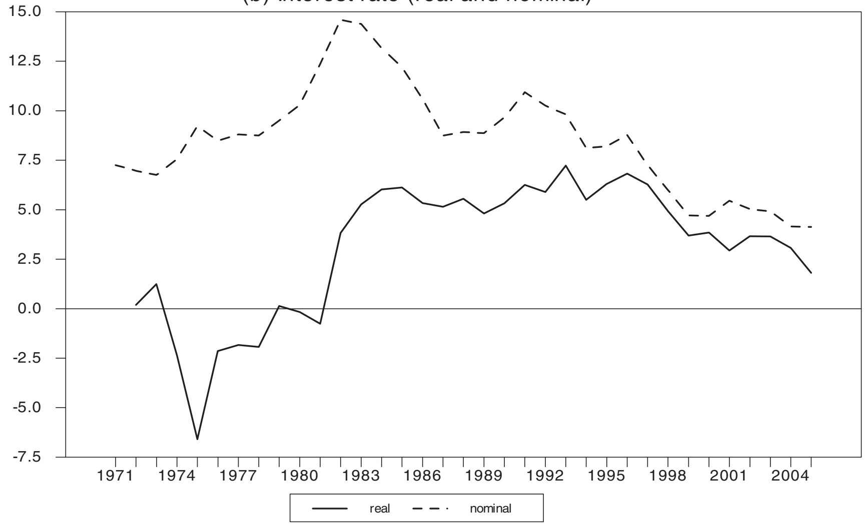

(b) Interest rate (real and nominal)

**FIGURE 2.** Capital income share and interest rate.

trend would mimic that in Panel F, namely following the expansion of services industries. Our framework accounts for this possibility by allowing in estimation the "observed" and de facto user cost to differ in the 1970s and merging them upon financial deregulation.

## 2.2. The Economics of Technical Change: Some Background

Neoclassical growth models assume that output is determined by factor accumulation and technical change (learning, new ideas, new procedures). Though technical change was always understood to reflect purposeful economic decisions, its specification was nonetheless kept exogenous. Since then, a substantial literature has arisen to address the issue of how technical change may be endogenized and linked to the optimizing decisions of agents. Typical themes include increasing labor-augmenting technical change by learning-by-doing [Arrow (1962)] and variety or quality improvements from R&D activities funded by monopoly rents [Romer (1990)] with consequent knowledge spillovers.[10]

Moreover, Acemoglu (2002a) [extending Hicks (1932), Kennedy (1964), and Samuelson (1965)] suggested that—irrespective of whether technical change results from expanding varieties of goods or quality improvements—three effects can be identified as determining the direction of technical change. First, a *price effect* increases the returns from improving productivity of scarcer factors and hence from allocating more resources (e.g., factor-augmenting technologies; targeted R&D) toward the scarce factor. Second, a *market-size effect* increases the improving productivity of more abundant factors and therefore of allocating more resources that favor the more abundant factor input (again reflecting factor-augmenting technologies and targeted R&D). Finally, *state dependency* occurs in factor-augmenting and R&D activities (i.e., current R&D activities depend on past ones and expected returns from future ones). The price effect dominates the market size effect if factors are gross complements, such that technical change will be biased toward the scarcer factor.

These concepts will be taken up more formally in the following section. An important point to stress here, though, is that our interest is in the *measurement* of factor-augmenting technical change and its congruence with models of directed technical change. Many studies [e.g., Caballero and Jaffe (1993); Alexopoulos (in press)] have tried to link technical change to indicators such as patent registration, R&D expenditures, and technical literature diffusion. Given the lags involved in the innovation process and the measurement errors associated with these indicators, such analysis can be empirically fragile. Accordingly, our purpose is a little different. We try to disentangle the effects of technical change by carefully following the metrics indicated by models of directed technical change. We carefully define the evolution of factor prices in the euro area and the nature of aggregate market production and substitutability, and model growth in technical progress in a smooth but time-varying manner.

## 2.3. The CES Function and Factor-Augmenting Technical Change

The factor-augmenting CES production function defining supply takes the form

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

where $Y_t$ represents real output, $K_t$ is the real capital stock, and $N_t$ is the labor input. $\pi \in (0, 1)$ reflects capital intensity in production and the elasticity of substitution is given by the percentage change in factor proportions due to a change in the factor price ratio along an isoquant:

$$\sigma \in [0, \infty] = \frac{d\log(K/N)}{d\log(F_N/F_K)}. \tag{2}$$

CD arises when $\sigma = 1$; Leontief (i.e., fixed factor proportions) when $\sigma = 0$; and a linear production function (i.e., perfect factor substitutes) when $\sigma \to \infty$. When $\sigma < 1$, factors are gross complements in production, and gross substitutes otherwise.

$\Gamma_t^i = \Gamma_0^i e^{\gamma_i \cdot t}$ captures technical progress where $\gamma_i$ denotes growth in technical progress associated with factor *i,* and *t* represents a time trend. $\gamma_K = \gamma_N > 0$ denotes Hicks-neutral technical progress; $\gamma_K > 0, \gamma_N = 0$ yields Solow neutrality; $\gamma_K = 0, \gamma_N > 0$ represents Harrod neutrality; and $\gamma_K, \gamma_N > 0$ but $\gamma_K \neq \gamma_N$ indicates factor-augmenting technical progress.

Assuming competitive markets and profit maximization, relative factor income shares and relative marginal products are (omitting the time subscript)

$$\Theta = \frac{qK}{wN} = \frac{\pi}{1-\pi}\left(\frac{\Gamma^K}{\Gamma^N}\frac{K}{N}\right)^{\frac{\sigma-1}{\sigma}} \tag{3}$$

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

where $q$ and $w$ denote the "user cost" (or marginal productivity) of capital and the real wage, respectively (Section 4 discuss data definitions more formally). We see straightforwardly that the effect of technical bias and capital deepening on these margins is related to whether factors are gross complements or not:[11]

$$\text{sign}\left\{\frac{\partial\iota}{\partial(\Gamma^K/\Gamma^N)}\right\}, \text{sign}\left\{\frac{\partial\Theta}{\partial(K/N)}\right\}, \text{sign}\left\{\frac{\partial\Theta}{\partial(\Gamma^K/\Gamma^N)}\right\} = \text{sign}\{\sigma - 1\}.$$

Accordingly, consider the following

Remark. An increase in labor-augmenting technical change "favors" labor (i.e., implying

$$\frac{\partial(F_N/F_K)}{\partial(\Gamma^N/\Gamma^K)} > 0$$

and raising labor's income share, $\frac{wN}{Y}$, for given factor proportions) if labor and capital are gross substitutes ($\sigma > 1$). The effects reverse if they are gross complements.

It is known that labor share in the euro area rose after first oil crisis. Concentrating on the gross-complements case, and exploiting equations (3) and (4) and the

Remark, the conditions for such a rise (fall) in the labor (capital) factor income share are as follows:

(i) $\dot{K}/K > \dot{N}/N$: Capital deepening increases (equivalently, capital becomes the relatively more abundant factor).
(ii) $\gamma_K > \gamma_N$: Technical progress becomes relatively more capital-saving.

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

$$\log\left(\frac{K_t}{N_t}\right) = \varphi(\sigma, \pi) + \sigma \cdot \log\left(\frac{w_t}{q_t}\right) + (\gamma_N - \gamma_K) \cdot (1 - \sigma) \cdot t. \qquad \textbf{(5)}$$

Capital deepening thus 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 net labor-augmenting. Under CD, capital deepening is driven solely by relative factor prices.

Biased technical change (ii) may be exogenous or the result of firms' profit incentives and innovation possibilities; as discussed in Acemoglu (2002a), the relative profitability of different technologies depends on the "market effect" (the factor ratio) and a "price effect" (relative technical improvements).[12] An increase in the proportions of factor A relative to factor B (given gross complements [substitutes]) will lower [raise] the profitability of technical improvements associated with factor A.

Making a priori assumptions about technical progress (i.e., imposing Hicks neutrality, exponential growth rates) is likely to cause misinterpretation of the contribution of technical change to income shares and production developments: Antràs (2004), León-Ledesma et al. (2010b). Given these conceptual uncertainties, we follow an agnostic approach by extracting technical progress in a flexible, data-oriented manner. Further, we apply de La Grandville's (1989) "normalization" methodology in a supply-side system, which turns out to be particularly convenient for analyzing technical biases [León-Ledesma et al. (2010a)].[13]

## 3. THE MODEL

We now study the intertemporal maximization problem of the representative (monopolistically competitive) firm, admitting a transitory role for financial restrictions. This is needed because (a) otherwise capital shares (and the markup) for euro-area economies in the 1970s are implausible low (implausible high); (b) the leap in capital share in the late 1980s clearly mirrors the fading of financial regulation; and, as we show later, (c) we witness a substantial improvement in supply estimation given its inclusion.

### 3.1. Maximization with Borrowing Constraints

Our framework is a close variant of Hubbard and Kashyap (1992) and Hubbard et al. (1995). We extend it by admitting an interfirm credit market. Besides increasing the realism of the framework, this extension solves the aggregation problem that regulation otherwise creates.[14] Accordingly, to mimic bank-centered financial markets in Europe, the only assumed sources of external financing are bank loans and, if the bank lending rate is regulated, the unregulated interfirm credit market. Naturally, in the latter, aggregation across firms implies that $\sum_{i=0}^{n} S_{it} = 0$, where $S_{it}$ denotes a firm $i$ one-period net credit from the interfirm credit market and $n$ is the number of firms. The sign of $S_{it}$ is positive (negative) if firm $i$ is a net debtor (creditor).

Define the demand function (solved for the price $P_{it}$) faced by a firm $i$ as

$$P_{it} = P_t \left( \frac{Y_{it}}{Y_t} \right)^{-\frac{1}{\varepsilon_i}} Y_t,$$

where $Y_{it}$ refers to the output of firm $i$ and $P_{it}$ to its price level. Variables $Y_t$ and $P_t$ refer to the corresponding aggregate level variables and $\varepsilon_i > 1$ denotes the price elasticity of demand.

Now real dividends ($D_{it}$) of a firm $i$ in terms of investment good are

$$D_{it} = \underbrace{p_t \left( \frac{Y_{it}}{Y_t} \right)^{-\frac{1}{\varepsilon_i}}}_{p_{it}} Y_{it} - w_t N_{it} - K_{it} + (1-\delta) K_{i,t-1} + B_{it}$$
$$- (1 + r_{t-1}) B_{i,t-1} + S_{it} - (1 + r_{t-1} + \kappa_{t-1}) S_{i,t-1}, \tag{6a}$$

where $p_t$ is the real price of aggregate output, $p_{it}$ the real price of firm $i$'s good, and $w$ the real wage rate (all in terms of the price of investment good), $\delta$ is the depreciation rate, $B_i$ is real one-period bank loans, $r$ is the real (possibly regulated) bank lending rate, and $r + \kappa$ is the real interest rate of the interfirm credit market. With bank loans and interfirm loans as perfect substitutes, it is clear that the interest spread $\kappa$ can deviate from zero only if firms face a binding, though possibly firm-specific, borrowing constraint $\overline{B}_i$ in the bank loan market.

The maximization problem of a firm $i$ in terms of the present discounted value of the real dividend stream is

$$\text{Max } V_t = E_t \sum_{s=0}^{\infty} \left[ \prod_{j=0}^{s} \beta_{ij} \right] \big\{ D_{i,t+s} + \Lambda_{i,t+s}^{F} [F(K_{i,t+s}, N_{i,t+s}) - Y_{i,t+s}]$$
$$+ \Lambda_{t+s}^{B} (\overline{B}_{i,t+s} - B_{i,t+s}) \big\}, \tag{6b}$$

where $\beta_{ij}$ is the firm's one-period discount factor and $\Lambda_{it}^{F}$ and $\Lambda_{it}^{B}$ are, respectively, Lagrange multipliers associated with the production and borrowing constraints.

Assuming that the transversality condition preventing the firm from borrowing an infinite amount holds, the optimality conditions with respect to the indicated variables are (with the relevant Kuhn–Tucker conditions)

$$\partial V_t/\partial Y_{it} = p_{it}(1+\mu_i)^{-1} - \Lambda_{it}^F = 0 \tag{7}$$

$$\partial V_t/\partial N_{it} = \Lambda_{it}^F F_{N_{it}} - w_t = 0 \tag{8}$$

$$\partial V_t/\partial K_{it} = E_t\{\beta_{i,t+1}(1-\delta)\} + \Lambda_{it}^F F_{K_{it}} - 1 = 0 \tag{9}$$

$$\partial V_t/\partial S_{it} = E_t\{\beta_{i,t+1}(1+r_t+\kappa_t)\} - 1 = 0 \tag{10}$$

$$\partial V_t/\partial \Lambda_{it}^F = F(K_{it}, N_{it}) - Y_{it} = 0 \tag{11}$$

$$\partial V_t/\partial B_{it} = 1 - E_t(\beta_{i,t+1}(1+r_t)) - \Lambda_{it}^B \leq 0;\ B_{it}(\partial V_t/\partial B_{it}) = 0 \tag{12}$$

$$\partial V_t/\partial \Lambda_{it}^B = \overline{B}_{it} - B_{it} \geq 0;\ \Lambda_{it}^B \geq 0;\ \Lambda_{it}^B\left(\partial V_t/\partial \Lambda_{it}^B\right) = 0, \tag{13}$$

where

$$\mu_i = \frac{1}{\varepsilon_i - 1} \geq 0$$

represents the markup over costs. Utilizing (7), equations (8) and (9) imply

$$p_{it} = (1+\mu_i)\frac{w_t}{F_{N_{it}}} \tag{14}$$

$$p_{it} = (1+\mu_i)\frac{1-(1-\delta)E_t\beta_{i,t+1}}{F_{K_{it}}}. \tag{15}$$

Equations (14) and (15) define the profit-maximizing price as markups of the marginal costs of labor and capital. The latter equation contains the discount factor, $E_t\beta_{i,t+1}$, which can be solved from condition (10),

$$\beta_{i,t+1} = \frac{1}{1+r_t+\kappa_t}. \tag{16}$$

Note that $r_t$ and $\kappa_t$ are considered exogenous to the firm, because our partial equilibrium framework does not separately determine the interest rate faced by the firm. However, if the firm's problem is to maximize its present value, then (16) must be assumed to hold and the discount factor will be tied to the inverse of the real market rate in this optimization framework. If the firm uses some other values, then it violates the requirements of present-value maximization.

This is fully compatible with the determination of the discount factor with perfectly functioning capital markets; see, e.g., Hubbard et al. (1995). The only difference from the conventional case is that the interfirm credit markets play the role of perfect capital markets so that, if the borrowing constraint is binding, i.e., in (13) $\partial V_t / \partial \Lambda_{it}^B = 0$ and, hence, $\Lambda_{it}^B > 0$, the equilibrium interest rate is determined in the interfirm credit markets. In addition, as the right-hand side of (16) is the same for all firms, then $\beta_{i,t+1} = \beta_{t+1} \; \forall i$, and on the basis of (12) and (13) we also have

$$\Lambda_{it}^B = \Lambda_t^B = \frac{\kappa_t}{1 + r_t + \kappa_t}.$$

Hence, if the interest spread $\kappa_t > 0$ then the bank borrowing constraint is binding (or vice versa) for all firms; otherwise no firm is constrained.[15] In our theoretical framework, the constraint may or may not bind. However, in our later empirical application, we assume that it binds by definition over the period of financial regulation ($\kappa_t > 0$).

Now the numerator of the right-hand side of (15) defines the user cost as the approximation

$$q_t = 1 - (1 - \delta)\beta_{t+1} \approx \underbrace{\frac{r_t + \delta}{1 + r_t}}_{q_t^{obs}} + \underbrace{\frac{\kappa_t}{1 + r_t + \kappa_t}}_{\Lambda_t^B = \tilde{\kappa}_t},$$

as the sum of an observed and (for the econometrician) an unobserved component. Importantly, however, $q$ (and $w$) is the same for all firms. Therefore, the homogeneity of the production function and conditions (14) and (15) imply that the capital intensity, the average and the marginal productivity of labor, and the marginal productivity of capital are equal across firms.

Under the assumption that the price elasticity of demand is common across firms (i.e., $\mu_i = \mu$), it is straightforward to show that the following three-equation system holds also at the macro level:

$$\frac{w_t N_t}{p_t Y_t} = \frac{1}{1 + \mu} \frac{N_t}{Y_t} F_{N,t} \tag{17}$$

$$\frac{\left(q_t^{obs} + \tilde{\kappa}_t\right) K_t}{p_t Y_t} = \frac{1}{1 + \mu} \frac{K_t}{Y_t} F_{K,t} \tag{18}$$

$$Y_t = F(K_t, N_t, \cdot). \tag{19}$$

Equation (17) equates the real wage with the marginal product of labor divided by the markup factor. Given our focus on tracking medium-run income share developments, we multiplied both sides by $N_t / Y_t$, turning this into an expression for the labor income share. Likewise, (18) is the marginal product of capital (cum capital shares) equation. However, the left-hand side of (18) is not directly observable from the data, given the correction, $\tilde{\kappa}_t$, to the user cost. We return to this issue in the context of estimation in Section 4. Equation (19) is the production function. The explicit normalized estimation form of these equations will be presented in Section 4.3.

It is now easy to see that under credit rationing in the bank-loan market, the markup in terms of observed variables gives an upward biased estimate of the markup (or profit) component of total income. Utilizing Euler's theorem, $Y \equiv F_N N + F_K K$, (17)–(19) imply

$$(1+\mu) = \frac{p_t Y_t}{w_t N_t + \underbrace{\left(q_t^{obs} + \tilde{\kappa}_t\right)}_{q_t} K_t}. \tag{20a}$$

This shows that if, in the period of credit rationing, $\tilde{\kappa}_t$ is incorrectly assumed to equal zero, then user-cost measures based only on observed data result in underestimation of the capital income and overestimation of the markup share.

In addition, the assumption $\mu_i = \mu$ is not necessary for the system (17)–(19) to hold at the aggregate level. In that case, however, the aggregate level markup, $1 + \mu_t^A$, is with the output shares, $s_{it} = Y_{it}/Y_t$, a weighted average of firm-level markups, $\mu_i$:

$$1 + \mu_t^A = \sum_i s_{it}(1+\mu_i) = \underbrace{1 + \sum_i s_{i0}\mu_i}_{1+\mu_0^A} + \underbrace{\sum_j (s_{it} - s_{i0})\mu_i}_{\eta(t-\bar{t})}, \tag{20b}$$

where $1 + \mu_0^A$ refers to the value of the aggregate markup at the point of normalization (the sample average) and where $\eta(t - \bar{t})$ denotes the trend in the markup resulting from sectoral shifts in the economy. Output shares $s_{it}$ contain a trend component, if income elasticity of demand for some goods (e.g., services) is above unity, whereas it is below unity for other or some other goods. Now, if $\mu_i \neq \mu_j$, this also introduces a trend into the aggregate level markups. This corresponds to a situation of economywide unbalanced growth, where firms and sectors may grow at different rates (recall Panel F, Figure 1).

## 3.2. Time-Varying Factor Augmenting Technical Progress and the Medium Run

Neoclassical growth theory 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., CD) or technical change be Harrod-neutral. Under CD, in turn, the direction of (or bias in) technical change is irrelevant to income distribution.

The pronounced trends in factor-income distribution witnessed in many countries[16] support the more general CES function and raise the importance of biases in technical progress. For CES, a steady state with constant factor-income shares is only possible if technical progress is labor-augmenting. Acemoglu (2002a) was able to derive this same result in a model with endogenous innovative activities, but demonstrated that transitory capital-augmenting progress can be expected from endogenous changes in the direction of innovations.

Earlier work on CES functions tended to assume constant technical growth. However, given these debates, it is not obvious that growth rates should be constant. The question becomes how this nonconstancy can be uncovered from the data in a tractable manner. Klump et al. (2007) proposed the use of a highly flexible functional form for $\Gamma_i$ based on the Box–Cox transformation: $\Gamma_i = e^{g_i(t)}$, where

$$g_i(t) = \frac{\gamma_i}{\lambda_i}[t^{\lambda_i} - 1], \quad i = K, N.$$

The curvature parameter $\lambda_i$ determines the shape of technical progress: $\lambda_i = 1$ yields the (textbook) linear specification; $\lambda_i = 0$ a log-linear specification; and $\lambda_i < 0$ a hyperbolic one for technical progress. Thus if $\lambda_i \geq 0$, the *level* of technical progress associated with factor $i$ tends to infinity, but it is bounded otherwise. If $\lambda_i = 1$, the growth of factor $i$ augmenting technical progress is constant, but it tends asymptotically to zero from above for any $\lambda_i < 1$.

This framework allows the data to decide on the presence and dynamics of factor-augmenting technical change rather than being imposed a priori. If, for example, the data supported an asymptotic steady state, this would arise from the estimated dynamics of these curvature functions (i.e., labor-augmenting technical progress becomes dominant (linear), that of capital absent or decaying).

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

$$\gamma_N > 0, \quad \lambda_N = 1; \quad \gamma_K = \lambda_K = 0, \tag{21}$$

coupled with the assumption $\sigma >> 1$, corresponds to that drawn upon by Blanchard (1997) and Caballero and Hammour (1997) in explaining the decline in the labor income share in continental Europe. Nevertheless, the case for above-unity elasticity appears both empirically weak and theoretically anomalous.[17]

Another combination, which we speculatively term "Acemoglu-augmented" technical progress, can be represented as

$$\gamma_N, \quad \gamma_K > 0; \quad \lambda_N = 1, \quad \lambda_K < 1, \tag{22}$$

where $\sigma < 1$ is natural. Consider two cases within (22). A "weak" variant, $\lambda_K < 0$, implies that the contribution of capital augmentation to TFP is bounded, with its growth component returning to zero; in the "strong" case, $0 < \lambda_K < 1$, capital imparts a highly persistent contribution with (asymptotic 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, $\gamma_N$. The interplay between $|\gamma_N - \gamma_K|$ and $\lambda_N, \lambda_K$ can thus permit a wide variety of types of BGP divergence.

Summing up, our purpose is to allow the data to robustly identify historical developments in factor-augmenting technical progress and map it to changes in productivity and income shares. We do not attempt an additional modeling layer of firms' innovation frontiers or the like because, on macro data, this is largely unrealistic. We extract the series for technical change by exploiting forms flexible enough to capture the data but that nonetheless nest balanced growth. Having extracted these series, we then assess their dynamics in relation to models of directed technical change.

## 4. DATA AND ESTIMATION

Following Smets and Wouters (2003) and others, we model interactions in continental Europe using aggregate euro-area data from an updated version of the AWM database, Fagan et al. (2001).[18] In contrast to those studies, though, we use the full range of the data sample, 1970q1–2007q4.

### 4.1. Labor Income

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) and McAdam and Willman (2004) we used the aggregate wage rate as a shadow wage rate for the labor income component of self-employed workers. We also account for the fact that part of the self-employed were unpaid family workers, whose share has continuously decreased.[19] Hence, labor income was calculated using

$$W_t N_t = \left(1 + \mathrm{SOSR}_t + \frac{N_t^S - N_t^{UP}}{N_t^E}\right) W_t^E \cdot N_t^E, \qquad \mathbf{(23)}$$

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).

### 4.2. Capital Income

Capital income is calculated as the "user cost" (the real interest rate $r_t$ plus depreciation) times the capital stock. The interest rate is that on 10-year government bonds in the AWM data set. To retain compatibility with national accounting practices, which assume no net operating surplus in the government sector, the rate of return requirement on government sector capital was assumed to equal the depreciation rate. Accordingly, we calculated capital income as

$$\begin{aligned} q_t K_t &= P_t^I \left[ \frac{K_t^P}{K_t} \cdot \left( \underbrace{i_t - \pi_t}_{r_t} + \delta + \underbrace{\kappa \cdot \mathrm{Dum}_t}_{\tilde{\kappa}_t} \right) \right] K_t \\ &= q_t^{obs} K_t + \underbrace{\kappa \cdot \mathrm{Dum}_t}_{\tilde{\kappa}_t} \left( \frac{K_t^P}{K_t} \right) P_t^I K_t, \end{aligned} \qquad (\mathbf{24})$$

where $P^I$ is the investment deflator, $K^P/K$ is the private-to-total capital stock ratio, $i$ is the long-term nominal interest rate, and $\pi$ is the (GDP deflator) inflation rate.

In line with our discussion in Section 2.1, to account for the possibility that regulated euro-area interest rates did not correctly measure the marginal cost of financing in the 1970s, we assumed a correction to the measured interest rate during this period.[20] This—in line with our discussion in Section 3.1—is interpreted as the shadow rate of bank loans or the rate equilibrating the unregulated interfirm credit market. The quantity

$$\mathrm{Dum}_t = 1 - \frac{1}{1 + e^{2-0.25(t-t^{mid})}},$$

is a smooth, sigmoid level-shift relation equaling around unity in the early 1970s and converging to zero around the mid-1980s[21] (with most of the shift concentrated in 1978–1982), where $t^{\mathrm{mid}}$ is the midpoint of the transition period of financial deregulation. Our choice of a sigmoid specification reflects the fact that aggregating over the euro area, there was a staggered experience of financial liberalization across countries, and, before legal deregulation, there were various “leakages” of the financial system.

Though estimated separately for each specification variant, parameter $\kappa$ is relatively stable. As demonstrated in Section 5, the presence of this correction markedly improves results and interpretation. Estimation, though, would be essentially unaffected if instead of a smooth form we imposed a step dummy (though with the latter individual equation, $R^{2\prime}$s and system log determinants would deteriorate slightly).

Measures of the capital user costs may also be supplemented with certain fiscal components. There are, however, no reliable tax data available for the euro area to address that question adequately, and thus we follow Smets and Wouters (2003) and omit these effects.[22] Capturing the historical user cost of capital in the aggregated euro area from the 1970s onward with appropriate corrections for capital taxes and offsets in allowances and depreciations would be a valuable but difficult task. Our analysis of selected EMU countries (the big five) suggests, however, that such factors were unlikely to play a decisive role in determining the phenomena of interest. They would likely add a *level* component into the accounting framework. Such a neglected level effect in the definition of user cost may lead to some bias in the estimation of the value of the markup, but almost certainly not in the time-series properties of our income shares, productivity profile, or markup component. Similarly, the user cost may be supplemented by some measure of firms' premium over the policy rate, although, as Lombardo and McAdam's (in press) euro-area calculations show, this has typically been relatively small and tends to co-move closely with the bond rate.

## 4.3. Estimation System

Our estimated system consists of, in addition to equations (17)–(19), the aggregate markup equation (20b) to identify the trend in its development. If the aggregate markup were constant, this last equation would not introduce any value-added into the system and could be excluded [Klump et al. (2007) did so in their estimation on the U.S. data]. For the euro area, where the observed markup is nonstationary, it offers a useful condition for identifying correctly and separating the trend in the aggregate markup from the two technical progress components driving the system.

As in Klump et al. (2007), we use the normalized CES production function with Box–Cox technical progress,

$$\frac{Y_t}{\overline{Y}} = \zeta\left[\pi\left(e^{\frac{\bar{t}\gamma_K}{\lambda_K}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_K}-1\right)}\frac{K_t}{\overline{K}}\right)^{\frac{\sigma-1}{\sigma}} + (1-\pi)\left(e^{\frac{\bar{t}\gamma_K}{\lambda_K}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_K}-1\right)}\frac{N_t}{\overline{N}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \qquad \textbf{(25)}$$

where the point of normalization is expressed in terms of the geometric averages of output, $\overline{Y}$, capital input, $\overline{K}$, and labor input, $\overline{N}$, and $\bar{t}$ corresponds to the middle value of the time variable in the sample. The parameter $\zeta$ is a normalization constant, whose expected value is around unity. An important implication of normalization is that the distribution parameter $\pi$ has a clear data-based interpretation. It corresponds to the capital income share of total factor income at the point of normalization. Therefore, it can either be prefixed before estimation or, alternatively, the sample average can be used as a very precise initial value of the distribution parameter. In our estimation, the latter was adopted, although it turned out that estimation results were largely insensitive either way.

Accordingly, our estimated system (corresponding to that described in Section 3.1) is

$$\log\left(\frac{w_t N_t}{p_t Y_t}\right) = \frac{1-\sigma}{\sigma}\left[\log\left(\frac{Y_t/\overline{Y}}{N_t/\overline{N}}\right) - \log\zeta - \frac{\bar{t}\gamma_N}{\lambda_N}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_N} - 1\right)\right]$$
$$-\log\left(\frac{1+\mu_A}{1-\pi}\right) - \eta(t-\bar{t}) \qquad \textbf{(17}'\textbf{)}$$

$$\log\left(\frac{\left(q_t^{obs}+\tilde{\kappa}_t\right)K_t}{p_tY_t}\right)=\frac{1-\sigma}{\sigma}\left[\log\left(\frac{Y_t/\overline{Y}}{K_t/\overline{K}}\right)-\log\zeta-\frac{\bar{t}\gamma_K}{\lambda_K}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_K}-1\right)\right]$$
$$-\log\left(\frac{1+\mu_A}{\pi}\right)-\eta(t-\bar{t})=0 \qquad \textbf{(18}'\textbf{)}$$

$$\log\left(\frac{Y_t/\overline{Y}}{N_t/\overline{N}}\right)=\log(\zeta)-\frac{\bar{t}\gamma_N}{\lambda_N}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_N}-1\right)$$
$$-\frac{\sigma}{1-\sigma}\log\left[\pi e^{\frac{1-\sigma}{\sigma}\left[\frac{\bar{t}\gamma_N}{\lambda_N}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_N}-1\right)-\frac{\bar{t}\gamma_K}{\lambda_K}\left(\left(\frac{t}{\bar{t}}\right)^{\lambda_K}-1\right)\right]}\left(\frac{K_t/\overline{K}}{N_t/\overline{N}}\right)^{\frac{\sigma-1}{\sigma}}+(1-\pi)\right] \qquad \textbf{(19}'\textbf{)}$$

$$\log\left(\frac{p_tY_t}{w_tN_t+q_t^{obs}K_t}\right)$$
$$=\left[\log\left(1+\mu_A\right)+\eta\left(t-\bar{t}\right)+\log\left(1+\tilde{\kappa}_t\frac{K_t}{w_tN_t+q_t^{obs}K_t}\right)\right], \qquad \textbf{(20}'\textbf{)}$$

Equation (17′) represents the explicitly normalized equation for the (log) labor factor income share. This is a function of labor productivity, labor-augmenting technical progress, and the aggregate markup. The latter, as noted earlier, has an aggregate and time-varying component. Likewise, (18′) represents the explicitly normalized equation for the (log) capital factor income share. This is a function of capital productivity, capital-augmenting technical progress, and the aggregate markup component. Equation (19′) represents the (log) production function, expressed in intensive form for convenience. Finally, (20′) solves for the aggregate markup.

## 5. RESULTS

Table 1 shows results for the estimation of the supply-side system (17)–(20): technical parameters ($\gamma_N$; $\gamma_K$; $\sigma$), factor-augmenting Box–Cox curvature parameters ($\lambda_N$; $\lambda_K$),the marginal financing parameter ($\kappa$), and the (average and time-varying) markup components ($1+\mu_A$) and $\eta\cdot t$.

We then report (fixed point) TFP growth; residual stationarity; the system metric (the log determinant); and, where applicable, tests for linear and logarithmic technical change dynamics and for measures of conventional technical neutrality. To generate TFP estimates in the presence of *biased* technical progress we do not use the (Hicks-neutral) Solow residual, but instead generalize Kmenta (1967) to the factor-augmenting case (details available). In terms of analyzing how well our

**TABLE 1.** Supply-side estimates, 1971:1–2007:4

| | A | | B | | C | |
|---|---|---|---|---|---|---|
| | CD* | CES | CD* | CES | CD* | CES |
| | Benchmark | | A + Financing regulation | | B + Break in technical progress | |
| $\zeta$ | 1.0206 | 1.0304 | 1.0170 | 1.0142 | 1.0131 | 1.0112 |
| | (0.0016) | (0.0016) | (0.0014) | (0.0039) | (0.0012) | (0.0013) |
| $\gamma_N$ | 0.0036 | 0.0107 | 0.0036 | −0.0002 | 0.0042 | 0.0037 |
| | (0.0000) | (0.0026) | (0.0000) | (0.0005) | (0.0001) | (0.0001) |
| $\lambda_N$ | 0.4580 | 1.1030 | 0.5356 | 0.9051 | 0.8737 | 1.4617 |
| | (0.0185) | (0.0394) | (0.0222) | (0.0724) | (0.0304) | (0.0779) |
| $\gamma_{N,t>1997}$ | — | — | — | — | −0.0031 | −0.0098 |
| | | | | | (0.0006) | (0.0010) |
| $\lambda_{N,t>1997}$ | — | — | — | — | 02776 | −1.8655 |
| | | | | | (1.3586) | (0.7042) |
| $\gamma_K$ | — | −0.0174 | — | 0.0086 | — | 0.0016 |
| | | (0.0068) | | (0.0012) | | (0.0002) |
| $\lambda_K$ | — | 1.4626 | — | 0.9051 | — | 0.1426 |
| | | (0.2466) | | (0.0724) | | (0.0918) |
| $\gamma_{K,t>1997}$ | — | — | — | — | — | 0.0112 |
| | | | | | | (0.0012) |
| $\lambda_{K,t>1997}$ | — | — | — | — | — | −1.8655 |
| | | | | | | (0.7042) |
| $\sigma$ | 1 | 0.8749 | 1 | 0.7776 | 1 | 0.6293 |
| | | (0.0400) | | (0.0211) | | (0.0101) |
| $\pi$ | 0.2842 | 0.2762 | 0.3285 | 0.3138 | 0.3328 | 0.3227 |
| | (0.0050) | (0.0051) | (0.0019) | (0.0043) | (0.0016) | (0.0019) |
| $\kappa$ | — | — | 0.0204 | 0.0272 | 0.0218 | 0.0279 |
| | | | (0.0004) | (0.0008) | (0.0004) | (0.0005) |
| $1+\mu_A$ | 1.0851 | 1.0907 | 1.0192 | 1.0358 | 1.0125 | 1.0327 |
| | (0.0078) | (0.0073) | (0.0032) | (0.0065) | (0.0027) | (0.0028) |
| $\eta$ | 0.0015 | 0.0006 | 0.0015 | 0.0027 | 0.0015 | 0.0027 |
| | (0.0000) | (0.0002) | (0.0000) | (0.0001) | (0.0000) | (0.0001) |
| TFP growth$^a$ | 0.0026 | 0.0030 | 0.0024 | 0.0026 | 0.0028 | 0.0030 |
| | | | **Parameter restrictions** | | | |
| $\lambda_N = 1$ | [0.0000] | [0.0140] | [0.0000] | —$^b$ | [0.0000] | [0.0000] |
| $\lambda_K \approx 0^c$ | — | [0.0000] | [0.0000] | — | — | [0.0965] |
| $\lambda_N = 1, \lambda_K \approx 0$ | — | [0.0000] | — | — | — | [0.0000] |
| | | | **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] |

**TABLE 1.** Continued

| | A | | B | | C | |
|---|---|---|---|---|---|---|
| | CD* | CES | CD* | CES | CD* | CES |
| | Benchmark | | A + Financing regulation | | B + Break in technical progress | |
| Hicks modified: | | | | | | |
| $\gamma_N = \gamma_K$, $\lambda_N = \lambda_K$ | — | [0.0000] | — | — | — | [0.0000] |
| Solow: | | | | | | |
| $\gamma_N = \lambda_N = 0$, $\lambda_K = 1$ | — | [0.0000] | | [0.1440] | — | [0.0000] |
| | | | **Stationarity** | | | |
| AD$F_{\text{MK-up}}$ | −2.615 | −2.793 | −4.025 | −4.593 | −4.021 | −4.763 |
| AD$F_N$ | −2.959 | −2.688 | −2.938 | −2.534 | −2.974 | −4.246 |
| AD$F_{cKn}$ | −3.939 | −4.230 | −3.999 | −4.232 | −4.025 | −4.888 |
| DF$_{Y/N}$ | −2.771 | −2.230 | −2.574 | −2.565 | −3.743 | −4.074 |
| Log determinant | −23.12 | −23.90 | −31.28 | −32.38 | −31.78 | −33.76 |

*Notes:* Standard errors in parenthesis, *p*-values in squared brackets, "—" denotes nonapplicable.

[a] TFP growth at the point corresponding to the sample averages (the fixed point).

[b] In this case, we found $\lambda_N$ and $\lambda_K$ not to be significantly different. We therefore imposed the constraint of equality.

[c] Wald test of the restriction $\lambda_K = -0.01$, which, within our sample, approximated a logarithmic function closely enough, because $\lambda_K = 0$ strictly renders the equation indeterminate.

*Technical progress estimates correspond to Hicks-neutral representation.

estimated system matches the data, we follow Krusell et al. (2000) by comparing the predictions of our system with the data.

In estimation, we use a generalized nonlinear least squares (GNLLS) estimator that is equivalent to a nonlinear SUR model, allowing for cross-equation error correlation. As shown in the Monte Carlo study of León-Ledesma et al. (2010b), this estimator is able (unlike single-equation estimators) to identify unbiasedly both the SE and factor-augmenting technical progress parameters. Because nonlinear estimation can be sensitive to initial parameter conditions, we varied parameters individually and jointly around plausible supports to ensure global results (details available). Standard errors in Table 1 are heteroskedasticity- and autocorrelation-consistent.

We estimate in three incremental blocks and within each block we estimate a supply-side system based on CD *and* CES technology. For CD, to retain comparability with the corresponding CES estimates,[23] we treat technical progress as degenerating to Harrod neutrality [Acemoglu (2009)]. In all cases technical progress is estimated using the flexible Box–Cox form. In the benchmark Case A, we omit the effects of financial regulation on the user cost of capital in the 1970s. This is then introduced in Case B. Finally, Case C incorporates case B plus a structural break in technical progress in the late 1990s (recall its importance from Figure 1, panel E).[24] Selected graphical representations of these A, B, and C cases are represented in Figures 3–5.

Overall, the (freely estimated) SE appears to be well below unity (around 0.6 in our preferred case);[25] annual TFP growth is just over 1% and the empirical importance of financial regulation, $\kappa$, is robustly confirmed. Most forms of conventional technical neutrality are rejected. Finally, the CES system always statistically dominates the CD cases, and the fit of the former improves as we move from Cases A to C.[26] We now discuss each in turn.

## 5.1. Case A: Time-Variation in Markup and Technical Progress

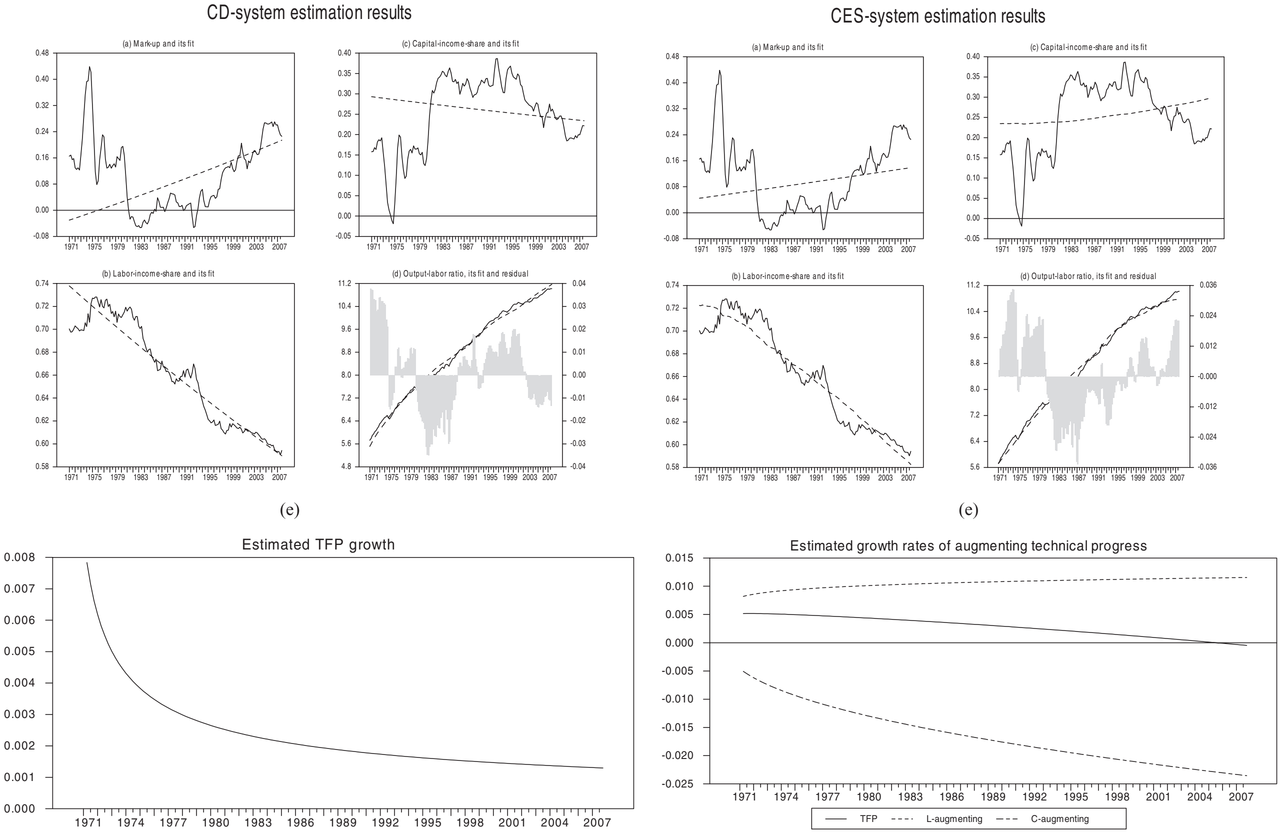
Looking at the A columns of Table 1 and the corresponding Figure 3, we can conclude the following. Both CD and CES supply sides are unable to explain level shifts in the markup and capital income share. Trend developments of labor income share and production are unsatisfactorily explained, as is the hump in the labor share in the 1970s, and the production function residuals are nonstationary. The production function residuals should reflect variation in factor intensities (i.e., in capacity utilization) and thus business cycles. However, both the CD and the CES residuals imply too persistent overutilization in the 1970s, underutilization in the 1980s and (for the CES) the early 1990s, and overutilization in the 1990s for the CD and since the latter part of the 1990s for the CES.

In both cases (CD and CES), consistent with observed average labor productivity, the estimate of TFP growth decelerates over the sample. In the latter, we are able to identify both labor and capital augmentation. The estimated TFP development is obtained by slightly accelerating labor augmentation and negatively accelerating capital augmentation. Although the realism of this latter development is questionable, it can easily be interpreted in terms of the observed data. The low real user cost (when defined in terms of observable variables) in the 1970s implies that the growth of the capital-augmenting technical progress component should have been negative for the marginal product of capital to equal (on average over the sample) the user cost of capital. Therefore, in fact, this estimation is entirely consistent with our "underestimated user cost" hypothesis.

## 5.2. Case B: A + Financial Regulation

Looking at the B columns of Table 1 and the corresponding Figure 4, we can conclude the following. Both specifications support the "underestimated user cost" hypothesis; they indicate that the level of real user cost corresponding to marginal financing costs in the 1970s (captured by $\kappa$) was on the average, in fact, somewhat above the level following thereafter (panel F of Figure 4[27]).

The ability of both systems to explain the developments of the markup and factor income share is improved, although the CD system underestimates the observed trend in the markup and capital income share in the post-deregulation period. The fits of labor income share and the production function, especially in the CD case, are less affected. Overall fits of the production functions are now, also in terms of residual profiles, very similar, indicating too persistent underutilization of inputs



(e)

(e)

**FIGURE 3.** Cases A in Table 1.

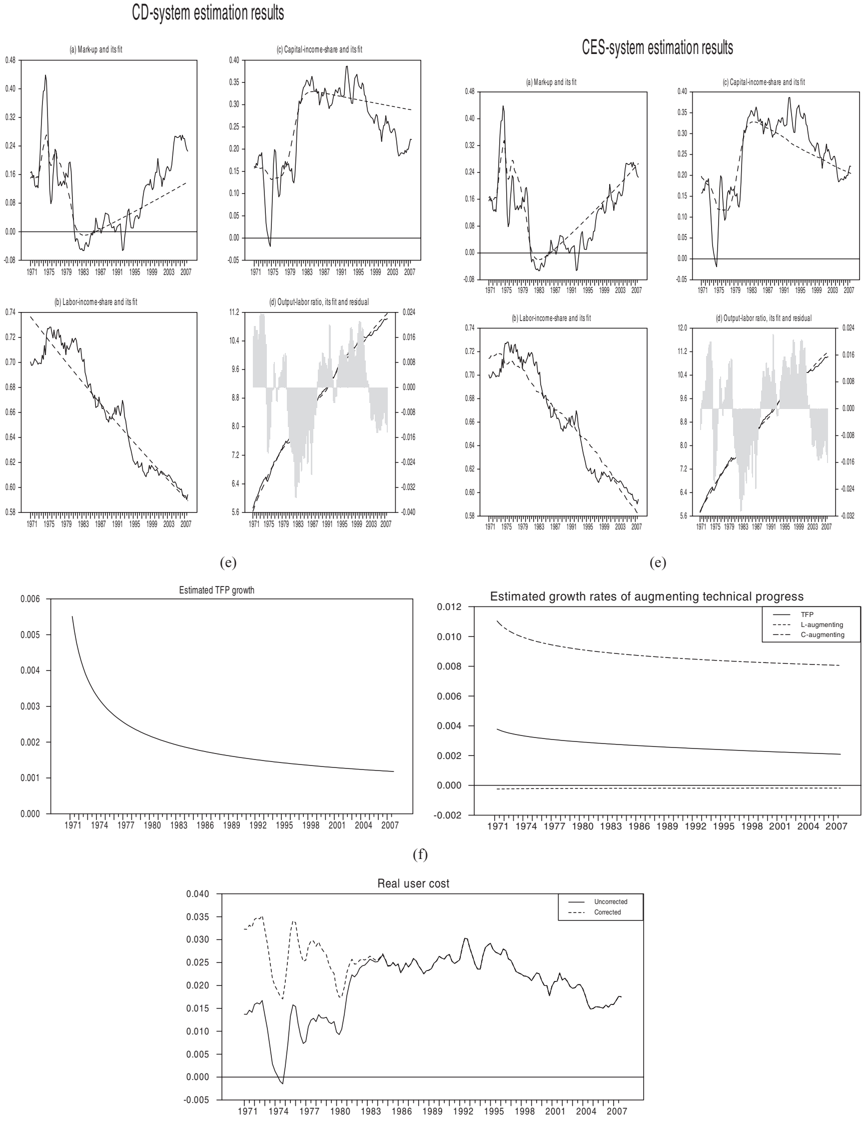


**FIGURE 4.** Cases B in Table 1: regulation dummy; no break in technical progress.

in the 1980s and overutilization in the 1990s (production function residuals again indicate nonstationarity).

Regarding the CES specification, the estimate of the SE decreases marginally from 0.87 (case A) to 0.78. However, the estimated technical progress is quite different. Case B indicates statistically nonsignificant and practically zero labor augmentation and strong, although somewhat decelerating, capital-augmenting technical progress ($\lambda_K = 0.9$). Again this result can be interpreted in terms of relative prices of inputs. The user cost—now accounting for financial regulation—and accordingly the required marginal productivity of capital were high in the 1970s. Therefore, with the observed capital stock development, the growth of capital-augmented technical progress must have been high to equal user cost developments.

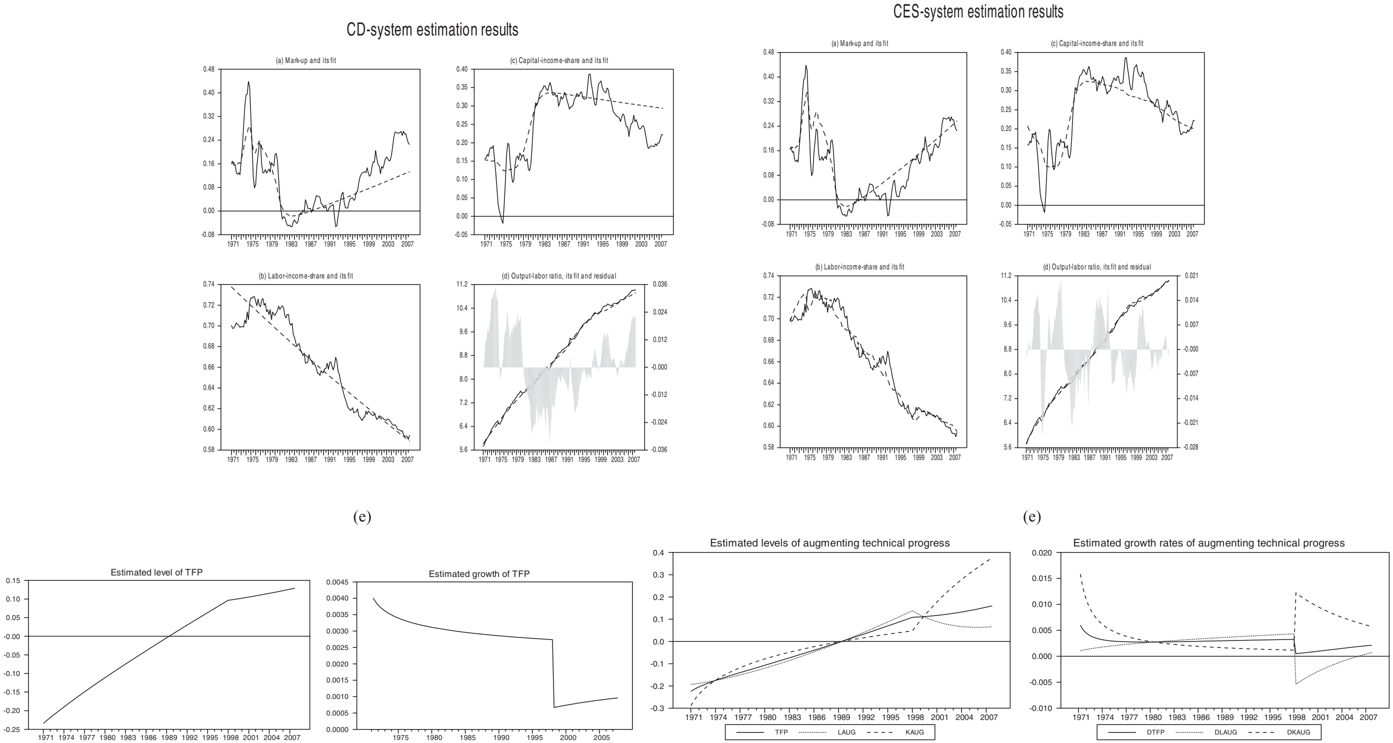
### 5.3. Case C: Case B plus Regime Shift in Technical Progress

Looking at the C columns and the corresponding Figure 5, we can conclude the following. To account for the possibility that the information and communication technologies (ICT) boom affected technical progress we allowed a regime change in the level developments of augmented technical progress. For extra clarity, in this case we show both TFP growth and levels. In terms of maximizing fit (i.e., log determinants), the break in technical progress was identified starting 1997:4. Note (recalling Figure 1, E) that the reduction in productivity in the mid-1980s is captured naturally by the declining curvature of capital augmentation (Figure 5, panel E). The overall fit of both the CD and the CES system is subsequently improved (especially the latter). It is, however, worth noting that the overall fit of the CES system excluding the break (i.e., case B) was already better than that of the CD system allowing the break (in Case C).

Thus, the last column of Table 1 (Case C, CES) represents the most data-congruent perspective (in terms of log determinant and visual fit). The SE is around 0.6. Capital augmentation, though initially high, falls continuously throughout the sample, consistent with the Acemoglu hypothesis. Labor-augmenting technical change starts to rise and dominates overall TFP growth. In 1997, though, there was a discreet change in the growth rate of technical progress because of that of capital shifting upward and that of labor shifting downward. Because TFP growth attributes a higher weight to the latter, overall TFP growth (the solid line in panels (e)) dropped sizably. The medium-run fits of factor shares and the markup (Panels A–C) are captured extremely well.

### 5.4. Rationalizing This Pattern of Technical Change

In the 1970s (and indeed since the war), there was an urgent need to increase and modernize the capital stock to close the gap with the United States. At the same time, there was also a heavily regulated financial market, and capital controls restrained financing from abroad. The demand for domestic finance exceeded supply and the de facto user cost exceeded the level implied by regulated rates over the 1970s. The *shadow* price of capital (and, in turn, its shadow income share) was therefore high, generating incentives for capital-saving technologies.[28] Moreover, the rapid growth of available labor in the late 1960s and early 1970s (e.g., large generations born postwar entered the labor market; part of the labor force was underutilized (especially in agriculture) and migrated to other industries;



(e)

(e)

**FIGURE 5.** Cases C in Table 1: financial market liberalization; break in technical progress.

female participation increased, etc.) may have made labor notionally abundant, necessitating relatively less labor saving.

However, following the first oil crisis and labor's successful appropriation push, there were incentives to shift gradually from capital augmentation to labor augmentation (reflecting the latter's larger factor share). Moreover, during the 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 settled down to almost BGP-like characteristics, being dominated by labor augmentation.

This pattern was stable until the mid to late 1990s, when there was a structural break in TFP growth. This sheds light on the puzzle of why the euro area appeared to miss out on the global IT boom: although the upward shift in capital augmentation is higher than the drop in labor augmentation, TFP growth *decelerates* because of the relatively lower share of capital in TFP. In the United States the IT revolution appeared to take the more standard labor-augmenting form with a corresponding TFP *acceleration* [e.g., Oliner and Sichel (2000), Fernald and Ramnath (2004)], reflecting that—in the medium run—U.S. labor availability remained a constraining factor for growth, indicated by low, stable unemployment and stable factor income shares, suggesting that the profitability of capital saving did not increase over time [Klump et al. (2007)].

Evidence for the relative scarcity of capital in the euro area, which then induced capital saving, also comes from an inspection of the growth rate of real wages, which since about 1976 have remained below labor productivity growth (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 $\approx 12\%$ to $8\%$) despite low growth in output and TFP (in stark contrast to the predictions of Okun's Law).[29]

## 6. CONCLUSIONS

This paper has set itself two objectives: 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.

To this end, we estimated a production-technology system. The elasticity of factor substitution, a key parameter in medium-run debates, was estimated as below unity and conventional measures of technical neutrality were rejected. Factor-augmenting technical change was modeled flexibly to assess its congruence with models of directed technical change.

Based on close scrutiny of the data, we further empirically detected the importance of financial regulations in determining capital income in the 1970s (to mid-1980s) and an upward trend in the markup (whose development we ascribed to the shift toward the higher-markup, less efficient services sector). The latter observation underpins the distinction made between factor income and GDP income shares in estimation.

We identified key phases of euro-area TFP growth, the boom of the early 1970s and the protracted decline thereafter, and related them to biases in technical change. The high shadow price of capital in the 1970s generated strong incentives for capital saving. Through the 1980s financial repression was in retreat and labor's appropriation push around the first oil shock generated increasing incentives for labor saving. With aggregate factor complementarity this, in turn, implied that labor's income share, high in the 1970s, would fall.

Consequently, TFP growth comprised decaying capital augmentation and increasing labor augmentation. This pattern was roughly stable until the mid to late 1990s, when there was an observed structural break in TFP growth explained and estimated in our framework by directed technical change toward capital. Again this combination (recall Figure 1, Panel C) led to a small rise in labor factor income share. It also overturned Okun's Law: low output growth coexisted with strong employment growth. This last constellation has barely been chronicled and to our understanding, so far, is unexplained.

In our paper, we thus modeled the main planks of the "medium-run" debate—fluctuating factor incomes, decelerating productivity, nonstationary markups, the role of factor substitution, technical biases etc.—consistent with nested asymptotic growth theory. We do not claim that our approach incorporates all perspectives. What we *do* claim (recalling Blanchard's opening quote) is that departures from balanced growth are important, interesting, and, with due care, recoverable and interpretable from the data. We do not exclude the compatibility of our explanations with traditional ones. Directed technical change as against the interaction between shocks and institutions may be related: if the success of labor's appropriation push reflected labor-sheltering institutions, this might precisely strengthen the case for firms manipulating technical biases to compensate.

Finally, though we have not developed the point, our work inevitably cautions against expressing economic models in steady-state, trend-deviation form when, as for the euro area and constituent members, economic time series exhibit such protracted, unbalanced growth features.[30]

Several future research directions are suggested by this study. At the outset, we hope our medium-run framework may be usefully applied to other countries and sectoral studies. We further hope that balanced growth will be seen for what it is: an empirical irregularity. In itself, the simple incorporation of CES aggregate production with both labor- and capital-augmenting technology improvements has enormous potential to improve the fit, robustness, and stylized-fact matching of (even otherwise conventional) business-cycle models and improve our understanding of the propagation mechanisms behind technology-induced business cycles [see Cantore et al. (2010)], such as in shock decomposition exercises. Our framework also highlights the possibility of being able to exploit changes in factor income shares to structurally identify technology shocks in modeling and structural VAR analysis. By identifying an empirical link between capital augmentation and financial regulation, our work also usefully highlights so far–unexplored links between financial frictions and biased technical change. Finally, although we have separated structural (sectoral) changes and directed technical change explanations for medium-run episodes, the interplay between these developments also appears promising.[31]

## NOTES

1. Likewise, Blanchard (2008) in his *State of Macro* survey: "I shall even leave out a topic close to my heart, the "medium run" . . . not much (not enough) has happened on this front."

2. The simulation evidence of Leung (2009) suggests that the attainment of the long run in growth models could be exceptionally long.

3. In many fields, accounting for technical progress is a key channel underpinning various economic phenomena [e.g., the welfare consequences of new technologies and production processes, Marquetti (2003); labor-market inequality and skills premia, Acemoglu (2002b), the evolution and stability of factor income shares, Kennedy (1964) and Acemoglu (2002a) etc.).

4. Recent developments in growth theory, though, have questioned the theoretical justification that a BGP cannot coexist with capital augmentation, e.g., Growiec (2008a, 2008b), de La Grandville (2012).

5. León-Ledesma et al. (2010b) discuss this aspect of possible observational equivalence in accounting for income share movements in detail.

6. The GDP share of the markup is the difference of the summed shares in panel (a) from unity.

7. The exact size of the aggregate markup is naturally subject to some caveats, because we have been unable to incorporate taxes into our user cost measure (there are no time series for euro-area capital taxes). This need not be a major defect, if (a) depreciation for tax purposes is strongly front-loaded and(or (b) there were no major changes in corporate taxation during our sample. Also, although it is standard practice to use (as here) the long (10-year) government bond rate to capture firms' marginal financing [e.g., Jorgensen and Yun (1991)], firms tend to pay some premium over the policy rate. Thus there may be some downward bias in our real user cost estimates even after the estimated correction in the 1970s and 1980s. But the time series profile of the aggregate markup—which is the *key* issue in our context—we believe to be correct.

8. In addition, there has also been strong structural change inside the manufacturing sector: the GDP share of electrical machinery grew from 3.2% (1971) to 8.2% (2005). The electric machinery sector produces high-technology products and the evidence suggestions their prices contain an above-average markup.

9. 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)]. 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 financing public deficits by purchasing bonds.

10. Barro and Sala-i-Martin (2004, Sect. I.4) provide a particularly readable account of the evolution of growth theory.

11. Naturally, the relations between the SE, technical bias, and factor shares evaporate under CD.

12. When factors are gross complements, it can be shown that the latter effect dominates. Indeed, deceleration in the rate of growth of a factor's accumulation may be considered indirect evidence of increased technical improvements.

13. Normalization fixes a benchmark value for the factor income shares. This is important when it comes to an empirical evaluation of changes in the income distribution that are the result of technical progress. If technical progress is biased, in the sense that factor income shares change over time, the nature of this bias can only be classified with regard to a given baseline value. León-Ledesma et al. (2010a) analyze normalization extensively; see also the more general survey in Klump et al. (2011).

14. Because our interest is *not* focused on investment dynamics, we abstract, for expositional simplicity, the adjustment cost of investment from the maximization framework.

15. We may think that some firms may be constrained to borrow directly from the bank loan market all the credit they need, whereas some other are not. However, the perfect substitutability of bank loans and interfirm loans and arbitrage ensure that it is profitable for unconstrained firms to borrow from banks and transmit funds to the bank-loan constrained firms until the demand of all firms for credit is satisfied at a rate equalling the bank lending rate.

16. The United States is often cited as a country with stable factor income shares. However, Young (2010), revisiting the results of Solow (1958), shows this is not compatible with the data.

17. An above-unity elasticity can generate perpetual growth (even without technical progress), because scarce labor can be completely substituted for by capital, implying that the marginal product of capital remains asymptotically bounded above zero [Solow (1956)]. The critical threshold level for the SE (to generate such perpetual growth) can be shown to be increasing in the growth of labor force and decreasing in the saving rate; see de La Grandville (1989). 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, counterfactually, either per capita living standards or the per capita growth rate in continental Europe to exceed those of the United States [because most studies also suggest below-unity elasticity for the United States, e.g., Chirinko (2008); León-Ledesma et al. (2010a, Table 1)].

18. However, our euro-area capital stock is based on Eurostat harmonized net capital stock data, which are directly related to underlying country data. These capital stock data are annual and cover 1970–1999, so we interpolated to quarterly frequency, using quarterly gross investment and depreciation rate data, after the latter were, 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 a perpetual inventory method, keeping the depreciation rate fixed at its 1999 level.

19. Because information 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.

20. The real euro-area interest rate was strongly negative throughout most of the 1970s, whereas the German rate was positive (from the mid-1980s onward, though, the two series are quite similar). The latter case is interesting because Germany took the lead in financial liberalization and all direct controls had been removed before 1974, i.e., by the point of time at which real interest rates in other euro-area countries turned negative [e.g., Issing (1997)]. However, Germany did not abandon interest rate regulation before 1981 [Gual (1999)].

21. 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 the 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 did the real interest rate remain positive through the whole sample period, consistent with the fact that Germany liberalized capital flows as early as 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)].

22. One possibility is to use the German rate (Germany was at the forefront of financial deregulation) as Coenen and Wieland (2005) did in a different context. However, this mixes data sets and ignores the underlying issue.

23. Estimates of the CD system without a time-varying markup (as well as with fixed-growth technical progress) are available on request. However, as might be imagined from Figure 1, their econometric and graphical fit is extremely poor.

24. We dated the break point by optimizing the log determinant across quarterly break increments from 1980q1 until the sample end. The break dates found correspond to those found in other studies for the euro area and also accord with results from the Bai–Perron (2003) flexible break tests when they are applied to output and labor productivity series.

25. Recursive estimation did not reveal any statistically significant drift in the SE over time. Accordingly, explanations of labor share dynamics based on elasticity shifts over time [e.g., Caballero and Hammour (1998)] are not part of our explanation.

26. Our longer working paper version presents equivalent estimates for the largest four euro-area countries. Results at the euro-area level are very well borne out at the country level. We thank Olivier Blanchard for encouraging us to work in that direction.

27. For brevity, for the last four cases in Table 1, we show only the increase in the real user cost associated with the CES specification in case B (Case B, Panel F). In the other cases, the increases in the interest rate were very similar, as can be judged by the similar $\kappa$ values in Table 1.

28. Note the generality here. With its vast 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.

29. Low output growth and high employment growth defy 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.

30. Interestingly, this finds an echo in the results of Christoffel et al. (in press). They report for their euro-area macroeconometric model, the NAWM (which imposes CD production), good forecasting performance for many real variables (including the output gap), but large and persistent errors in forecasting real wages and the labor share.

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

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