The Evolution of TFP in Spain and Italy

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Abstract

This paper reexamines the evolution of total factor productivity (TFP) and its relationship to aggregate welfare in Spain and Italy. Using a growth-accounting framework for open and distorted economies with input-output linkages, I construct new TFP series that correct for biases in conventional estimates. I show that productivity declines in both countries were milder and occurred later than previously reported—starting in 1995 in Spain and 2000 in Italy—reflecting a secular rise in distortions that bias standard TFP measures downward. I find that these declines are largely attributable to deteriorations in sectoral productivity and misallocation across sectors. The central finding of the paper is that, despite falling productivity, both Spain and Italy experienced welfare gains, driven by improved access to global markets and more efficient international resource allocation. These findings underscore the importance of incorporating distortions and open-economy forces into empirical assessments of productivity and welfare.

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1 Introduction

Measured total factor productivity (TFP) in Southern European countries has stagnated or declined over the past several decades according to widely used statistical sources such as EU KLEMS and the Penn World Tables.[1] In Spain and Italy, conventional estimates show sustained declines beginning in the late 1980s and mid-1990s, respectively. Figure 1 illustrates this pattern, showing that aggregate TFP in both countries peaked decades ago and has since followed a downward trajectory.

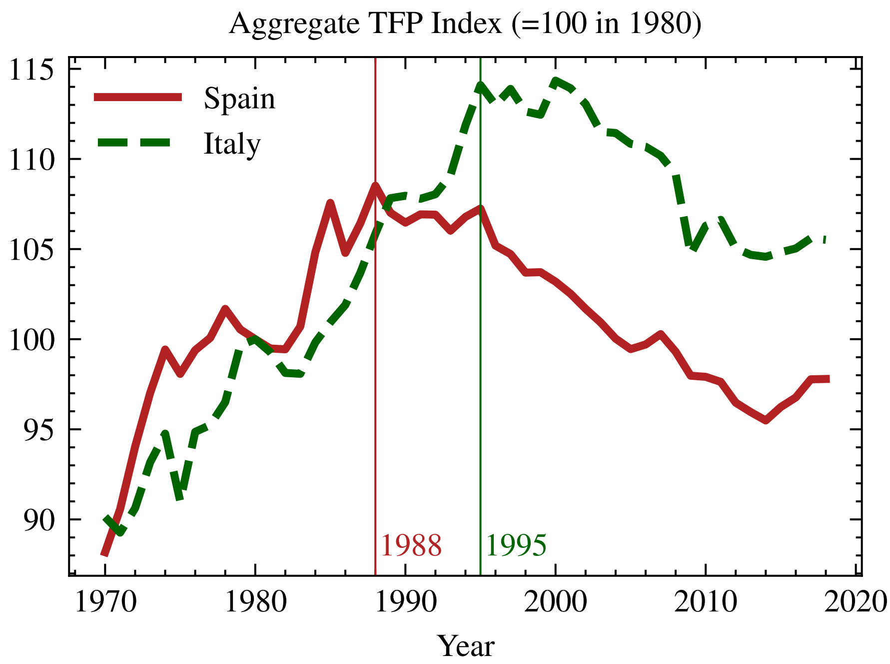


Figure 1: Evolution of aggregate TFP in Spain and Italy.

Figure Notes. Aggregate TFP indices are constructed using two releases (2007/08 and 2021) of the *EU KLEMS Growth and Productivity Accounts*. Each index is based on the value-added concept of TFP—that is, it is implicitly assumed that technical change operates only through capital and labor—and follows a top-down approach in which TFP is computed as the traditional Solow residual. The resulting series is normalized to 100 in 1980. TFP is reported at the level of total industries ("`TOT`"), which includes both market and non-market sectors. Vertical lines indicate the year in which each TFP series reaches its respective peak.

This apparent deterioration in efficiency has puzzled economists and raised important questions about the drivers of long-run growth and competitiveness in these economies. A large literature has sought to explain these trends through various mechanisms, including structural transformation, capital misallocation, financial frictions, institutional decline, and technological stagnation. Yet no unified explanation has emerged. Existing studies often focus on specific sectors, rely on closed-economy

[1] Data from the *Penn World Tables 10* show that aggregate TFP ("`rtfpna`") has stagnated or declined in Spain, Portugal, Italy, and Greece since the 1970s–1980s. The *EU KLEMS Growth and Productivity Accounts* report similar declines ("`TFP_vaI`") for Spain and Italy, although well-known discrepancies in timing exist between datasets—particularly for Italy—while data for Portugal and Greece are unavailable. As is common in the literature, I rely on KLEMS data, which are generally considered more reliable due to their greater sectoral detail and methodological rigor.

frameworks, or examine time periods that do not fully capture the duration of the productivity decline. Moreover, most analyses consider only one or a small subset of these explanations in isolation, limiting our understanding of how different structural forces interact. Many also take measured productivity at face value, overlooking the extent to which it is shaped by distortions rather than by true technological efficiency. As first emphasized by Hall (1988), the traditional Solow residual—the foundation for most empirical TFP series—is biased in the presence of markups, taxes, and other frictions. When such distortions are present, measured productivity can either overstate or understate the economy's true productivity.

In this paper, I construct TFP series that correct for these distortions, yielding a measure that more accurately reflects aggregate productivity. Throughout the paper, I refer to this object as *true TFP* or *true productivity*—or simply as *TFP* or *productivity*, when the context permits—to distinguish it from *conventional TFP* or *standard TFP*, which is computed under the assumption of undistorted markets. To this end, I adopt the general-equilibrium framework of Baqaee and Farhi (2024), which imposes minimal restrictions on technology, market structure, and international integration. The framework accommodates heterogeneous producers and consumers, arbitrary input-output linkages, imperfect competition modeled as price wedges, and openness to international trade in both intermediate inputs and final consumption. A key advantage of this approach is that it enables a structural decomposition of aggregate TFP into the contributions of technical efficiency, domestic reallocation, and international trade, while also allowing for an integrated analysis of welfare and the forces that shape it.

Main Findings. The main contribution of this paper is empirical. Using a growth-accounting framework for open and distorted economies with arbitrary input-output linkages, I document that the evolution of aggregate productivity in Spain and Italy between 1970 and 2010 has been more favorable than conventional estimates suggest. The discrepancy with statistical agencies and prior studies arises from a secular increase in distortions, which depresses the Solow residual and biases conventional estimates. Because traditional measures of TFP abstract from such inefficiencies, they significantly understate the evolution of underlying productivity. Once distortions are accounted for, I find that productivity began to decline in 1995 in Spain and in 2000 in Italy—seven and five years later, respectively, than previously reported. Moreover, the decline in Spain is approximately seven percentage points, compared to ten in standard estimates.

Motivated by these findings, I examine the underlying causes of the productivity declines and their welfare implications. My analysis reveals that these declines were primarily driven by reductions in technical efficiency and negative reallocation effects. The decline in technical efficiency reflects deteriorations in sectoral productivities, while the negative reallocation effects stem from increased misallocation of resources across sectors. International trade, on the other hand, contributed positively to productivity growth—primarily through improved access to more efficient intermediate inputs. Notably, I find that welfare in both Spain and Italy increased despite falling productivity. These gains can be attributed to global technological progress and improved international resource allocation, facilitated by greater engagement in trade and deeper integration into global value chains.

Contributions. My findings complement and extend a large empirical literature on the causes of the productivity decline in Southern Europe. Previous studies have emphasized between-sector misallocation, in which labor and capital shift toward less productive sectors, often driven by falling interest rates and increased access to foreign capital (Benigno and Fornaro, 2014; Reis, 2013). Others have focused on within-sector misallocation, highlighting the role of financial frictions (Gopinath et al., 2017), institutional deterioration (García-Santana et al., 2020), or declining allocative efficiency (Calligaris et al., 2016; Fu and Moral Benito, 2018). A third view stresses technological stagnation, managerial inefficiencies, and policy distortions such as subsidies (Díaz and Franjo, 2016; Pellegrino and Zingales, 2019; Schivardi and Schmitz, 2020). While insightful, these studies typically overlook recent important trends such as increased openness to trade, rising market power, and the expansion of global value chains.

My contribution to this literature is twofold. First, I provide a unified account that incorporates international trade and multiple interacting distortions within a general-equilibrium framework featuring input-output linkages. I demonstrate that each of these elements plays a crucial role in understanding not only productivity declines, but also the evolution of welfare. The emphasis on trade is motivated by a series of major trade-related developments during this period—including the creation of the Single Market, the adoption of the euro, and the accession of China and India to the WTO—which profoundly altered the structure of European economies and their integration into the global economy.[2] These transformations contributed to the rising importance of global value chains (Antrás and Chor, 2022; Baldwin and Lopez-Gonzalez, 2015; Johnson and Noguera, 2017) and coincided with a period of increasing market power (De Loecker et al., 2020; Edmond et al., 2023; Hasenzagl and Perez, 2023).

My second contribution is to show empirically the divergence between aggregate productivity and welfare. This divergence underscores an important conceptual point: in open economies, aggregate welfare is not necessarily proportional to domestic TFP. A country may experience a decline in aggregate productivity while still increasing

[2]Major international and regional developments during this period include: the European Economic Community (ECC)'s grant of most favored nation (MFN) status to China in 1978, the Single Market Act of 1987, the formation of the European Union in 1992, the creation of the European Economic Area in 1994, the euro's adoption in 2002, and the WTO accessions of India in 1995 and China in 2001.

welfare. This can occur if changes in the terms of trade lead to a reallocation of resources within domestic borders toward less productive producers, while simultaneously allowing consumers to expand their consumption possibilities through international trade. That trade can raise consumer welfare is the foundational insight of comparative advantage. As shown by Arkolakis et al. (2012), under a broad class of trade models, the welfare gains from trade depend primarily on import penetration and trade elasticities, rather than domestic productivity levels. More novel, however, is the empirical finding that trade can simultaneously enhance welfare despite a decline in aggregate TFP—a pattern documented, for instance, in Caliendo and Parro (2015)'s quantitative analysis of NAFTA—highlighting a more nuanced relationship between trade and productivity.

In addition to the literature on aggregate productivity in Southern Europe, this paper relates to the literatures on growth accounting, international trade, misallocation, and market power.

The growth-accounting methodology is rooted in neoclassical production theory. Since the foundational contributions of Tinbergen (1942) and Solow (1957), the standard approach has been to decompose output growth into contributions from factor inputs and a residual, often interpreted as technical change. Building on this foundation, a large literature has relaxed Solow's original assumptions, one at a time, to examine their implications for productivity measurement.[3] Key contributions include Domar (1961), Jorgenson and Griliches (1967), Hulten (1978), Hall (1988), and Basu and Fernald (2002). More recently, Baqaee and Farhi (2024) extend the traditional framework to permit the study of inefficient, disaggregated, and open economies with heterogeneous agents.[4] My paper builds on these recent theoretical developments to revisit the evolution of TFP and its welfare implications in Spain and Italy.

This paper also relates to the literature on international trade that examines how trade affects aggregate productivity (e.g., Huo et al., 2023; Kehoe and Ruhl, 2008; Melitz, 2003; Menezes-Filho and Muendler, 2011; Young, 1991). Most closely related to my work is the research of Kehoe and Ruhl (2008), who, using data for Mexico and the United States, show that sharp deteriorations in the terms of trade coincide with declines in real GDP, primarily driven by reductions in TFP. They conclude that "*if we think that terms of trade cause TFP fluctuations, we need to develop a new mechanism for generating this causal relation and build it into our models*." In this paper, I emphasize one such mechanism. I show that when there are multiple producers and mobile factors of production, changes in the terms of trade can reallocate resources across domestic producers, potentially affecting both real GDP and aggregate TFP.

[3] Solow's framework assumes a representative firm, perfectly competitive product and factor markets, and a closed economy.

[4] See also Baqaee and Farhi (2019a, 2018, 2019b, 2020).

Other studies in the trade literature have proposed alternative mechanisms through which trade influences aggregate productivity. Young (1991) introduced a model of endogenous growth in which trade affects productivity via learning-by-doing and knowledge spillovers. Melitz (2003) developed a model of firm heterogeneity with endogenous entry and exit to examine the effects of trade within a single industry. In his framework, increased exposure to trade induces the exit of the least productive domestic firms, thereby raising aggregate productivity through intra-industry reallocation. While both Melitz's mechanism and the one put forth in this paper involve resource reallocation across producers in response to trade, their implications differ. In Melitz's model, trade exposure unambiguously increases aggregate productivity as less productive firms exit the market. In contrast, in my framework, aggregate productivity rises only if production factors reallocate toward more productive firms or sectors. Trade-induced reallocation may therefore raise welfare while lowering TFP depending on the direction of adjustment.

Finally, this paper relates to the literatures on misallocation and market power. In my benchmark specification, misallocation is captured through wedges, which are introduced in the spirit of Chari et al. (2007). These wedges represent reduced-form distortions that drive a "wedge" between efficient allocations and those observed in equilibrium. Such distortions may arise from market power, financial frictions, distortionary taxation, or regulatory barriers. Using this approach, I find that misallocation has played a significant role in shaping aggregate TFP dynamics in Southern Europe, consistent with the findings of Restuccia and Rogerson (2008), Hsieh and Klenow (2009), and Gopinath et al. (2017), among others.

Layout of the Paper. The rest of the paper is organized as follows. Section 2 discusses the conceptual and measurement challenges associated with TFP and develops two mechanisms that motivate the inclusion of both distortions and open-economy forces in the analysis of aggregate productivity. Section 3 introduces the general-equilibrium model of Baqaee and Farhi (2024), featuring production networks, distortions, and trade, which forms the basis of the empirical analysis. Section 4 offers first-order theoretical decompositions of aggregate TFP and welfare changes. Section 5 describes the data sources and the estimation strategy. Section 6 presents the main empirical results for Spain. To streamline the exposition, results for Italy are presented in Appendix F. Section 7 concludes.

2 Aggregate TFP: Measurement and Mechanisms

In this section, I argue that accounting for both distortions and international trade is crucial for understanding the evolution of aggregate productivity. This claim rests on two interrelated considerations: one concerning measurement, and the other concerning the mechanisms that shape aggregate TFP.

First, following the seminal contribution of Hall (1988), I show that in the presence of distortions, the traditional Solow residual does not reliably measure TFP growth. When an economy is distorted, accurate measurement requires using cost-based rather than revenue-based input shares to weight input growth. Second, I present a set of stylized theoretical examples that illustrate how changes in either distortions or the terms of trade can trigger factor reallocation and affect aggregate productivity.

2.1 TFP Measurement

The simplest way to understand how distortions affect TFP measurement is to consider an economy with a representative producer that generates output Y using a constant returns-to-scale production technology $F : \mathbb{R}_+^N \to \mathbb{R}_+$ that maps N input quantities L_n to gross output. Output is produced according to:

$$Y = AF(L_1, \ldots, L_N), \tag{1}$$

where A denotes Hicks-neutral productivity, and L_n is the quantity of input $n \in \{1, \ldots, N\}$.[5]

Suppose the producer has market power and sets price P above marginal cost MC, with a markup $\mu := P/\mathrm{MC} \in (1, +\infty)$. In this case, the traditional Solow residual—defined as output growth minus revenue-weighted input growth—takes the form:[6]

$$\underbrace{\Delta \log Y - \sum_{n \in N} \Lambda_n \Delta \log L_n}_{\text{Traditional Solow residual}} = \underbrace{\Delta \log A}_{\text{TFP growth}} + \underbrace{\left(\frac{\mu - 1}{\mu}\right)\left\{\Delta \log Y - \Delta \log A\right\}}_{\text{Distortion bias}}, \tag{2}$$

where $\Lambda_n \equiv w_n L_n/(PY)$ is the revenue share of input n, and $\Delta \log X = \log X_t - \log X_{t-1}$ denotes the log difference over time.

Equation (2) clarifies that in the absence of distortions ($\mu \to 1$), the traditional Solow residual accurately measures aggregate TFP growth. In the presence of distortions

[5] The production function F is assumed to satisfy standard regularity conditions: continuity, differentiability, and the Inada conditions.

[6] See Appendix B.3 for a derivation. This expression is the discrete-time analogue of equation (2).

($\mu > 1$), however, this residual is generally biased, and the direction of the bias depends on whether output grows faster or slower than productivity.

To address this issue, Hall (1988) proposed using cost shares rather than revenue shares to weight input growth. With this adjustment, a modified Solow residual—referred to as the "distorted" Solow residual—correctly captures productivity growth:[7]

$$\underbrace{\Delta \log Y - \sum_{n \in N} \tilde{\Lambda}_n \Delta \log L_n}_{\text{Distorted Solow residual}} = \underbrace{\Delta \log A}_{\text{TFP growth}}, \tag{3}$$

where $\tilde{\Lambda}_n \equiv w_n L_n / (\sum_k w_k L_k) = \mu \Lambda_n$ is the cost share of input n.

Example: Cobb–Douglas Production Function. With a Cobb–Douglas production function that employs capital and labor, the two residuals take the following forms:

$$\Delta \log Y - \alpha \Delta \log K - (1-\alpha) \Delta \log L = \Delta \log A + \left(\frac{\mu - 1}{\mu}\right) \left\{\Delta \log Y - \Delta \log A\right\}, \quad \text{(Traditional Solow residual)}$$

$$\Delta \log Y - \mu\alpha \Delta \log K - \mu(1-\alpha) \Delta \log L = \Delta \log A, \quad \text{(Distorted Solow residual)}$$

where $\alpha = RK/(PY)$ and $(1-\alpha) = WL/(PY)$ are the revenue shares of capital and labor, respectively.

Representative vs. Heterogeneous Producers. For expositional clarity, the discussion thus far has assumed a representative producer. In economies with heterogeneous producers, analogous measurement issues arise, and TFP growth is still computed by subtracting cost-weighted input growth from real output growth. The key difference is that aggregate output becomes more difficult to define. With differentiated goods, output is no longer the number of physical units of a single good, but a vector of quantities—one for each distinct product. In this context, real output growth is typically measured using a Divisia quantity index, which aggregates the growth rates of individual goods using their nominal output shares as weights.

2.2 TFP Mechanisms

There are at least three mechanisms that are potentially important for understanding the evolution of aggregate productivity. The most obvious one is technological change. In an economy with a representative producer, aggregate productivity increases when

[7] See Appendix B.3, Proposition 3.

technology improves—that is, when more output can be produced with the same inputs. This mechanism is straightforward and visible in equation (3).

This section focuses on two additional mechanisms that operate through compositional shifts: changes in the terms of trade and changes in distortions. Both can induce the reallocation of mobile factors of production across sectors. When sectoral productivity growth differs, such reallocation affects aggregate TFP. Evidence in Appendices D.7–D.10 suggests these mechanisms are particularly relevant for Spain and Italy. For clarity, I present these mechanisms informally through stylized theoretical examples, and relegate a formal treatment to Appendix A.

Mechanism: ΔTerms of Trade $\rightarrow$ Factor Reallocation $\rightarrow$ ΔTFP. Consider a closed economy with two competitive sectors, wine and textiles. Each sector employs labor, which is perfectly mobile across sectors, and a fixed sector-specific factor (e.g., land for wine and managerial ability for textiles). In equilibrium, consumer preferences and technological parameters determine both the employment distribution and the total output of each sector. Since the economy is closed, final consumption equals domestic production (i.e., $\boldsymbol{c}^{\text{aut}} = \boldsymbol{y}^{\text{aut}}$). The relative price of wine to textiles in autarky, $P_W^{\text{aut}}/P_T^{\text{aut}}$, determines the slope of line A in the left panel of Figure 2, which depicts the production possibilities frontier and summarizes the equilibrium configuration.

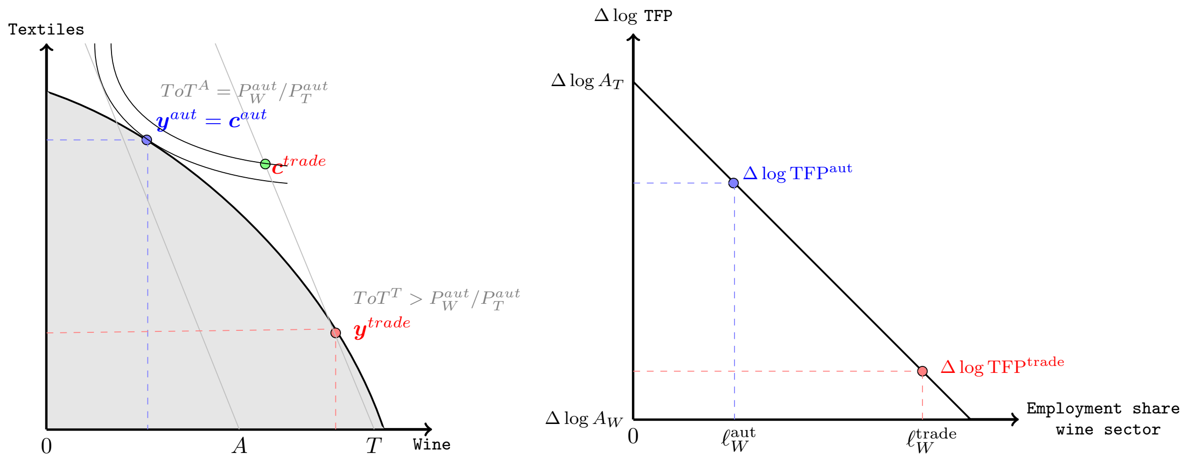


Figure 2: Trade–TFP Mechanism.

Now suppose the economy opens up to trade and the terms of trade shift to ToT^T—that is, the relative price of wine rises above its autarky level—and assume that the home country is a small open economy facing perfectly elastic foreign supply. In the initial autarky equilibrium, the terms of trade equal the domestic relative price, making autarky a feasible outcome. A change in the terms of trade induces a reallocation of mobile factors toward the sector with comparative advantage, as first emphasized by

Ricardo.[8] Labor shifts toward the wine industry, which expands output ($y_W^{\text{trade}} > y_W^{\text{aut}}$), and the economy moves to a new point along the PPF ($\boldsymbol{y}^{\text{trade}} \neq \boldsymbol{y}^{\text{aut}}$). Under the new terms of trade, the country exports wine and imports textiles, so production and consumption no longer coincide ($\boldsymbol{y}^{\text{trade}} \neq \boldsymbol{c}^{\text{trade}}$). By engaging in trade, the home country achieves a higher level of welfare, as indicated by $\boldsymbol{c}^{\text{trade}}$ lying on a higher indifference curve than $\boldsymbol{c}^{\text{aut}}$ in the left panel of Figure 2.[9]

The idea that trade can increase welfare is well established. However, I wish to emphasize that changes in the terms of trade can also affect aggregate productivity. Even when trade raises welfare, it may simultaneously reduce aggregate TFP if factors of production are reallocated toward less productive sectors. This channel is illustrated in the right panel of Figure 2, which traces a line from the productivity growth of the textiles sector ($\Delta \log A_T$) to that of the wine sector ($\Delta \log A_W$). When all labor is concentrated in a single sector, aggregate TFP growth matches that sector's productivity growth. With multiple sectors, aggregate TFP growth depends on the distribution of production factors across sectors. For illustrative purposes, Figure 2 depicts TFP growth as a simplified (employment) average across sectors. The key insight is that changes in the terms of trade alter factor allocations, thereby influencing productivity growth through compositional effects.

At a more formal level, the impact of terms-of-trade shifts on aggregate productivity can be understood from the expression

$$\Delta \log \text{TFP} = \Delta \log Y - \sum_{f \in \{L, K_T, K_W\}} \Lambda_f \Delta \log L_f,$$

where L is labor, K_T and K_W are sector-specific factors, Λ_f is the revenue share of factor f, and $\Delta \log L_f$ is the growth rate of that input. Real output growth, in turn, is given by a Divisia quantity index:

$$\Delta \log Y = \sum_{i \in \{T, W\}} \frac{p_i y_i}{PY} \Delta \log y_i,$$

where $PY = \sum_{i \in \{T,W\}} p_i y_i$ is nominal GDP, and y_i is gross output in sector i.

Since sectoral output depends on labor allocation, $y_i = f(\ell_i)$, and labor allocation responds to relative prices, $\ell_i = g(\text{ToT})$, changes in the terms of trade affect aggregate

[8]Unlike in the classic Ricardian model, the presence of sector-specific fixed factors prevents full specialization. These fixed factors also generate curvature in the production possibilities frontier shown in Figure 2. I include them to illustrate how trade volumes adjust smoothly to changes in prices.

[9]The gains from trade can be quantified by comparing the income level, e, needed to reach the utility under trade, $\mathcal{W}_T$, at autarky prices, with the income required to reach autarky utility, $\mathcal{W}_A$, at the same prices. Formally, the gains from trade are given by $1 - e(\text{TOT}^{\text{A}}, \mathcal{W}_T)/e(\text{TOT}^{\text{A}}, \mathcal{W}_A)$.

productivity through induced compositional shifts in production (see Appendix A.1 for a formal treatment).

Mechanism: ΔDistortions $\rightarrow$ Factor Reallocation $\rightarrow$ ΔTFP. Now consider a closed economy with two monopolistic sectors, wine and textiles. Each good is produced using labor—which is perfectly mobile across sectors—and a sector-specific fixed factor. Due to monopolistic markups $\boldsymbol{\mu} \gg \mathbf{1}$, the quantity produced in each sector is suboptimal whenever markups differ across sectors.[10] This misallocation is depicted by the output vector $\boldsymbol{y}(\mu_1, \mu_2)$, which lies strictly inside the production possibilities frontier shown in Figure 3. In equilibrium, consumer preferences, markups, and technological parameters jointly determine employment shares and sectoral production levels. Market clearing ensures that all output is consumed.

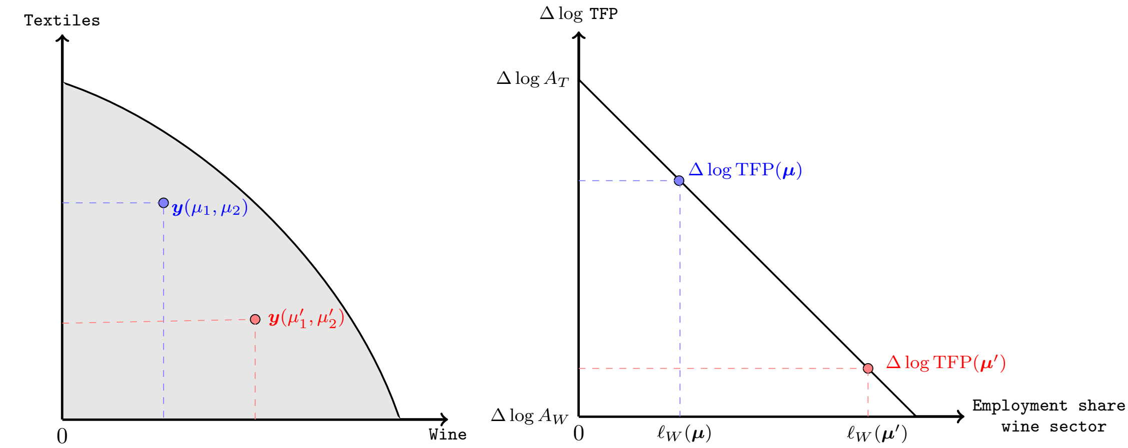


Figure 3: Misallocation–TFP Mechanism.

Now suppose producers adjust their markups to (μ_1', μ_2'), resulting in a new allocation $\boldsymbol{y}(\mu_1', \mu_2')$. As with changes in the terms of trade, differential changes in markups reallocate mobile factors across sectors. If labor shifts toward a sector with negative TFP growth, aggregate productivity declines due to compositional effects. This mechanism is illustrated in the right panel of Figure 3, which parallels the trade-induced reallocation channel discussed earlier.

Taking stock. In this section, I showed that accurate measurement of aggregate productivity requires accounting for distortions. I then illustrated two mechanisms—changes in the terms of trade and changes in distortions—that can plausibly account for observed patterns in aggregate productivity in Southern Europe. Both mechanisms operate through the same mediating channel—factor reallocation across sectors—and are relevant for Spain and Italy, as documented in Appendices D.8–D.10.

[10]In this example, labor supply is inelastic, so distortions affect only the allocation of labor across sectors, not its aggregate level.

3 General Theoretical Framework

In this section, I introduce the general-equilibrium model of Baqaee and Farhi (2024), which incorporates input-output networks, distortions, and international trade. This model serves as the foundation for the empirical analysis that follows.

Environment

The world economy consists of a set of countries $\mathcal{C} = \{1, \ldots, C\}$, a set of producers $\mathcal{I} = \{1, \ldots, I\}$, and a set of factors $\mathcal{F} = \{1, \ldots, F\}$. Factors and producers are physically located in particular countries, but can be owned by foreign households. The set of factors and producers located in country c are denoted by $\mathcal{F}_c$ and $\mathcal{I}_c$, respectively.

Households. Each country is populated by a representative household, so the terms "households" and "countries" can be used interchangeably. The preferences of household c are:

$$W_c = \mathcal{W}_c\left(\{c_{ci}\}_{i \in \mathcal{I}}\right), \tag{4}$$

where $\mathcal{W}_c$ is a homothetic aggregator that takes as an argument a sequence of consumption goods $\{c_{ci}\}$ demanded by household c and supplied by producers $i \in \mathcal{I}$.

Household c demands a sequence of consumption goods to maximize its preferences, (4), subject to the budget constraint

$$\sum_{i \in \mathcal{I}} p_i c_{ci} = \sum_{f \in \mathcal{F}} \Phi_{cf} w_f L_f + \sum_{i \in \mathcal{I}} \Phi_{ci} \left(1 - \frac{1}{\mu_i}\right) p_i y_i + T_c, \tag{5}$$

where p_i is the price of good i, Φ_{cf} is its ownership share of factor f, w_f is the rental price of factor f and L_f its quantity, Φ_{ci} is its ownership share on producer $i \in \mathcal{I}$, μ_i is an exogenous wedge, y_i is the quantity produced of good i, and T_c is a household-specific lump-sum tax/transfer that potentially captures trade imbalances.

Producers. Each producer $i \in \mathcal{I}$ located in $c \in \mathcal{C}$ produces output according to

$$y_i = A_i F_i\left(\{x_{ij}\}_{j \in \mathcal{I}}, \{\ell_{if}\}_{f \in \mathcal{F}_c}\right),$$

where A_i is Hicks-neutral productivity, and F_i is a producer-specific CRS technology that takes as inputs intermediate goods $\{x_{ij}\}_{j \in \mathcal{I}}$ and domestic factors $\{\ell_{if}\}_{f \in \mathcal{F}_c}$.

Each producer demands sequences of intermediate goods and factor inputs to minimize total costs, and sets price equal to marginal cost times an exogenous wedge: $p_i = \mu_i \times \mathrm{mc}_i$.

Factors. Primary factors are endowment goods which are inelastically supplied and earn Ricardian rents. These include the different types of labor and capital goods.

Ownership Shares. Ownership of firms and factors is encoded in the ownership matrix Φ, with dimension $C \times (I + F)$ and generic entries Φ_{ci} and Φ_{cf}, giving households' ownership shares of firms and factors.

Equilibrium. Given productivities $\{A_i\}$, wedges $\{\mu_i\}$, an ownership matrix Φ, and a vector of transfers $\{T_c\}$ respecting $\sum_c T_c = 0$, an equilibrium is a set of prices $\{p_i, w_f\}$, intermediate-input choices $\{x_{ij}\}$, factor-input choices $\{\ell_{if}\}$, outputs $\{y_i\}$, and final-consumption goods $\{c_{ci}\}$, such that:

(i) The price of each good equals its wedge times its marginal cost.

(ii) Producers choose intermediate goods and factor inputs to minimize total costs taking prices as given.

(iii) Households choose consumption goods to maximize preferences (4) subject to budget constraint (5) taking prices as given.

(iv) Markets clear:

$$\sum_{c\in\mathcal{C}} c_{ci} + \sum_{j\in\mathcal{I}} x_{ji} = y_i, \quad \forall i \in \mathcal{I}, \tag{Goods}$$

$$\sum_{i\in\mathcal{I}} \ell_{if} = L_f, \quad \forall f \in \mathcal{F}. \tag{Factors}$$

Nominal Output and Expenditure. Nominal gross domestic product (GDP) is the total value of the final goods produced inside a country. For country c,

$$\mathrm{GDP}_c := \sum_{i\in\mathcal{I}} p_i q_{ci} = \sum_{f\in\mathcal{F}_c} w_f L_f + \sum_{i\in\mathcal{I}_c} \left(1 - \frac{1}{\mu_i}\right) p_i y_i,$$

where $q_{ci} \equiv y_i \mathbf{1}_{\{i\in\mathcal{I}_c\}} - \sum_{j\in\mathcal{I}_c} x_{ji}$ is the quantity of good i produced in country c, net of the quantity of that good that is demanded for intermediate uses by domestic producers. In accordance with the System of National Accounts, GDP equals the total income generated by the factors of production employed in its production.

The nominal gross national expenditure (GNE) of a country is the total final expenditures of the residents of that country. Since there is no role for savings, GNE coincides with gross national income (GNI). Thus, for country c,

$$\mathrm{GNE}_c := \sum_{i\in\mathcal{I}} p_i c_{ci} = \sum_{f\in\mathcal{F}} \Phi_{cf} w_f L_f + \sum_{i\in\mathcal{I}} \Phi_{ci} \left(1 - \frac{1}{\mu_i}\right) p_i y_i + T_c.$$

In contrast to GDP, ownership shares Φ_c are relevant for GNE. This is because income, which determines expenditures, may originate from different geographical sources.

Real Output and Expenditure. One can convert nominal variables into real ones by using Divisia indices. The change in real GDP and the corresponding GDP deflator are

$$\mathrm{d}\log Y_c = \sum_{i\in\mathcal{I}} \Omega_{Y_c,i} \mathrm{d}\log q_{ci}, \qquad \mathrm{d}\log P_{Y_c} = \sum_{i\in\mathcal{I}} \Omega_{Y_c,i} \mathrm{d}\log p_i,$$

where $\Omega_{Y_c,i} \equiv (p_i q_{ci})/\mathrm{GDP}_c$ is the share of good i in final output of country c.

Similarly, the change in real GNE for country c and the corresponding deflator are

$$\mathrm{d}\log W_c = \sum_{i\in\mathcal{I}} \Omega_{W_c,i} \mathrm{d}\log c_{ci}, \qquad \mathrm{d}\log P_{W_c} = \sum_{i\in\mathcal{I}} \Omega_{W_c,i} \mathrm{d}\log p_i,$$

where $\Omega_{W_c,i} \equiv (p_i c_{ci})/\mathrm{GNE}_c$ is the share of good i in country c's consumption basket. As noted by Baqaee and Farhi, an implication of Shephard's lemma is that, in this economy, changes in real GNE are equal to changes in welfare.[11]

Input-Output Matrices. The world's revenue-based input-output (IO) matrix, denoted by Ω, is of dimension $(C+I+F)\times(C+I+F)$ and has generic entries Ω_{ij} specifying i's expenditures on j as a share of i's total revenues or income. Hence,

$$\Omega_{ij} = \frac{p_j c_{ij}}{\mathrm{GNE}_i}\mathbf{1}_{\{i\in\mathcal{C}\ \wedge\ j\in\mathcal{I}\}} + \frac{p_j x_{ij}}{p_i y_i}\mathbf{1}_{\{i\in\mathcal{I}\ \wedge\ j\in\mathcal{I}\}} + \frac{w_f \ell_{if}}{p_i y_i}\mathbf{1}_{\{i\in\mathcal{I}\ \wedge\ j\in\mathcal{F}\}}.$$

Thus, whenever $i\in\mathcal{F}$ or $j\in\mathcal{C}$, $\Omega_{ij}=0$ (factors have zero expenditures and households sell no resources). If $i\in\mathcal{C}$ and $j\in\mathcal{F}$, $\Omega_{ij}=0$ (households demand no primary factors). The only interesting cases are: $i\in\mathcal{C}$ and $j\in\mathcal{I}$ (household's final consumptions), $i,j\in\mathcal{I}$ (intermediate input transactions), and $i\in\mathcal{I}$ and $j\in\mathcal{F}$ (producers' factor demands).

Equipped with the revenue-based IO matrix, one can construct the revenue-based Leontief inverse according to:

$$\Psi = (\boldsymbol{I}-\Omega)^{-1} = \sum_{p=0}^{\infty}\Omega^p.$$

In addition to the revenue-based IO matrix Ω, one can define the cost-based IO matrix $\tilde{\Omega}$ and the associated Leontief inverse $\tilde{\Psi}$, which capture exposures in costs.

[11] In Basu and Fernald (2002)'s framework, welfare change is proportional to the change in real GDP because the economy is closed and, in that case, real GDP and real GNE coincide in the absence of savings. Moreover, factors of production are elastically supplied in Basu and Fernald's economy, in which case the relationship between welfare change and real GDP change is proportional, not exact.

Doing so requires additional knowledge on the vector of wedges $\boldsymbol{\mu}$. These objects are:

$$\tilde{\Omega} = \text{diag}(\boldsymbol{\mu})\Omega, \qquad \tilde{\Psi} = (\boldsymbol{I} - \tilde{\Omega})^{-1}.$$

Cost-based concepts are relevant in distorted economies where $\Omega \neq \tilde{\Omega}$ and, hence, $\Psi \neq \tilde{\Psi}$. In efficient economies, these objects coincide since $\boldsymbol{\mu} = \mathbf{1}$ (there are no distortions).

Exposures and Domar Weights. Each $i \in \mathcal{C} + \mathcal{I} + \mathcal{F}$, where the symbol $+$ here denotes set union, is exposed to each $j \in \mathcal{C} + \mathcal{I} + \mathcal{F}$ through both revenues Ψ_{ij} and costs $\tilde{\Psi}_{ij}$. While Ψ_{ij} captures *backward* linkages (i.e., how expenditures on i affect the sales of j), $\tilde{\Psi}_{ij}$ reflects *forward* linkages (i.e., how the price of j affects the marginal cost of i).

A country or household is exposed in production (or GDP) and in welfare (or GNE) to each $j \in \mathcal{C} + \mathcal{I} + \mathcal{F}$, as reflected by the following equations:

$$\lambda_j^{Y_c} = \sum_{i \in \mathcal{I}} \Omega_{Y_c,i} \Psi_{ij}, \qquad \tilde{\lambda}_j^{Y_c} = \sum_{i \in \mathcal{I}} \Omega_{Y_c,i} \tilde{\Psi}_{ij}, \qquad \text{(Exposures in production)}$$

$$\lambda_j^{W_c} = \Psi_{cj} = \sum_{i \in \mathcal{I}} \Omega_{c,i} \Psi_{ij}, \qquad \tilde{\lambda}_j^{W_c} = \tilde{\Psi}_{cj} = \sum_{i \in \mathcal{I}} \tilde{\Omega}_{c,i} \tilde{\Psi}_{ij}. \qquad \text{(Exposures in welfare)}$$

Importantly, note that welfare exposures are recorded in Leontief inverses. Moreover, notice that when $j \in \mathcal{I}_c$, $\lambda_j^{Y_c}$ and $\tilde{\lambda}_j^{Y_c}$ give the revenue-based and cost-based (local) Domar weights of producer j in country c, respectively. The former is simply the sales of producer j as a fraction of country c's GDP. That is, $\lambda_j^{Y_c} = (p_j y_j)/\text{GDP}_c$, for $j \in \mathcal{I}_c$. Domar weights for foreign producers $j \in \mathcal{I} - \mathcal{I}_c$ are computed as

$$\lambda_j^{Y_c} = \sum_{k \in \mathcal{I}_c} \sum_{l \in \mathcal{I}_c} \Omega_{Y_c,k} \Psi_{kl}^c \Omega_{lj} = -\frac{p_j q_{cj}}{\text{GDP}_c}, \qquad \tilde{\lambda}_j^{Y_c} = \sum_{k \in \mathcal{I}_c} \sum_{l \in \mathcal{I}_c} \Omega_{Y_c,k} \tilde{\Psi}_{kl}^c \tilde{\Omega}_{lj},$$

where c superscripts denote local objects of country c. That is, Ψ^c and $\tilde{\Psi}^c$ are country c's revenue-based and cost-based Leontief inverses, respectively. It follows from this notation that the revenue-based Domar weight of a foreign producer is simply the ratio of this producer's sales to local producers to domestic GDP.

Since exposures of factors are prominent objects on their own, it is convenient to adopt special notation to differentiate them from others. When j is a factor, let Λ and $\tilde{\Lambda}$ denote exposures. That is, when $f \in \mathcal{F}$, $\Lambda_f^{Y_c} \equiv \lambda_f^{Y_c}$, $\Lambda_f^{W_c} \equiv \lambda_f^{W_c}$, $\tilde{\Lambda}_f^{Y_c} \equiv \tilde{\lambda}_f^{Y_c}$, and $\tilde{\Lambda}_f^{W_c} \equiv \tilde{\lambda}_f^{W_c}$. Hence, $\Lambda_f^{Y_c}$ records the income that accrues to factor f as a share of the nominal output of country c, and $\tilde{\Lambda}_f^{Y_c}$ gives the costs of factor f as a share of the total costs incurred in the production of output in country c. Importantly, $\Lambda_f^{Y_c}$ is not to be confused with the income share of factor f in country c, which is given by $\Lambda_f^c = \frac{\Phi_{cf} w_f L_f}{\text{GNI}_c} = \frac{\Phi_{cf} w_f L_f}{\text{GNE}_c}$.

4 First-Order Decompositions of TFP and Welfare Growth

Definition 1 (Aggregate TFP Growth)**.** *Aggregate TFP growth of country c is*

$$\mathrm{d}\log TFP_c := \mathrm{d}\log Y_c - \sum_{f\in\mathcal{F}_c} \tilde{\Lambda}_f^{Y_c}\,\mathrm{d}\log L_f,$$

where $\mathrm{d}\log Y_c$ is the real-output growth of country c, $\tilde{\Lambda}_f^{Y_c}$ is the cost-based factor share of domestic factor $f \in \mathcal{F}_c$, and $\mathrm{d}\log L_f$ is its growth rate.

This definition generalizes earlier formulations by Solow (1957) and Hall (1988), allowing for open economies, multiple production sectors, and arbitrary input-output linkages. As discussed in Section 2.1, the use of cost-based shares is necessary to isolate true productivity changes from changes in distortions. Following Baqaee and Farhi (2024), aggregate TFP and welfare growth can be decomposed into structural forces using first-order approximations.

Theorem 1 (**First-Order Decomposition of Aggregate TFP Growth**)**.** *Aggregate TFP growth for country c can be decomposed up to a first-order approximation into changes in technical efficiency, distortions, income shares, and international trade:*

$$\mathrm{d}\log TFP_c \approx \underbrace{\sum_{i\in\mathcal{I}_c} \tilde{\lambda}_i^{Y_c}\,\mathrm{d}\log A_i}_{\Delta\textit{Technical efficiency}} \underbrace{- \underbrace{\sum_{i\in\mathcal{I}_c} \tilde{\lambda}_i^{Y_c}\,\mathrm{d}\log \mu_i}_{\Delta\textit{Distortions}} - \underbrace{\sum_{f\in\mathcal{F}_c} \tilde{\Lambda}_f^{Y_c}\,\mathrm{d}\log \Lambda_f^{Y_c}}_{\Delta\textit{Income shares}}}_{\Delta\ \textit{Domestic reallocation}}$$
$$+ \underbrace{\sum_{i\in\mathcal{I}-\mathcal{I}_c} \left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right)\left(\mathrm{d}\log q_{ci} - \mathrm{d}\log \lambda_i^{Y_c}\right)}_{\Delta\textit{International trade}}. \tag{6}$$

See Proof in Appendix B.4.

This decomposition extends Hulten (1978) and Baqaee and Farhi (2020). When the economy is closed and undistorted, it collapses to the classic Domar-weighted sum:

$$\mathrm{d}\log TFP_c \approx \sum_{i\in\mathcal{I}_c} \lambda_i^{Y_c}\,\mathrm{d}\log A_i. \tag{7}$$

In distorted economies, reallocation effects appear. The international term captures compositional shifts due to changing reliance on foreign intermediate inputs. Whether this raises or lowers TFP depends on the correlation between foreign inputs' growth and their cost-based Domar weights.

Theorem 2 (First-Order Decomposition of Welfare Growth). *Welfare growth for country c can be decomposed up to a first-order approximation into changes in technical efficiency, factors, distortions, income shares, and transfers:*

$$\begin{aligned}
\mathrm{d}\log W_c \approx\; & \underbrace{\underbrace{\sum_{i\in\mathcal{I}} \tilde{\lambda}_i^{W_c}\,\mathrm{d}\log A_i}_{\Delta\text{Technical efficiency}} + \underbrace{\sum_{f\in\mathcal{F}} \tilde{\Lambda}_f^{W_c}\,\mathrm{d}\log L_f}_{\Delta\text{Factors}}}_{\Delta\text{ Technology}} \\
& \underbrace{\underbrace{-\sum_{i\in\mathcal{I}} \tilde{\lambda}_i^{W_c}\,\mathrm{d}\log \mu_i}_{\Delta\text{Distortions}} + \underbrace{\sum_{f\in\mathcal{F}^*} \left(\Lambda_f^c - \tilde{\Lambda}_f^{W_c}\right)\mathrm{d}\log \Lambda_f}_{\Delta\text{Factor income shares}} + \underbrace{\frac{\mathrm{d}T_c}{GNE_c}}_{\Delta\text{Transfers}}}_{\Delta\text{ Allocation}},
\end{aligned} \tag{8}$$

where $\mathcal{F}^*$ denotes the set of all factors (fictitious and real), where fictitious factors f^* capture exposures to wedges and for which $\tilde{\Lambda}_f^{W_c} = 0$.

See Proof in Appendix B.5.

Expression (8) shows that welfare changes arise from technical progress, factor accumulation, reallocation, and transfers. Unlike the decomposition of TFP—which captures only domestic production-side forces—the welfare decomposition accounts for all factors that influence a country's ability to consume, including foreign productivity and distortions affecting imported goods.

5 Data and Estimation

This section describes the data sources and estimation procedures used to measure aggregate productivity and welfare.

I rely on four main data sources. The World Input-Output Database (WIOD) provides sector-level data on input-output linkages within and across countries, final consumption demand, and supplementary information on factor usage. I use WIOD to estimate distortions and construct input-output matrices. These data are complemented by the KLEMS Growth and Productivty Accounts, which offer industry-level measures of output and inputs. KLEMS provides more detailed information on the composition of production factors than WIOD, though the two datasets are consistent, as WIOD was constructed using KLEMS as an input. To estimate sector-specific depreciation rates, I use KLEMS data on capital stocks together with asset-specific depreciation rates from the Bureau of Economic Analysis (BEA) Fixed Asset Tables. Finally, I use the World

Bank database for GDP and CPI deflators to compute real GDP and real GNE. Fruther details on data construction and adjustments are provided in Appendices D.1–D.6.

The analysis spans the period 1970–2010 and uses annual data.[12] The units of observation are 25 countries or regions (24 individual countries plus a rest-of-world region), each comprising 23 production sectors and 2 primary factors (capital and labor). This yields a global production network of 575 producers (25 × 23) in each year, summarized by a 575×575 Leontief inverse matrix containing approximately 330,000 entries annually. Over the 40-year sample period, the Leontief matrices alone yield over 13 million data points. Additional data include sector-level expenditures on capital and labor, and households-level final demands for domestic and foreign goods.

5.1 Estimation

To compute and decompose aggregate TFP and welfare, I estimate three key inputs for each sector-country-year: distortions, net-of depreciation user costs of capital, and depreciation rates.

5.1.1 Distortions

A central challenge in measuring aggregate TFP in distorted economies is the need to quantify producer-level distortions. In my preferred specification, I estimate distortions non-parametrically for each producer i as

$$\mu_i = 1 + \frac{\text{wedge margin}_i}{1 - \text{wedge margin}_i},$$
$$\text{Wedge margin}_i := \frac{p_i y_i - \sum_{j \in \mathcal{I}} p_j x_{ij} - w_i \ell_i - (\delta_i + r_i) k_i}{p_i y_i},$$

where $p_i y_i$ denote sales, $\sum_j p_j x_{ij}$ is total intermediate input expenditure, $w_i \ell_i$ is the wage bill, and $(\delta_i + r_i) k_i$ is the gross user cost of capital.

The wedge margin captures the share of revenue not absorbed by input costs and thus reflects pricing above marginal cost. This residual may arise from monopolistic markups, taxes, or other frictions. By construction, $\mu_i = 1$ under marginal-cost pricing, so $\mu_i > 1$ signals distortions. An undistorted economy satisfies $\mu_i = 1$ for all i.

This approach allows distortions to vary flexibly across sectors, countries, and over time. Appendix C elaborates on this method and presents other measures used for robustness checks. My baseline estimates point to a clear upward trend in distortions

[12]The end year is 2010 because WIOD extends only to 2014, and capital stock series are truncated for many countries beginning in 2010.

in Spain between 1970 and 2010 (see Figure 13 in Appendix D.7). For Italy, distortions remain relatively constant over time.

5.1.2 Net-of-depreciation User Cost of Capital

To compute distortions, I must estimate both net-of-depreciation user costs of capital and depreciation rates. While data on sectoral output, intermediate input purchases, and labor compensation are directly observed, capital costs must be imputed. I estimate user costs using the method of van Vlokhoven (2022), described in Appendix C.1. This approach exploits cross-sectional variation in input choices to infer implicit user costs.

A key identifying assumption is that net-of-depreciation user costs are equalized across sectors within each country. Although admittedly strong—sectoral heterogeneity in user costs likely exists—it is preferable to the alternative of assuming that user costs are equalized across countries within each sector. Given data limitations, this tradeoff is necessary for implementation.

5.1.3 Depreciation Rates

Sector-specific depreciation rates are computed as weighted averages of asset-specific rates, where the weights reflect the composition of the sector's capital stock:

$$\delta_{ict} = \sum_j \frac{K_{jict}}{K_{ict}} \delta_{jt},$$

where i indexes sectors, c countries, t years, and j asset types (e.g., IT, machinery, transportation equipment). Consequently, K_{jict} denotes the amount of capital of type j in sector i of country c at time t, and K_{ict} is the sector's total capital stock. The term δ_{jt} is the depreciation rate associated with asset type j in year t.

A detailed explanation of the estimation procedure is provided in Appendix D.6. In brief, the method accommodates changing asset compositions across sectors and time. The resulting depreciation rates fall within plausible ranges and exhibit a gradual upward trend from 1970 to 2010, consistent with the increasing role of high-depreciation capital such as computing, communications, and transport equipment.

Aggregate TFP and Welfare. With distortion estimates in hand, I compute cost-based domestic factor shares as $\tilde{\Lambda}_f^{Y_c} = \sum_{i \in \mathcal{I}} \Omega_{Y_c,i} \tilde{\Psi}_{if}$ and construct the aggregate TFP following Definition 1. I measure welfare growth as the growth rate of real GNE per capita. Appendix D.5 details how the model maps to the data.

6 Empirical Analysis

The Evolution of Aggregate Productivity. Figure 4 shows the evolution of aggregate TFP in Spain from 1970 to 2010. The dashed line represents the traditional Solow-based TFP index, which ignores distortions. In contrast, the solid line incorporates distortions and thus provides a more accurate measure of productivity.

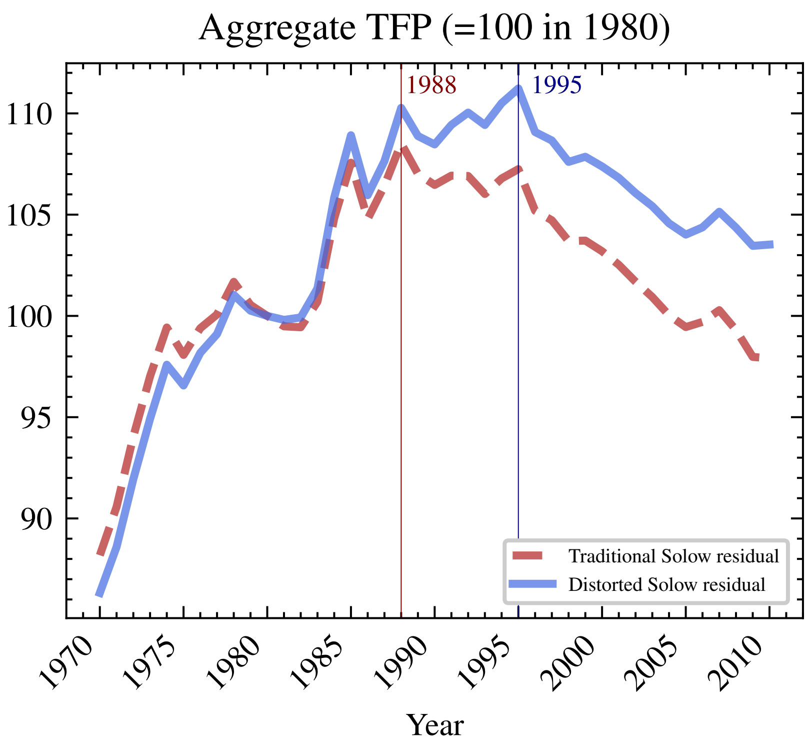


Figure 4: The Evolution of Aggregate TFP in Spain, 1970–2010.

Figure Notes. The index based on the traditional Solow residual assumes efficiency. The index based on the distorted Solow residual relaxes this assumption incorporating distortions, which are estimated non-parametrically using wedge margins. Indices are normalized to 100 in 1980. Vertical lines indicate the years in which the respective indices peak.

The first empirical finding of this paper is that the decline in aggregate productivity in Spain has been less severe than previously thought once distortions are taken into account. As shown in Figure 4, aggregate TFP continued to grow until 1995—rather than peaking in 1988, as implied by the traditional index. Moreover, the peak-to-trough decline is less pronounced under the distortion-adjusted index: seven percentage points, compared to ten under the standard measure.

The Sources of Productivity Growth. Figure 5 presents a cumulative first-order decomposition of aggregate TFP over the full sample period. The left panel disaggregates the contribution of each component, showing that improvements in technical efficiency, shifts in factor income shares, and international trade all contributed positively to productivity growth, while rising distortions had a negative impact. The right panel groups these drivers into three categories, combining distortions and factor shares into a single "reallocation" term. This decomposition reveals that technical efficiency was the dominant force, accounting for approximately 90% of aggregate TFP growth. International trade played a substantial supporting role, contributing around 40%. By contrast, reallocation across sectors reduced TFP by five percentage points—roughly 30% of the total gain.

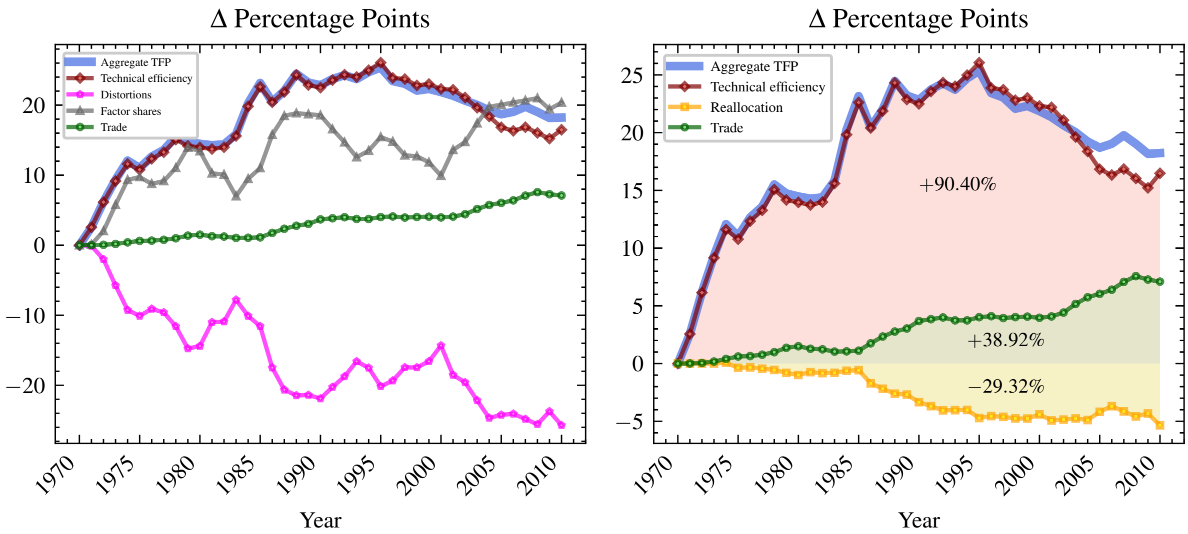


Figure 5: Cumulative First-order Decomposition of TFP in Spain, 1970–2010.

Figure Notes. Both panels present a first-order decomposition of aggregate TFP growth. The left panel displays the individual components of equation (6), while the right panel combines "distortions" and "income shares" into a single "reallocation" term. The decomposition uses Törnqvist weights and accumulates year-over-year changes.

Table 1 provides a detailed breakdown of the contributions of different channels to aggregate TFP growth in Spain. The analysis divides the 1970–2010 period into two subperiods: a trough-to-peak phase (1970–1995) and a peak-to-end phase (1995–2010). It also disaggregates the international trade term to isolate the contributions of major trade partners. The results reveal stark contrasts between the two periods, particularly in the trajectory of technical efficiency: it rose steadily before 1995, accounting for the bulk of TFP growth, but declined thereafter, exerting persistent downward pressure on productivity. The findings also underscore the importance of intra-European trade in sustaining Spanish TFP, reflecting the country's deepening regional integration.

Zooming into the Productivity Decline. Figure 6 focuses on the 1995–2010 subperiod to unpack the sources of Spain's productivity decline. As the preceding table shows, most of the decline was driven by deteriorating technical efficiency and adverse reallocation effects. Technical efficiency is computed as a residual and therefore captures not only pure efficiency losses but also higher-order effects. By contrast, international trade continued to support productivity during this period, primarily through increased integration with European partners.

Table 1: First-order decomposition of aggregate TFP growth in Spain, 1970–2010.

Time Period	Δ TFP	Δ Technical Efficiency	Δ Distortions	Δ Factor Shares	Δ Trade
1970–2010	+18.23 pp	+16.48 pp	−25.71 pp	+20.37 pp	+7.10 pp
(Overall period)	(100%)	(+90.40%)	(−141.03%)	(+111.71%)	(+38.92%)
Trade with:					
European countries*					+3.58 pp
China					+0.08 pp
India					+0.02 pp
Rest of world					+3.42 pp
1970–1995	+25.36 pp	+26.06 pp	−20.16 pp	+15.44 pp	+4.02 pp
(Through to peak)	(100%)	(+102.76%)	(−79.50%)	(+60.88%)	(+15.86%)
Trade with:					
European countries*					+1.99 pp
China					+0.01 pp
India					+0.01 pp
Rest of world					+2.01 pp
1995–2010	−7.13 pp	−7.82 pp	−10.07 pp	+7.97 pp	+2.78 pp
(Peak to end)	(100%)	(+109.52%)	(−141.04%)	(+111.62%)	(−38.93%)
Trade with:					
European countries*					+1.59 pp
China					+0.12 pp
India					+0.02 pp
Rest of world					+1.05 pp

Table Notes. Gains and losses are expressed in percentage points ("pp"). The list of European countries includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Sweden, and the United Kingdom.

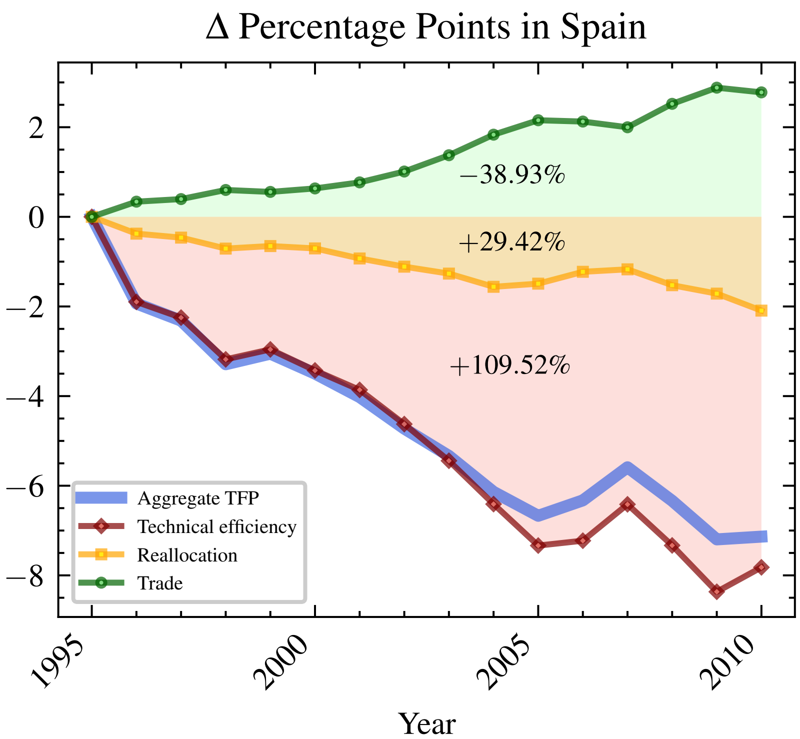


Figure 6: Cumulative First-Order Decomposition of TFP Decline in Spain, 1995–2010.

Figure Notes. Technical efficiency is computed as the residual of TFP minus the reallocation and trade terms. The reallocation term is the sum of changes in distortions and income shares.

The Diverging Paths of Productivity and Welfare. Figure 7 presents the joint evolution of aggregate TFP and welfare in Spain, with welfare measured as real GNE per capita, alongside a first-order decomposition of welfare growth. As the left panel shows, both indicators rose steadily from 1970 to 1995. Afterward, however, their trajectories diverged: aggregate productivity declined, while welfare continued to rise. This divergence underscores a key insight: in an open economy, production and consumption need not move in tandem. A country may experience declining production efficiency yet still enjoy rising welfare if international trade enables consumers to access cheaper or higher-quality goods. This pattern characterizes Spain's post-1995 experience. It also exposes a limitation of much of the existing literature, which often relies on closed-economy growth accounting framework where welfare is implicitly assumed to move proportionally with productivity.

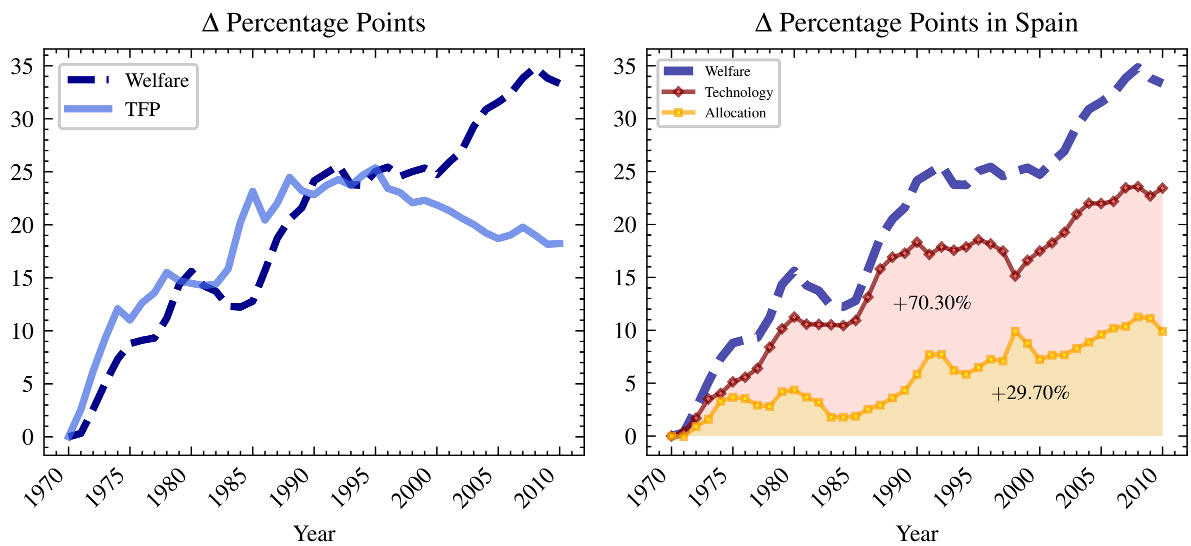


Figure 7: The Evolution of Welfare and TFP in Spain, 1970–2010.

Figure Notes. The left panel shows the evolution of aggregate productivity *vis-à-vis* welfare. The right panel provides a first-order decomposition of welfare growth into technology and allocative efficiency.

The right panel of the figure reveals that Spain's welfare gains were primarily driven by global technological progress and cross-country reallocation effects. These forces once again underscore the interconnected nature of the modern global economy and the extent to which external dynamics can shape domestic welfare.

The Evolution of TFP and Welfare Under a Counterfactual Allocation. To assess the role of structural transformation in shaping the dynamics of aggregate productivity and welfare, I construct a counterfactual scenario in which sectoral weights are held constant at their 1995 levels—the year in which aggregate TFP began to decline. Figure 8 presents the results of this exercise. The left panel displays the evolution of TFP and its first-order decomposition under the counterfactual from 1995 onward. Strikingly, aggregate productivity increases by nearly fifteen percentage points between 1995 and 2010, implying an average annual gain of about one percentage point. This stands in sharp contrast to actual TFP, which fell by approximately seven percentage points over the same period. The decomposition shows that reallocation effects contribute just half a percentage point to the counterfactual productivity increase, while international trade adds around two percentage points. The remainder—more than twelve percentage points—is attributable to gains in technical efficiency. These findings suggest that the observed decline in productivity was primarily driven by compositional changes in the structure of production, rather than by technological regress.

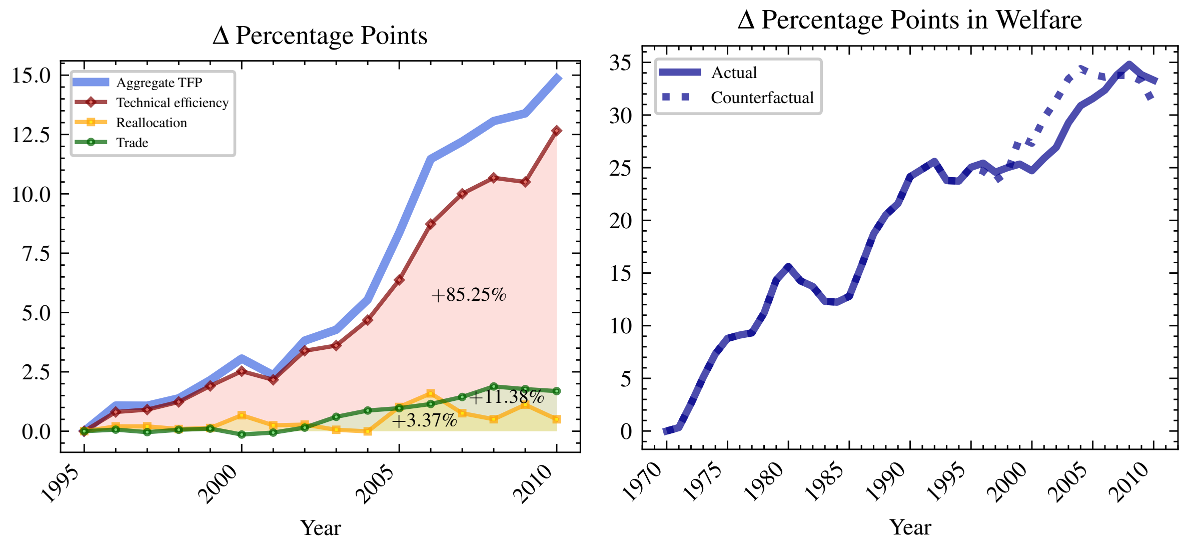


Figure 8: Counterfactual TFP and Welfare in Spain, 1970–2010.

Figure Notes. The left panel shows the evolution of aggregate TFP and its first-order decomposition under the counterfactual in which the allocation of labor and capital across sectors is held constant at 1995 levels. The right panel compares actual welfare with its counterfactual counterpart computed under the same fixed allocation.

The right panel compares actual and counterfactual changes in welfare over the full sample period. By construction, both series coincide through 1995, as the counterfactual scenario beings only in that year. From 1995 onward, welfare increases more rapidly under the counterfactual scenario, reflecting the productivity gains from holding producer weights fixed. Over time, however, the gap narrows, and by 2010, the actual welfare gain slightly exceeds the counterfactual one by more than two percentage points. This suggest that, despite the adverse impact of structural transformation on productivity, the reallocation of resources across sectors ultimately supported aggregate welfare—likely through improved consumption opportunities enabled by trade integration and external technological progress.

Production Networks, TFP Decompositions, and Income Shares. While input-output linkages do not affect the measurement of aggregate productivity, they are crucial for understanding related outcomes—such as the sources of productivity growth and the distribution of income. Figure 9 illustrates this point: ignoring production networks leaves the TFP index unchanged (left panel) but leads to markedly different estimates of income shares (see right panel) due to double marginalization—that is, the amplification of distortions as they propagate through the production network.

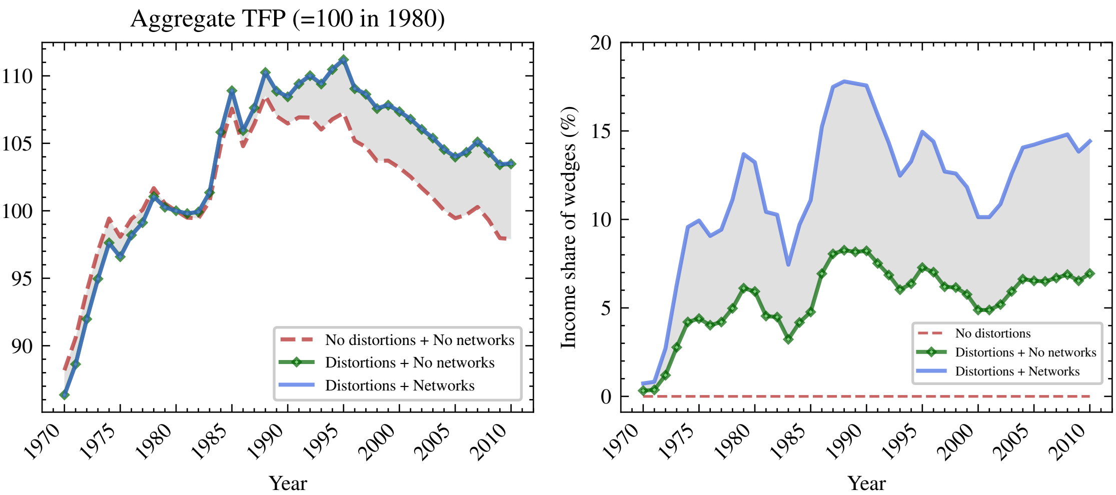


Figure 9: Biases in TFP indices and the income share of wedges, Spain, 1970–2010.

Figure Notes. The left panel plots three different TFP indices, all normalized to 100 in 1980. The right panel shows the share of income that accrues to wedges under three different assumptions: (i) there are no distortions, (ii) there are distortions but no production linkages; (iii) there are both distortions and global production linkages.

The finding that ignoring production networks leads to substantially underestimating the share of income accruing to wedges (or profits) carries important implications for the large empirical literature on market power. In particular, profit shares computed using sales-weighted profit rates systematically understate the true profit share (see Hasenzagl and Perez, 2023, for a related discussion.)[13]

Figure 10 plots the evolution of income shares in Spain from 1970 to 2010. The labor share declined from 63% to 57%, consistent with the global trend documented by Karabarbounis and Neiman (2014). The capital share also fell—from 37% to 28%—with most of the decline occurring before the mid-1980s. In contrast, the income share accruing to wedges rose steadily, reaching 15% by 2010. While this trend is noteworthy, it should be interpreted with caution. The analysis abstracts from returns to scale, and it is plausible that rising distortions coincided with increasing returns to scale, as documented by Hasenzagl and Perez (2023) for the United States during a similar period. If so, the capital share shown in Figure 10 likely understates its true value, while the wedge share is overstated.

[13] Hasenzagl and Perez (2023) generalize the production side of Baqaee and Farhi (2024) to allow for arbitrary returns to scale and market power in input markets. They provide a characterization of the aggregate profit share in terms of the input-output multiplier and economy-wide indicators of market power, including the aggregate markup, aggregate monopsony power, and aggregate returns to scale.

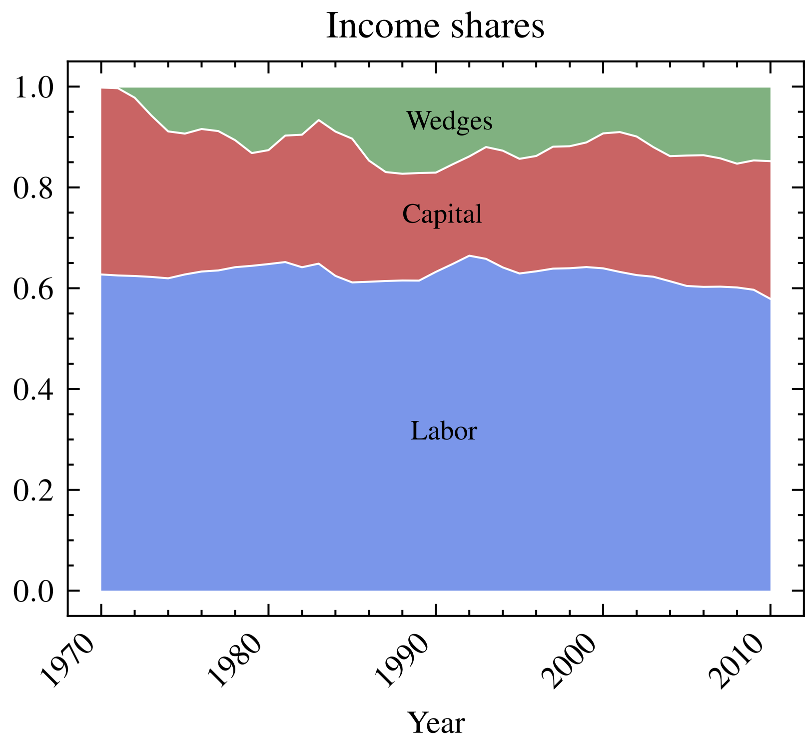


Figure 10: Evolution of Income Shares in Spain, 1970–2010.

Figure Notes. Income shares are computed after subtracting taxes from total income. That is, I compute the share of labor-, capital-, and wedge income by dividing the income generated by that factor/source over net-of-taxes aggregate value added.

Robustness Exercises. All results in this section depend on distortions estimated using wedge margins. Because these estimates are central to the analysis of both aggregate TFP dynamics and income share accruing to wedges, I conduct robustness checks in Appendix E. The main finding is that alternative measures of distortions do not qualitatively change the results—neither the trajectory of TFP nor the evolution of income shares.

The Case of Italy. To streamline the exposition, I focus on Spain in the main text and relegate the discussion of Italy to Appendix F. Nevertheless, the conclusions from that analysis are qualitatively similar. First, the decline in aggregate TFP in Italy appears less severe than suggested by the traditional Solow-based index: aggregate TFP peaks in 2000 rather than in 1995, a result that is robust across alternative distortion estimates. Second, the main contributors to Italy's TFP growth are technical efficiency, international trade, and reallocation—a ranking that holds across different specifications. Third, whereas the wedge income share in Spain rose substantially over time, in Italy it remained relatively stable, fluctuating around 3% and 5%. Italy's TFP decline is thus driven almost entirely by deteriorating technical efficiency. Finally, as in Spain, welfare increased despite falling productivity.

7 Conclusion

In this paper, I reexamine the evolution of total factor productivity (TFP) and its relationship to welfare in Spain and Italy from 1970 to 2010. Using a growth-accounting framework tailored to open and distorted economies with input-output linkages, I find that the trajectory of aggregate TFP has been less dismal than previously thought. Discrepancies with earlier studies stem from the presence of distortions which, as Hall (1988) first noted, bias traditional TFP measures. Accounting for distortions, I show that aggregate TFP peaked later than commonly reported—1995 for Spain and 2000 for Italy, rather than the conventional dates of 1988 and 1995. Moreover, I find that the magnitude of the declines is 25–40% smaller than implied by conventional estimates.

To understand the sources of these productivity declines, I perform non-parametric, first-order decompositions. These reveal that falling technical efficiency is the principal contributor to TFP losses, followed by sectoral reallocation. In contrast, international trade consistently supported productivity. While the decline in technical efficiency may appear to reflect technological regress, this interpretation is likely too strong. Because technical efficiency is computed as a residual, it also captures nonlinear effects, measurement errors, and unobserved within-sector reallocation.

A central finding in this paper is that, despite declining TFP, welfare—measured by real GNE per capita—increased in both Spain and Italy. This divergence between productivity and welfare arises naturally in an open-economy setting where the gains from trade can raise living standards even as domestic production efficiency deteriorates. First-order decompositions of welfare growth reveal that both countries benefited substantially from global technological progress and cross-country reallocation effects, which more than offset the drag from domestic productivity losses.

While this analysis departs from standard approaches by incorporating distortions, openness to trade, and production networks, it has several limitations. Chief among them is aggregation bias: sector-level data obscure potentially important within-sector reallocations, which may account for part of the decline in technical efficiency. Addressing this limitation would require firm-level data with input-output linkages, which are rarely available. Additional challenges include measurement issues, such as estimating capital stocks and depreciation rates—especially for intangible and organizational capital, which are poorly captured in National Accounts. Finally, the analysis abstracts from variation in factor utilization and assumes full mobility of production factors.

References

Ackerberg, D. A., Caves, K. and Frazer, G. (2015). Identification properties of recent production function estimators, *Econometrica* **83**(6): 2411–2451.

Anderson, E., Rebelo, S. and Wong, A. (2020). Markups across space and time.

Antrás, P. and Chor, D. (2022). Global value chains, *Handbook of international economics* **5**: 297–376.

Arkolakis, C., Costinot, A. and Rodríguez-Clare, A. (2012). New trade models, same old gains?, *American Economic Review* **102**(1): 94–130.

Baldwin, R. and Lopez-Gonzalez, J. (2015). Supply-chain trade: A portrait of global patterns and several testable hypotheses, *The world economy* **38**(11): 1682–1721.

Baqaee, D. and Farhi, E. (2019a). A short note on aggregating productivity, *Technical report*, National Bureau of Economic Research.

Baqaee, D. R. and Farhi, E. (2018). Macroeconomics with heterogeneous agents and input-output networks, *Technical report*, National Bureau of Economic Research.

Baqaee, D. R. and Farhi, E. (2019b). The macroeconomic impact of microeconomic shocks: Beyond hulten's theorem, *Econometrica* **87**(4): 1155–1203.

Baqaee, D. R. and Farhi, E. (2020). Productivity and misallocation in general equilibrium, *The Quarterly Journal of Economics* **135**(1): 105–163.

Baqaee, D. R. and Farhi, E. (2024). Networks, barriers, and trade, *Econometrica* **92**(2): 505–541.

Basu, S. and Fernald, J. G. (2002). Aggregate productivity and aggregate technology, *European Economic Review* **46**(6): 963–991.

Benigno, G. and Fornaro, L. (2014). The financial resource curse, *The Scandinavian Journal of Economics* **116**(1): 58–86.

Caliendo, L. and Parro, F. (2015). Estimates of the trade and welfare effects of nafta, *The Review of Economic Studies* **82**(1): 1–44.

Calligaris, S., Del Gatto, M., Hassan, F., Ottaviano, G. I., Schivardi, F. et al. (2016). Italy's productivity conundrum. a study on resource misallocation in italy, *Technical report*, Directorate General Economic and Financial Affairs (DG ECFIN), European ....

Chari, V. V., Kehoe, P. J. and McGrattan, E. R. (2007). Business cycle accounting, *Econometrica* **75**(3): 781–836.

De Gregorio, J., Giovannini, A. and Wolf, H. C. (1994). International evidence on tradables and nontradables inflation, *European Economic Review* **38**(6): 1225–1244.

De Loecker, J., Eeckhout, J. and Unger, G. (2020). The rise of market power and the macroeconomic implications, *The Quarterly Journal of Economics* **135**(2): 561–644.

De Loecker, J., Goldberg, P. K., Khandelwal, A. K. and Pavcnik, N. (2016). Prices, markups, and trade reform, *Econometrica* **84**(2): 445–510.

Díaz, A. and Franjo, L. (2016). Capital goods, measured tfp and growth: The case of spain, *European Economic Review* **83**: 19–39.

Domar, E. D. (1961). On the measurement of technological change, *The Economic Journal* **71**(284): 709–729.

Domowitz, I., Hubbard, R. G. and Petersen, B. C. (1986). Business cycles and the relationship between concentration and price-cost margins, *The RAND Journal of Economics* pp. 1–17.

Edmond, C., Midrigan, V. and Xu, D. Y. (2023). How costly are markups?, *Journal of Political Economy* **131**(7): 000–000.

Foster, L., Haltiwanger, J. and Syverson, C. (2008). Reallocation, firm turnover, and efficiency: Selection on productivity or profitability?, *American Economic Review* **98**(1): 394–425.

Fu, C. and Moral Benito, E. (2018). The evolution of spanish total factor productivity since the global financial crisis, *Documentos ocasionales/Banco de España, 1808* .

García-Santana, M., Moral-Benito, E., Pijoan-Mas, J. and Ramos, R. (2020). Growing like spain: 1995–2007, *International Economic Review* **61**(1): 383–416.

Gopinath, G., Kalemli-Özcan, Ş., Karabarbounis, L. and Villegas-Sanchez, C. (2017). Capital allocation and productivity in south europe, *The Quarterly Journal of Economics* **132**(4): 1915–1967.

Hall, R. E. (1986). Market structure and macroeconomic fluctuations, *Brookings papers on economic activity* **1986**(2): 285–338.

Hall, R. E. (1988). The relation between price and marginal cost in us industry, *Journal of political Economy* **96**(5): 921–947.

Hasenzagl, T. and Perez, L. (2023). The micro-aggregated profit share, *Working Paper* .

Hsieh, C.-T. and Klenow, P. J. (2009). Misallocation and manufacturing tfp in china and india, *The Quarterly Journal of Economics* **124**(4): 1403–1448.

Hulten, C. R. (1978). Growth accounting with intermediate inputs, *The Review of Economic Studies* **45**(3): 511–518.

Huo, Z., Levchenko, A. A. and Pandalai-Nayar, N. (2023). Utilization-adjusted tfp across countries: Measurement and implications for international comovement, *Journal of International Economics* **146**: 103753.

Johnson, R. C. and Noguera, G. (2017). A portrait of trade in value-added over four decades, *Review of Economics and Statistics* **99**(5): 896–911.

Jorgenson, D. W. and Griliches, Z. (1967). The explanation of productivity change, *The review of economic studies* **34**(3): 249–283.

Karabarbounis, L. and Neiman, B. (2014). The global decline of the labor share, *The Quarterly journal of economics* **129**(1): 61–103.

Kehoe, T. J. and Ruhl, K. J. (2008). Are shocks to the terms of trade shocks to productivity?, *Review of Economic Dynamics* **11**(4): 804–819.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity, *econometrica* **71**(6): 1695–1725.

Menezes-Filho, N. A. and Muendler, M.-A. (2011). Labor reallocation in response to trade reform, *Technical report*, National Bureau of Economic Research.

Olley, G. S. and Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment, *Econometrica* **64**(6): 1263–1297.

Oulton, N. (2017). The mystery of tfp.

O'Mahony, M. and Timmer, M. P. (2009). Output, input and productivity measures at the industry level: the eu klems database, *The Economic Journal* **119**(538): F374–F403.

Pellegrino, B. and Zingales, L. (2019). Diagnosing the italian disease, *Technical report*, Working paper.

Reis, R. (2013). The portuguese slump and crash and the euro crisis, *Brookings Papers on Economic Activity* pp. 143–193.

Restuccia, D. and Rogerson, R. (2008). Policy distortions and aggregate productivity with heterogeneous establishments, *Review of Economic Dynamics* **11**(4): 707–720.

Schivardi, F. and Schmitz, T. (2020). The it revolution and southern europe's two lost decades, *Journal of the European Economic Association* **18**(5): 2441–2486.

Solow, R. M. (1957). Technical change and the aggregate production function, *The review of Economics and Statistics* pp. 312–320.

Timmer, M. P., O Mahony, M., Van Ark, B. et al. (2007). Eu klems growth and productivity accounts: an overview, *International Productivity Monitor* **14**: 71.

Tinbergen, J. (1942). Zur theorie der langfristigen wirtschaftsentwicklung, *Weltwirtschaftliches Archiv* pp. 511–549.

van Vlokhoven, H. (2022). Estimating the cost of capital and the profit share, *Working paper* .

Young, A. (1991). Learning by doing and the dynamic effects of international trade, *The Quarterly Journal of Economics* **106**(2): 369–405.

Appendices

"The Evolution of TFP in Spain and Italy"

Luis Pérez

May 23, 2025

List of Appendices

A TFP Mechanisms

This appendix provides a formal discussion of the mechanisms introduced in Section 2. To underscore the importance of accounting for both international trade and distortions when analyzing aggregate productivity, I present two illustrative examples. These examples demonstrate that either shifts in the terms of trade or changes in distortions can, in principle, generate the negative TFP growth observed in Spain and Italy.

The first example considers a small open economy with perfectly competitive producers. It shows that changes in the terms of trade can induce negative TFP growth, even in the absence of distortions. The second example examines a closed economy with exogenous markups, illustrating how changes in distortions can similarly induce negative productivity growth. Taken together, these examples suggest that a comprehensive framework for studying aggregate TFP must integrate both open-economy forces and distortions.

A.1 Trade and Aggregate TFP

Consider a small open economy with two production sectors (denoted by $i = 1, 2$), three factors of production (labor and sector-specific factors), and a representative household.

Producers. Each sector produces a tradable good using a constant returns-to-scale production function:

$$y_i = A_i \ell_i^{\phi} F_i^{1-\phi}, \quad \phi \in (0, 1), \tag{A.1}$$

where A_i denotes sector-specific productivity, ℓ_i is labor, F_i is a sector-specific fixed factor, and ϕ is a factor-intensity parameter that is common across sectors. Without loss of generality, I normalize $F_i = 1$, yielding $y_i = A_i \ell_i^{\phi}$.[14] Foreign producers supply perfect substitutes for each good at exogenous world prices.

Households. The representative household has Cobb–Douglas preferences

$$U(c_1, c_2) = c_1^{\alpha} c_2^{1-\alpha}, \qquad \alpha \in (0, 1), \tag{A.2}$$

and faces budget constraint

$$\sum_i p_i^w c_i \leq wL + \sum_i r_i, \tag{A.3}$$

[14]Notice that one can scale the productivity parameter to reflect differences in sector-specific factors.

where p_i^w is the world price of good i, w is the wage, L is inelastically labor, and r_i denotes the return to fixed factor F_i.

Definition 2 (Equilibrium in Small Open Economy)**.** *An equilibrium is a sequence of prices* $(\boldsymbol{p}^w, \boldsymbol{r}, w) \in \mathbb{R}^5_{++}$ *and allocations* $(\boldsymbol{c}, \boldsymbol{y}, \boldsymbol{\ell}, \boldsymbol{nx}) \in \mathbb{R}^8_+$ *such that:*

(i) World prices $\boldsymbol{p}^w$ *are exogenous, and rents of fixed factors satisfy* $r_i = p_i^w y_i - w\ell_i$.

(ii) The representative household chooses consumption goods $\boldsymbol{c} \in \mathbb{R}^2_+$ *to maximize (A.2) subject to budget constraint (A.3), taking prices as given.*

(iii) Producers choose labor demand $\ell_i \in \mathbb{R}_+$ *to maximize profits,* $p_i^w y_i - w\ell_i - r_i$*, where* y_i *is given by (A.1), taking prices as given.*

(iv) Markets clear. That is, $L = \sum_i \ell_i$ *for labor, and* $nx_i = y_i - c_i$ *for each good* $i \in \{1, 2\}$.

(v) The balance-of-payments condition holds: $\sum_i p_i^w nx_i = 0$.

Figure 11 depicts the equilibrium in the small open economy, shown in the left panel, and compares it with the autarky equilibrium, shown in the right panel.

Figure 11: Equilibrium in Undistorted Economies.

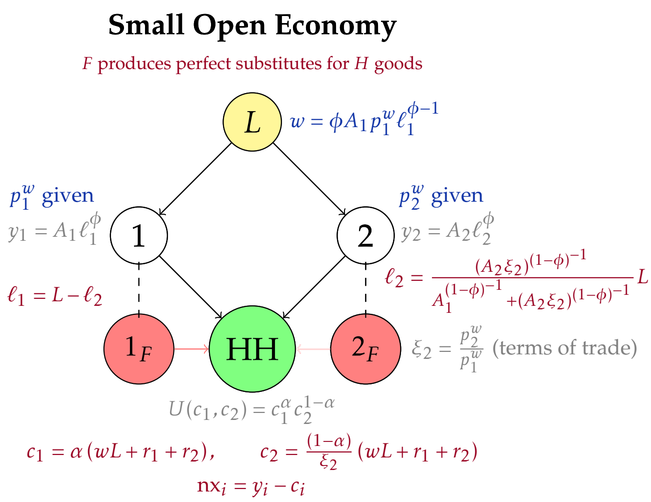


Figure Notes. L denotes labor, HH stands for household, 1 and 2 are domestic sectors, and 1_F and 2_F are foreign sectors. Objects in gray are model primitives (technology and preferences,) objects in blue are equilibrium prices (subject to the normalization $p_1 = 1$,) and objects in red are equilibrium allocations. For expositional clarity, sector-specific fixed factors and their rents are omitted.

Special Cases and Mechanism. The equilibrium characterization in Figure 11 is useful to illustrate several special cases, as well as for understanding the mediating channel through which changes in the terms of trade affect TFP growth. First, note that when the world's relative price of traded goods, p_2^w/p_1^w, equals the autarky relative price, p_2/p_1, no-trade is an equilibrium of the small open economy. Second, as $\phi \to 1$, the model converges to the classic Ricardian framework, where trade can lead to full specialization. The model features sector-specific factors to prevent the complete reallocation of mobile factors which would occur in the Ricardian model when the domestic economy opens up to trade and the world relative price differs from the autarky price. These sector-specific factors illustrate the key mechanism: Mobile production factors adjust in response to changes in the terms of trade, affecting the production structure and TFP growth when differences in productivity growth exist across sectors.

Growth Accounting. Nominal output is the value of final goods produced domestically. Since there are no intermediate goods in the small open economy outlined above, nominal output is simply given by $PY := \sum_i p_i^w y_i$. In light of the discussion in Section 2.1, the traditional Solow residual yields aggregate TFP growth since the economy is undistorted. Aggregate TFP growth is thus given by

$$\mathrm{d}\log \mathrm{TFP} := \mathrm{d}\log Y - \sum_f \Lambda_f \mathrm{d}\log L_f, \tag{A.4}$$

where $\mathrm{d}\log Y$ is real output growth, $\Lambda_f = w_f L_f/(PY)$ is the revenue share of factor $f \in \{L, F_1, F_2\}$, and $\mathrm{d}\log L_f$ is the growth of domestic factor f.

In an economy with multiple production sectors, calculating aggregate TFP growth requires having a notion of real output growth. Following standard practice in the literature, I obtain changes in real output using a Divisia quantity index:

$$\mathrm{d}\log Y = \sum_i \frac{p_i^w y_i}{PY} \mathrm{d}\log y_i.$$

This notion of real output growth weighs sectoral output growth using base-period weights. Importantly, all of the results provided in this section continue to apply with alternative notions of real output growth.[15]

Proposition 1 (Trade–TFP growth)**.** *There exist parametrizations for the small open economy in which: (i) absent terms-of-trade shocks, there is positive TFP growth; and (ii) for large-enough terms-of-trade shocks, there is negative TFP growth.* *See Proof in Appendix B.1.*

Interpretation and Remarks. Proposition 1 establishes that an economy can experience a decline in TFP due to changes in the terms of trade, and that, in absence of these changes, TFP would have grown. This proposition thus emphasizes the importance of considering international trade when studying TFP.

[15] Alternative notions of real output growth may use future-period weights, Törnqvist weights, or obtain real GDP using the ideal Fisher index.

Three remarks are worth noting. First, positive TFP growth can arise simply from productivity growth being larger in one sector than in the other (result i). Second, negative TFP growth can result from terms-of-trade shocks, which, when combined with productivity differences across sectors, can lead to a reallocation of resources toward the less productive sector (result ii). The combination of results (i) and (ii) requires parametrizations like those in Proposition 1, where both productivity and the terms of trade change in the right magnitude and direction.

Trade, TFP, and Welfare. Proposition 1 also highlights an important distinction: unlike in closed economy, TFP and welfare are not necessarily correlated in an open economy. Specifically, welfare can increase even in the presence of declining TFP, as demonstrated this proposition.[16]

A.2 Distortions and Aggregate TFP

Consider a closed economy with two production sectors ($i = 1, 2$), three factors of production (labor and sector-specific factors,) and a representative household.

Producers. Each sector produces a final consumption good using the technology described in equation (A.1), where once again the endowments of sector-specific fixed factors are normalized to unity without loss of generality. Producers set prices by charging exogenous markup $\mu_i \geq 1$ over marginal cost mc_i. The economy is distorted if at least one producer operates with a markup greater than unity (i.e., $\mu_i > 1$ for some i).

Households. The representative household has preferences as described by equation (A.2) and is subject to budget constraint

$$\sum_i p_i c_i \leq wL + \sum_i r_i + \sum_i \pi_i, \tag{A.5}$$

where p_i denotes the price of good i, c is consumption, w is the rate of return to labor L, which is inelastically supplied, r_i are the rents of sector-specific fixed factor F_i, and π_i is profit income of producer i, which is owned by the household. Profits are given by

$$\pi_i = p_i y_i - w\ell_i - r_i = \left(1 - \frac{1}{\mu_i}\right) p_i y_i. \tag{A.6}$$

[16] In a closed economy, welfare and TFP are perfectly correlated because, in the absence of savings, consumption equals production. Thus, one can show that welfare change is proportional to TFP change, assuming the existence of a representative consumer with homothetic preferences. In contrast, in an open economy, domestic production and consumption not need to equal each other. Domestic consumption can increase even if domestic production efficiency declines, for example, if domestic goods become relatively more valuable in international markets. In an open economy where each country is inhabited by a representative consumer with homothetic preferences, it can be shown that welfare changes are proportional to changes in real GNE, rather than to changes in domestic TFP.

Definition 3 (Equilibrium in Distorted Economy)**.** *An equilibrium is a sequence of prices* $(\boldsymbol{p}, \boldsymbol{r}, w) \in \mathbb{R}^5_{++}$ *and allocations* $(\boldsymbol{c}, \boldsymbol{y}, \boldsymbol{\ell}, \boldsymbol{\pi}) \in \mathbb{R}^8_+$ *such that:*

(i) Consumption goods' prices are set according to $p_i = \mu_i \times mc_i$ *for all* i*.*

(ii) Producers choose labor demand $\ell_i \in \mathbb{R}_+$ *to minimize costs taking prices as given.*

(iii) The representative household chooses consumption goods $\boldsymbol{c} \in \mathbb{R}^2_+$ *to maximize (A.2) subject to budget constraint (A.5), taking prices as given.*

(iv) Markets clear. That is, $L = \sum_i \ell_i$ *for labor, and* $y_i = c_i$ *for each good* $i \in \{1, 2\}$*.*

Figure 12 depicts the equilibrium in the distorted closed economy, where distortions take the form of markups.

Figure 12: Equilibrium in Distorted Closed Economy.

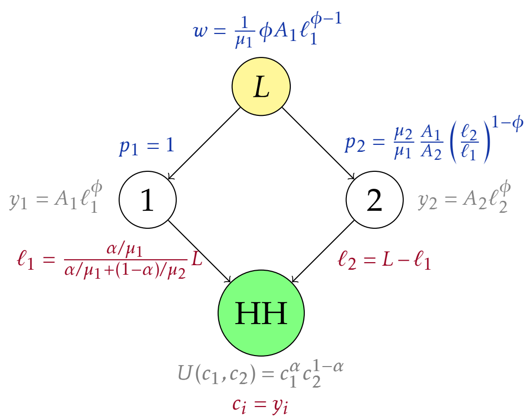


Figure Notes. L denotes labor, HH stands for household, 1 and 2 are production sectors. Objects in gray are model primitives (technology and preferences), objects in blue are equilibrium prices (subject to the normalization $p_1 = 1$), and objects in red are equilibrium allocations. For expositional clarity, sector-specific fixed factors and their rents are omitted.

Special Cases and Mechanism. When $\mu_1 \to 1$ for all $i \in \{1, 2\}$, this model simplifies to a perfectly competitive economy. In this case, producers charge prices equal to marginal costs, and the distortions introduced by markups are absent. This perfectly competitive scenario corresponds to the closed economy equilibrium depicted in Figure 11. Similar to the case of changes in the terms of trade, differential changes in markups can lead to the reallocation of production factors across sectors.

Growth Accounting. Nominal output and changes in real output are calculated in the same way as in Example A.1, using a Divisia index. However, because this economy is distorted due to the presence of markups, we adjust our measurement of TFP growth to account for these distortions. Specifically, instead of relying on revenue shares to weigh input growth, we use cost shares. By using the distorted Solow residual, we accurately measure TFP growth, which is given by

$$\mathrm{d}\log \mathrm{TFP} := \mathrm{d}\log Y - \sum_{f} \tilde{\Lambda}_f \,\mathrm{d}\log L_f, \tag{A.7}$$

where $\mathrm{d}\log Y$ is the growth of real output, $\tilde{\Lambda}_f = \frac{w_f L_f}{wL + r_1 + r_2}$ is the cost share of domestic factor $f \in \{L, F_1, F_2\}$, and $\mathrm{d}\log L_f$ is its growth.

Proposition 2 (Distortions–TFP growth)**.** *There exist parametrizations for the distorted economy in which: (i) absent markup shocks, there is positive TFP growth; and (ii) for large-enough markup shocks, there is negative TFP growth. See Proof in Appendix B.2.*

Interpretation and Remarks. Proposition 2 demonstrates that an economy can experience a decline in TFP due to changes in distortions and that TFP would have increased in the absence of these changes. This insight, along with the measurement problems discussed in section 2.1, leads to incorporate distortions into the analysis of aggregate TFP in Southern Europe.

Extending the logic of Proposition 1, positive TFP growth requires productivity to grow proportionally more in one sector than in the other. Conversely, negative TFP growth occurs when markup shocks induce substantial factor reallocation toward the less productive sector. Achieving both results (i) and (ii) requires a parametrization that includes productivity growth in at least one sector and sufficiently-large markup shocks to drive resource misallocation.

Distortions, TFP, and Welfare. In a closed economy, differential increases in distortions can lead to declines in both TFP and welfare, as demonstrated in the parametrization of Proposition 2. Furthermore, it is important to highlight that even with distortion are reduced across all sectors, TFP can still decline due to changes in allocative efficiency.

B Proofs

B.1 Proposition 1 (Trade–TFP Growth)

Proof. Any equilibrium of the small open economy is characterized by:

$$
\begin{aligned}
&(p_1^w, p_2^w) \gg \mathbf{0} \text{ given},\\
&r_i = p_i^w y_i - w\ell_i,\\
&w = \phi p_1^w A_1 \ell_1^{\phi-1},\\
&c_i = \frac{\alpha_i}{\xi_i}\Big(wL + r_1 + r_2\Big), \quad \text{where} \quad \xi_i = \frac{p_i^w}{p_1^w} \quad \text{and} \quad \alpha_i = \begin{cases} \alpha, & i = 1 \\ 1-\alpha, & i = 2 \end{cases},\\
&\ell_i = \frac{(A_i\xi_i)^{\frac{1}{1-\phi}}}{(A_1)^{\frac{1}{1-\phi}} + (A_2\xi_2)^{\frac{1}{1-\phi}}} L,\\
&y_i = A_i \ell_i^{\phi},\\
&\mathrm{nx}_i = y_i - c_i.
\end{aligned}
$$

Let the original equilibrium be parametrized by

$$(p_1^w, p_2^w, \alpha, \phi, L, A_1, A_2) = (1, 1, 0.5, 0.7, 1, 1, 1).$$

Consider the following perturbations:

- Perturbation 1: $(A_1', A_2') = (0.99, 1.02)$.
- Perturbation 2: $(A_1', A_2', p_2^{w'}) = (0.99, 1.02, 0.8)$.

With perturbation 1, $\mathrm{d}\log \mathrm{TFP} > 0$, and with perturbation 2, $\mathrm{d}\log \mathrm{TFP} < 0$.

$\square$

B.2 Proposition 2 (Distortions–TFP Growth)

Proof. Any equilibrium is characterized by:

$$
\begin{aligned}
&p_1 = 1 \text{ (normalization)}, \qquad p_2 = \frac{\mu_2}{\mu_1}\frac{A_1}{A_2}\left(\frac{\ell_2}{\ell_1}\right)^{1-\phi}, \\
&r_i = \frac{p_i y_i}{\mu_i} - w\ell_i, \\
&w = \frac{1}{\mu_1}\phi A_1 \ell_1^{\phi-1}, \\
&c_i = y_i = A_i \ell_i^{\phi}, \\
&\ell_i = \frac{\alpha_i/\mu_i}{\alpha/\mu_1 + (1-\alpha)/\mu_2} L, \text{ where } \alpha_i = \begin{cases} \alpha, & i = 1 \\ 1-\alpha, & i = 2 \end{cases}, \\
&\pi_i = p_i y_i - w\ell_i - r_i,
\end{aligned}
$$

Let the original equilibrium be parametrized by

$$(\mu_1, \mu_2, \alpha, \phi, L, A_1, A_2) = (1, 1, 0.5, 0.7, 1, 1, 1).$$

Consider the following perturbations:

- Perturbation 1: $A_2' = 1.02$.
- Perturbation 2: $(A_2', \mu_2') = (1.02, 1.5)$.

With perturbation 1, $\mathrm{d}\log \mathrm{TFP} > 0$, and with perturbation 2, $\mathrm{d}\log \mathrm{TFP} < 0$. $\square$

B.3 Proposition 3 (Bias in Traditional Solow Residual)

Proposition 3 (Bias in Traditional Solow Residual)**.** *Assume that there is a representative producer, producing output Y using technology $Y = AF(L_1, \ldots, L_N)$, where $A > 0$ is a productivity parameter and F is a constant returns-to-scale production function which satisfies standard regularity conditions (i.e., continuity, differentiability, and Inada conditions.) Moreover assume that the representative producer is monopolistic and prices its output charging a markup $\mu \geq 1$ over marginal cost MC; that is, $P = \mu \times MC$. Then, the traditional Solow residual, defined as output growth minus revenue-based input growth, can be written as*

$$\mathrm{d}\log Y - \sum_{f \in \mathcal{F}} \Lambda_n \mathrm{d}\log L_n = \mathrm{d}\log A + \left(\frac{\mu - 1}{\mu}\right)\Big\{\mathrm{d}\log Y - \mathrm{d}\log A\Big\}, \tag{2}$$

where $\Lambda_n \equiv w_n L_n/(PY)$ is the revenue-based share of input n.

Proof. Taking logs and differentiating both sides of the production function with respect to time yields

$$\mathrm{d}\log Y = \mathrm{d}\log A + \sum_{n \in N}\left(\frac{\partial F}{\partial L_n}\frac{L_n}{F}\right)\mathrm{d}\log L_n, \tag{B.1}$$

where $\mathrm{d}\log X \equiv \frac{\mathrm{d}\log X}{\mathrm{d}t}$.

The cost-minimization problem of the representative producer may be written as

$$\begin{aligned} \min_{\boldsymbol{L} \geq \boldsymbol{0}} \quad & C(\boldsymbol{w}) \equiv \sum_{n \in N} w_n L_n \\ \text{s.t.} \quad & Y = AF(L_1, \ldots, L_N) \geq \overline{Y}, \end{aligned}$$

where w_n is the price of input n, L_n is the quantity demanded of input n, and $\overline{Y}$ is a minimal-output constraint.

Letting λ denote the Lagrange multiplier associated with the constraint, a generic first-order condition for an interior demand reads as:

$$w_n = \lambda A \frac{\partial F}{\partial L_n} \qquad \Longleftrightarrow \qquad w_n L_n = \lambda A \frac{\partial F}{\partial L_n} L_n.$$

By the Envelope Theorem, it follows that $\lambda = MC$. Hence, we have

$$\begin{aligned} w_n L_n &= MC \times A \frac{\partial F}{\partial L_n} L_n \\ &= \frac{\mu}{P} \times A \frac{\partial F}{\partial L_n} L_n && \text{(using the price-setting condition)} \end{aligned}$$

Rearranging and doing simple algebraic manipulations, it follows that

$$\frac{\partial F}{\partial L_n}\frac{L_n}{F} = \mu \times \frac{w_n L_n}{PY} \equiv \tilde{\Lambda}_n,$$

where $\tilde{\Lambda}_n \equiv \mu \times w_n L_n/(PY)$ and $\Lambda_n \equiv w_n L_n/(PY)$ are the cost- and revenue-based shares of input n, respectively.

The fact that $\tilde{\Lambda}_n$ is the cost-based share of input n, follows from noting that with a CRS production function, the profit rate s_π is given by

$$s_\pi = 1 - \frac{1}{\mu},$$

which implies that the markup can be written as

$$\mu = (1 - s_\pi)^{-1} = \left(1 - \frac{\sum_{k \in N} w_k L_k}{PY}\right)^{-1} = \frac{PY}{\sum_{k \in N} w_k L_k}.$$

Hence,

$$\tilde{\Lambda}_n = \mu \times \frac{w_n L_n}{PY} = \frac{w_n L_n}{\sum_{k \in N} w_k L_k},$$

which is the cost share of input n.

Plugging cost-based shares into expression (B.1) and re-arranging, we obtain that the distorted Solow residual correctly measures TFP growth:

$$\mathrm{d}\log Y - \sum_{n \in N} \tilde{\Lambda}_f \mathrm{d}\log L_n = \mathrm{d}\log A. \tag{B.2}$$

To obtain the bias associated with the traditional Solow residual, defined as output growth minus revenue-weighted input growth, we can algebraically manipulate expression (B.2). That is, we can write

$$\begin{aligned}
\mathrm{d}\log Y - \sum_{f \in \mathcal{F}} \Lambda_f \mathrm{d}\log L_f &= \mathrm{d}\log A + \sum_{f \in \mathcal{F}} \left(\tilde{\Lambda}_f - \Lambda_f\right) \mathrm{d}\log L_f \\
&= \mathrm{d}\log A + (\mu - 1) \sum_{f \in \mathcal{F}} \Lambda_f \mathrm{d}\log L_f \\
&= \mathrm{d}\log A + \left(\frac{\mu - 1}{\mu}\right) \sum_{f \in \mathcal{F}} \tilde{\Lambda}_f \mathrm{d}\log L_f \\
&= \mathrm{d}\log A + \left(\frac{\mu - 1}{\mu}\right) \left\{\mathrm{d}\log Y - \mathrm{d}\log A\right\}.
\end{aligned}$$

The equation in the main text is the discrete-time analog of this last expression. □

B.4 Theorem 1 (First-Order Decomposition of Aggregate TFP Growth)

This proof replicates Baqaee and Farhi (2024)'s proof of Theorem 1 taking more detailed steps, and then uses the definition of aggregate TFP growth to provide a first-order decomposition of this object.

Proof. The nominal output of country c can be obtained as the revenue generated by domestic producers via wedges and the income that accrues to primary factors. That is,

$$P_{Y_c} Y_c = \sum_{i \in \mathcal{I}_c} \left(1 - \frac{1}{\mu_i}\right) p_i y_i + \sum_{f \in \mathcal{F}_c} w_f L_f.$$

Totally differentiating this expression gives

$$\mathrm{d}P_{Y_c} Y_c + P_{Y_c} \mathrm{d}Y_c = \sum_{i \in \mathcal{I}_c} \left\{ \mathrm{d}\left(1 - \frac{1}{\mu_i}\right) p_i y_i + \left(1 - \frac{1}{\mu_i}\right) \mathrm{d}p_i y_i + \left(1 - \frac{1}{\mu_i}\right) p_i \mathrm{d}y_i \right\} + \sum_{f \in \mathcal{F}_c} \left(\mathrm{d}w_f L_f + w_f \mathrm{d}L_f\right).$$

Using simple algebraic manipulations, we can write

$$P_{Y_c} Y_c \left(\frac{\mathrm{d}P_{Y_c}}{P_{Y_c}} + \frac{\mathrm{d}Y_c}{Y_c}\right) = \sum_{i \in \mathcal{I}_c} \left(1 - \frac{1}{\mu_i}\right) p_i y_i \left\{ \frac{\mathrm{d}(1 - 1/\mu_i)}{1 - 1/\mu_i} + \frac{\mathrm{d}p_i}{p_i} + \frac{\mathrm{d}y_i}{y_i} \right\} + \sum_{f \in \mathcal{F}_c} w_f L_f \left(\frac{\mathrm{d}w_f}{w_f} + \frac{\mathrm{d}L_f}{L_f}\right),$$

Using $\mathrm{d}\log x \equiv \mathrm{d}x/x$, the linearity of $\mathrm{d}\log$, and rearranging, we have

$$\mathrm{d}\log Y_c = \sum_{i \in \mathcal{I}_c} \left(1 - \frac{1}{\mu_i}\right) \lambda_i^{Y_c} \mathrm{d}\log\left(\left[1 - \frac{1}{\mu_i}\right] p_i y_i\right) + \sum_{f \in \mathcal{F}_c} \Lambda_f^{Y_c} \left(\mathrm{d}\log w_f + \mathrm{d}\log L_f\right) - \mathrm{d}\log P_{Y_c}.$$

By Sheppard's lemma, the change in the price of a domestic good i is given by

$$\mathrm{d}\log p_i = \mathrm{d}\log \mu_i - \mathrm{d}\log A_i + \sum_{j \in \mathcal{I}_c} \tilde{\Omega}_{ij} \mathrm{d}\log p_j + \sum_{j \in \mathcal{I} - \mathcal{I}_c} \tilde{\Omega}_{ij} \mathrm{d}\log p_j + \sum_{f \in \mathcal{F}_c} \tilde{\Omega}_{if} \mathrm{d}\log w_f.$$

Using recursion on p_i, we can write

$$\begin{aligned}
\mathrm{d}\log p_i = & \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{j \in \mathcal{I}_c} \tilde{\Omega}_{ij} \Bigg\{ \left(\mathrm{d}\log \mu_j - \mathrm{d}\log A_j\right) + \sum_{k \in \mathcal{I}_c} \tilde{\Omega}_{jk} \mathrm{d}\log p_k + \sum_{k \in \mathcal{I} - \mathcal{I}_c} \tilde{\Omega}_{jk} \mathrm{d}\log p_k \\
& + \sum_{f \in \mathcal{F}_c} \tilde{\Omega}_{jf} \mathrm{d}\log w_f \Bigg\} + \sum_{j \in \mathcal{I} - \mathcal{I}_c} \tilde{\Omega}_{ij} \mathrm{d}\log p_j + \sum_{f \in \mathcal{F}_c} \tilde{\Omega}_{if} \mathrm{d}\log w_f \\
= & \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{j \in \mathcal{I}_c} \tilde{\Omega}_{ij} \Bigg\{ \left(\mathrm{d}\log \mu_j - \mathrm{d}\log A_j\right) + \sum_{k \in \mathcal{I}_c} \tilde{\Omega}_{jk} \left(\mathrm{d}\log \mu_k - \mathrm{d}\log A_k\right) + \cdots \Bigg\} \\
& + \sum_{j \in \mathcal{I} - \mathcal{I}_c} \tilde{\Omega}_{ij} \mathrm{d}\log p_j + \sum_{f \in \mathcal{F}_c} \tilde{\Omega}_{if} \mathrm{d}\log w_f.
\end{aligned}$$

Since the world's GDP was taken as the *numeraire*, we have that $\lambda_i = (p_i y_i)/\text{GDP} = p_i y_i$ for any $i \in \mathcal{I}$, and $\Lambda_f = (w_f L_f)/\text{GDP} = w_f L_f$ for any $f \in \mathcal{F}$. Totally differentiating the second expression and rearranging gives $\mathrm{d}\log w_f = \mathrm{d}\log \Lambda_f - \mathrm{d}\log L_f$. Hence,

$$\mathrm{d}\log p_i = \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{j\in\mathcal{I}_c} \tilde{\Omega}_{ij} \left\{ \left(\mathrm{d}\log \mu_j - \mathrm{d}\log A_j\right) + \sum_{k\in\mathcal{I}_c} \tilde{\Omega}_{jk} \left(\mathrm{d}\log \mu_k - \mathrm{d}\log A_k\right) + \cdots \right\}$$
$$+ \sum_{j\in\mathcal{I}-\mathcal{I}_c} \tilde{\Omega}_{ij} \mathrm{d}\log p_j + \sum_{f\in\mathcal{F}_c} \tilde{\Omega}_{if} \left(\mathrm{d}\log \Lambda_f - \mathrm{d}\log L_f\right).$$

By definition,

$$\begin{aligned}
\mathrm{d}\log P_{Y_c} &= \sum_{i\in\mathcal{I}} \Omega_{Y_c,i} \mathrm{d}\log p_i \\
&= \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \mathrm{d}\log p_i + \sum_{i\in\mathcal{I}-\mathcal{I}_c} \Omega_{Y_c,i} \mathrm{d}\log p_i \\
&= \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \mathrm{d}\log p_i - \sum_{i\in\mathcal{I}-\mathcal{I}_c} \lambda_i^{Y_c} \mathrm{d}\log p_i \qquad \text{(since } \Omega_{Y_c,i} = -\lambda_i^{Y_c} \text{ for imported intermediates)} \\
&= \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \Bigg[\left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{j\in\mathcal{I}_c} \tilde{\Omega}_{ij} \left\{ \left(\mathrm{d}\log \mu_j - \mathrm{d}\log A_j\right) + \sum_{k\in\mathcal{I}_c} \tilde{\Omega}_{jk} \left(\mathrm{d}\log \mu_k - \mathrm{d}\log A_k\right) + \cdots \right\} \\
&\qquad + \sum_{j\in\mathcal{I}-\mathcal{I}_c} \tilde{\Omega}_{ij} \mathrm{d}\log p_j + \sum_{f\in\mathcal{F}_c} \tilde{\Omega}_{if} \left(\mathrm{d}\log \Lambda_f - \mathrm{d}\log L_f\right) \Bigg] - \sum_{i\in\mathcal{I}-\mathcal{I}_c} \lambda_i^{Y_c} \mathrm{d}\log p_i \\
&= \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \sum_{j\in\mathcal{I}_c} \tilde{\Omega}_{ij} \left(\mathrm{d}\log \mu_j - \mathrm{d}\log A_j\right) + \cdots \\
&\qquad + \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \left\{ \sum_{i\in\mathcal{I}-\mathcal{I}_c} \tilde{\Omega}_{ii} \mathrm{d}\log p_i + \sum_{f\in\mathcal{F}_c} \tilde{\Omega}_{if} \mathrm{d}\left(\mathrm{d}\log \Lambda_f - \mathrm{d}\log L_f\right) \right\} - \sum_{i\in\mathcal{I}-\mathcal{I}_c} \lambda_i^{Y_c} \mathrm{d}\log p_i \\
&= \sum_{i\in\mathcal{I}_c} \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \left[(I-\tilde{\Omega})^{-1}\right]_{ii} \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{i\in\mathcal{I}_c} \sum_{i\in\mathcal{I}-\mathcal{I}_c} \Omega_{Y_c,i} \left[(I-\tilde{\Omega})^{-1}\right]_{ii} \mathrm{d}\log p_i \\
&\qquad + \sum_{i\in\mathcal{I}_c} \sum_{f\in\mathcal{F}_c} \Omega_{Y_c,i} \left[(I-\tilde{\Omega})^{-1}\right]_{if} \left(\mathrm{d}\log \Lambda_f - \mathrm{d}\log L_f\right) - \sum_{i\in\mathcal{I}-\mathcal{I}_c} \lambda_i^{Y_c} \mathrm{d}\log p_i \\
&= \sum_{i\in\mathcal{I}_c} \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \tilde{\Psi}_{ii} \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{i\in\mathcal{I}-\mathcal{I}_c} \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \tilde{\Psi}_{ii} \mathrm{d}\log p_i \\
&\qquad + \sum_{f\in\mathcal{F}_c} \sum_{i\in\mathcal{I}_c} \Omega_{Y_c,i} \tilde{\Psi}_{if} \left(\mathrm{d}\log \Lambda_f - \mathrm{d}\log L_f\right) - \sum_{i\in\mathcal{I}-\mathcal{I}_c} \lambda_i^{Y_c} \mathrm{d}\log p_i \\
&= \sum_{i\in\mathcal{I}_c} \tilde{\lambda}_i^{Y_c} \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{f\in\mathcal{F}_c} \tilde{\Lambda}_f^{Y_c} \left(\mathrm{d}\log \Lambda_f - \mathrm{d}\log L_f\right) + \sum_{i\in\mathcal{I}-\mathcal{I}_c} \left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right) \mathrm{d}\log p_i.
\end{aligned}$$

Substituting this expression of $\mathrm{d}\log P_{Y_c}$ into that of $\mathrm{d}\log Y_c$ gives

$$\mathrm{d}\log Y_c = \sum_{i\in\mathcal{I}_c} \left(1 - \frac{1}{\mu_i}\right) \lambda_i^{Y_c} \mathrm{d}\log\left(\left[1 - \frac{1}{\mu_i}\right] p_i y_i\right) + \sum_{f\in\mathcal{F}_c} \Lambda_f^{Y_c} \left(\mathrm{d}\log w_f + \mathrm{d}\log L_f\right)$$
$$- \left\{ \sum_{i\in\mathcal{I}_c} \tilde{\lambda}_i^{Y_c} \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{f\in\mathcal{F}_c} \tilde{\Lambda}_f^{Y_c} \left(\mathrm{d}\log \Lambda_f - \mathrm{d}\log L_f\right) + \sum_{i\in\mathcal{I}-\mathcal{I}_c} \left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right) \mathrm{d}\log p_i \right\}.$$

Next note that since $\Lambda_f = (w_f L_f)/\text{GDP} = w_f L_f$, we can write

$$\sum_{f\in\mathcal{F}_c} \Lambda_f^{Y_c}\left(\mathrm{d}\log w_f + \mathrm{d}\log L_f\right) \qquad \Longleftrightarrow \qquad \sum_{f\in\mathcal{F}_c} \Lambda_f^{Y_c}\mathrm{d}\log \Lambda_f.$$

Moreover, since all the income generated in the production of Y_c accrues to domestic factors or wedges, and $-\mathrm{d}\log GDP = 0$, we can write

$$\sum_{i\in\mathcal{I}_c}\left(1-\frac{1}{\mu_i}\right)\lambda_i^{Y_c}\mathrm{d}\log\left(\left[1-\frac{1}{\mu_i}\right]p_i y_i\right) \equiv \Lambda_{f^*}^{Y_c}\,\mathrm{d}\log\Lambda_{f^*},$$

where f^* denotes fictitious factor f^* (i.e., wedges.) By using this notation, one can write the above expressions more compactly. Letting $\mathcal{F}_c^*$ denote the set of all domestic production factors (fictitious and real), we can write

$$\sum_{i\in\mathcal{I}_c}\left(1-\frac{1}{\mu_i}\right)\lambda_i^{Y_c}\mathrm{d}\log\left(\left[1-\frac{1}{\mu_i}\right]p_i y_i\right) + \sum_{f\in\mathcal{F}_c}\Lambda_f^{Y_c}\mathrm{d}\log\Lambda_f \equiv \sum_{f\in\mathcal{F}_c^*}\Lambda_f^{Y_c}\mathrm{d}\log\Lambda_f.$$

Hence, we have

$$\begin{aligned}\mathrm{d}\log Y_c = &\sum_{f\in\mathcal{F}_c^*}\Lambda_f^{Y_c}\mathrm{d}\log\Lambda_f - \sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log\Lambda_f + \sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log L_f \\ &+ \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log A_i - \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log\mu_i + \sum_{i\in\mathcal{I}-\mathcal{I}_c}\left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right)\mathrm{d}\log p_i.\end{aligned}$$

Using the identity $\lambda_i^{Y_c} = (p_i q_{ci})/\text{GDP}_c$ for $i \in \mathcal{I} - \mathcal{I}_c$, we can obtain

$$\mathrm{d}\log p_i = \mathrm{d}\log\lambda_i^{Y_c} - \mathrm{d}\log q_{ci} + \mathrm{d}\log\text{GDP}_c,$$

which allows to write

$$\begin{aligned}\mathrm{d}\log Y_c = &\sum_{f\in\mathcal{F}_c^*}\Lambda_f^{Y_c}\mathrm{d}\log\Lambda_f - \sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log\Lambda_f + \sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log L_f + \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log A_i \\ &- \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log\mu_i + \sum_{i\in\mathcal{I}-\mathcal{I}_c}\left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right)\left(\mathrm{d}\log\lambda_i^{Y_c} - \mathrm{d}\log q_{ci} + \mathrm{d}\log\text{GDP}_c\right).\end{aligned}$$

With simple algebraic manipulations we can obtain

$$
\begin{aligned}
\mathrm{d}\log Y_c = &\sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log L_f + \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log A_i - \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log\mu_i - \sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\left(\mathrm{d}\log\Lambda_f^{Y_c} + \mathrm{d}\log\mathrm{GDP}_c\right)\\
&+ \sum_{f\in\mathcal{F}_c^*}\Lambda_f^{Y_c}\left(\mathrm{d}\log\Lambda_f^{Y_c} + \mathrm{d}\log\mathrm{GDP}_c\right) + \sum_{i\in\mathcal{I}-\mathcal{I}_c}\left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right)\left(\mathrm{d}\log q_{ci} - \mathrm{d}\log\lambda_i^{Y_c}\right)\\
&- \sum_{i\in\mathcal{I}-\mathcal{I}_c}\left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right)\mathrm{d}\log\mathrm{GDP}_c\\
= &\sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log L_f + \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log A_i - \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log\mu_i - \sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log\Lambda_f^{Y_c}\\
&\underbrace{\sum_{f\in\mathcal{F}_c^*}\Lambda_f^{Y_c}\mathrm{d}\log\Lambda_f^{Y_c}}_{\substack{=0\text{ since the revenue share gained by}\\ \text{one factor is lost by other(s)}}} + \sum_{i\in\mathcal{I}-\mathcal{I}_c}\left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right)\left(\mathrm{d}\log q_{ci} - \mathrm{d}\log\lambda_i^{Y_c}\right)\\
&+\Bigg[\underbrace{\sum_{f\in\mathcal{F}_c^*}\Lambda_f^{Y_c}}_{\substack{=1\text{ since all income accrues to}\\ \text{domestic factors and wedges}}} - \sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c} - \sum_{i\in\mathcal{I}-\mathcal{I}_c}\left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right)\Bigg]\mathrm{d}\log\mathrm{GDP}_c.
\end{aligned}
$$

Noting that

$$
\sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c} + \sum_{i\in\mathcal{I}-\mathcal{I}_c}\tilde{\lambda}_i^{Y_c} = 1 + \sum_{i\in\mathcal{I}-\mathcal{I}_c}\lambda_i^{Y_c}
$$

gives

$$
\begin{aligned}
\mathrm{d}\log Y_c = &\sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log L_f + \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log A_i - \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log\mu_i - \sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log\Lambda_f^{Y_c}\\
&+ \sum_{i\in\mathcal{I}-\mathcal{I}_c}\left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right)\left(\mathrm{d}\log q_{ci} - \mathrm{d}\log\lambda_i^{Y_c}\right).
\end{aligned}
$$

Using definition 1, we can decompose this object up to a first-order approximation as

$$
\begin{aligned}
\mathrm{d}\log\mathrm{TFP}_c \approx &\sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log A_i - \sum_{i\in\mathcal{I}_c}\tilde{\lambda}_i^{Y_c}\mathrm{d}\log\mu_i - \sum_{f\in\mathcal{F}_c}\tilde{\Lambda}_f^{Y_c}\mathrm{d}\log\Lambda_f^{Y_c}\\
&+ \sum_{i\in\mathcal{I}-\mathcal{I}_c}\left(\tilde{\lambda}_i^{Y_c} - \lambda_i^{Y_c}\right)\left(\mathrm{d}\log q_{ci} - \mathrm{d}\log\lambda_i^{Y_c}\right).
\end{aligned}
$$

□

B.5 Theorem 2 (First-Order Decomposition of Welfare Growth)

This is an alternative proof to Baqaee and Farhi (2024)'s proof of Theorem 2.

Proof. Nominal gross national expenditure of country c is

$$P_{W_c} W_c = \sum_{f \in \mathcal{F}} \Phi_{cf} w_f L_f + \sum_{i \in \mathcal{I}} \Phi_{ci} \left(1 - \frac{1}{\mu_i}\right) p_i y_i + T_c.$$

Totally differentiating this expression assuming constant ownership shares gives

$$\mathrm{d}\log W_c = \sum_{f \in \mathcal{F}} \Lambda_f^c \left(\mathrm{d}\log w_f + \mathrm{d}\log L_f\right) + \sum_{i \in \mathcal{I}} \lambda_i^c \mathrm{d}\log\left(\Phi_{ci}\left[1 - \frac{1}{\mu_i}\right] p_i y_i\right) + \frac{\mathrm{d}T_c}{\mathrm{GNE}_c} - \mathrm{d}\log P_{W_c}.$$

An implication of Sheppard's lemma is that

$$\begin{aligned}
\mathrm{d}\log p_i &= \mathrm{d}\log \mu_i - \mathrm{d}\log A_i + \sum_{j \in \mathcal{I}} \tilde{\Omega}_{ij} \mathrm{d}\log p_j + \sum_{f \in \mathcal{F}} \tilde{\Omega}_{if} \mathrm{d}\log w_f \\
&= \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{j \in \mathcal{I}} \tilde{\Omega}_{ij} \left\{\left(\mathrm{d}\log \mu_j - \mathrm{d}\log A_j\right) + \sum_{k \in \mathcal{I}} \tilde{\Omega}_{jk}\left(\mathrm{d}\log \mu_k - \mathrm{d}\log A_k\right) + \cdots\right\} \\
&\quad + \sum_{f \in \mathcal{F}} \tilde{\Omega}_{if} \mathrm{d}\log w_f + \sum_{j \in \mathcal{I}} \tilde{\Omega}_{ij} \left\{\sum_{f \in \mathcal{F}} \tilde{\Omega}_{jf} \mathrm{d}\log w_f + \cdots\right\}.
\end{aligned}$$

Using the definition of $\mathrm{d}\log P_{W_c}$, we can write

$$\begin{aligned}
\mathrm{d}\log P_{W_c} &= \sum_{i \in \mathcal{I}} \Omega_{W_c,i} \left\{\left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{j \in \mathcal{I}} \tilde{\Omega}_{ij} \left[\left(\mathrm{d}\log \mu_j - \mathrm{d}\log A_j\right)\right.\right. \\
&\qquad \left.\left. + \sum_{k \in \mathcal{I}} \tilde{\Omega}_{jk}\left(\mathrm{d}\log \mu_k - \mathrm{d}\log A_k\right) + \cdots + \sum_{f \in \mathcal{F}} \tilde{\Omega}_{jf} \mathrm{d}\log w_f + \cdots\right]\right\} + \sum_{f \in \mathcal{F}} \tilde{\Omega}_{if} \mathrm{d}\log w_f \\
&= \sum_{i \in \mathcal{I}} \sum_{i \in \mathcal{I}} \Omega_{W_c,i} \left[(I - \tilde{\Omega})^{-1}\right]_{ii} \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{i \in \mathcal{I}} \sum_{f \in \mathcal{F}} \Omega_{W_c,i} \left[(I - \tilde{\Omega})^{-1}\right]_{if} \mathrm{d}\log w_f \\
&= \sum_{i \in \mathcal{I}} \sum_{i \in \mathcal{I}} \Omega_{W_c,i} \tilde{\Psi}_{ii} \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{f \in \mathcal{F}} \sum_{i \in \mathcal{I}} \Omega_{W_c,i} \tilde{\Psi}_{if} \mathrm{d}\log w_f \\
&= \sum_{i \in \mathcal{I}} \tilde{\lambda}_i^{W_c} \left(\mathrm{d}\log \mu_i - \mathrm{d}\log A_i\right) + \sum_{f \in \mathcal{F}} \tilde{\Lambda}_f^{W_c} \mathrm{d}\log w_f.
\end{aligned}$$

Substituting this last expression of $\mathrm{d}\log P_{W_c}$ into $\mathrm{d}\log W_c$ gives

$$\begin{aligned}
\mathrm{d}\log W_c &= \sum_{f\in\mathcal{F}} \Lambda_f^c \left(\mathrm{d}\log w_f + \mathrm{d}\log L_f\right) + \sum_{i\in\mathcal{I}} \lambda_i^c \mathrm{d}\log\left(\Phi_{ci}\left[1-\frac{1}{\mu_i}\right]p_i y_i\right) + \frac{\mathrm{d}T_c}{\mathrm{GNE}_c} \\
&\qquad - \left\{\sum_{i\in\mathcal{I}} \tilde{\lambda}_i^{W_c}\left(\mathrm{d}\log\mu_i - \mathrm{d}\log A_i\right) + \sum_{f\in\mathcal{F}} \tilde{\Lambda}_f^{W_c}\mathrm{d}\log w_f\right\} \\
&= \sum_{f\in\mathcal{F}} \Lambda_f^c \mathrm{d}\log\Lambda_f + \sum_{i\in\mathcal{I}} \lambda_i^c \mathrm{d}\log\left(\Phi_{ci}\left[1-\frac{1}{\mu_i}\right]p_i y_i\right) + \frac{\mathrm{d}T_c}{\mathrm{GNE}_c} \\
&\qquad - \left\{\sum_{i\in\mathcal{I}} \tilde{\lambda}_i^{W_c}\left(\mathrm{d}\log\mu_i - \mathrm{d}\log A_i\right) + \sum_{f\in\mathcal{F}} \tilde{\Lambda}_f^{W_c}\left(\mathrm{d}\log\Lambda_f - \mathrm{d}\log L_f\right)\right\} \\
&= \sum_{i\in\mathcal{I}} \tilde{\lambda}_i^{W_c}\mathrm{d}\log A_i + \sum_{f\in\mathcal{F}} \tilde{\Lambda}_f^{W_c}\mathrm{d}\log L_f - \sum_{i\in\mathcal{I}} \tilde{\lambda}_i^{W_c}\mathrm{d}\log\mu_i + \frac{\mathrm{d}T_c}{\mathrm{GNE}_c} \\
&\qquad + \sum_{f\in\mathcal{F}}\left(\Lambda_f^c - \tilde{\Lambda}_f^{W_c}\right)\mathrm{d}\log\Lambda_f + \sum_{i\in\mathcal{I}} \lambda_i^c \mathrm{d}\log\left(\Phi_{ci}\left[1-\frac{1}{\mu_i}\right]p_i y_i\right)
\end{aligned}$$

Noting that $\lambda_i = \frac{p_i y_i}{\mathrm{GNE}} = p_i y_i$ and $\mathrm{d}\log\mathrm{GNE} = 0$, we can write

$$\sum_{i\in\mathcal{I}} \lambda_i^c \mathrm{d}\log\left(\Phi_{ci}\left[1-\frac{1}{\mu_i}\right]p_i y_i\right) \equiv \Lambda_{f^*}^c \mathrm{d}\log\Lambda_{f^*},$$

where f^* stands for wedges, a fictitious factor, $\tilde{\Lambda}_{f^*}^c$ is the share of income/expenditure of country c that comes from domestic and foreign wedges, and Λ_{f^*} is the share of world's GDP/GNE owned by country c. Letting $\mathcal{F}^*$ denote the set of all (fictitious and real) factors, and noting that $\tilde{\Lambda}_{f^*}^{W_c} = 0$ for $f^* \in \mathcal{F}^*$, we can write

$$\mathrm{d}\log W_c \approx \sum_{i\in\mathcal{I}} \tilde{\lambda}_i^{W_c}\mathrm{d}\log A_i + \sum_{f\in\mathcal{F}} \tilde{\Lambda}_f^{W_c}\mathrm{d}\log L_f - \sum_{i\in\mathcal{I}} \tilde{\lambda}_i^{W_c}\mathrm{d}\log\mu_i + \sum_{f\in\mathcal{F}^*}\left(\Lambda_f^c - \tilde{\Lambda}_f^{W_c}\right)\mathrm{d}\log\Lambda_f + \frac{\mathrm{d}T_c}{\mathrm{GNE}_c}.$$

□

C Estimation of Distortions

This appendix describes the methods used to estimate the distortions underlying the empirical results. Two main approaches are considered: (i) the margins approach and (ii) the production-function approach.

C.1 The Margins Approach

Following Domowitz et al. (1986), I estimate distortions using gross profit margins, defined as the ratio of gross operating surplus to total sales. For each producer i, the gross margin is given by

$$\text{Gross Margin}_i := \frac{\text{Gross Operating Surplus}_i}{\text{Sales}_i} = \frac{p_i y_i - \sum_{j\in\mathcal{I}} p_j x_{ij} - \sum_{f\in\mathcal{F}^V} w_f l_{if}}{p_i y_i}, \quad \text{(C.1)}$$

where $p_i y_i$ denotes sales, $\sum_j p_j x_{ij}$ is intermediate input expenditures, and $\sum_{f\in\mathcal{F}^V} w_f l_{if}$ is the cost of variable factors of production.

The gross margins approach avoids assumptions about production technologies or market structure, and it requires minimal data: revenues, intermediate input costs, and compensation for variable factors (typically labor). These data are readily available in sources such as KLEMS and WIOD. Empirically, Anderson et al. (2020) show that gross margins co-move closely with markups computed from marginal replacement costs, suggesting that gross margins provide a reliable proxy for markups in terms of their distribution (though not their level).

Margins and Distortions. In my preferred specification, distortions μ_i represents wedges between marginal cost and price, capturing market imperfections such as market power or distorting taxes. To quantify these wedges, I compute wedge margins, which adjust gross margins by accounting for expenditures in fixed or quasi-fixed factors such as capital:

$$\text{Wedge margin}_i := \frac{p_i y_i - \sum_{j\in\mathcal{I}} p_j x_{ij} - \sum_{f\in\mathcal{F}^V} w_f l_{if} - \sum_{f\in\mathcal{F}^F} \delta_f \ell_{if} - \sum_{f\in\mathcal{F}^F} r_f \ell_{if}}{p_i y_i}, \quad \text{(C.2)}$$

where δ_f is the depreciation rate of factor f, and r_f is its net-of-depreciation rental rate.

Wedge margins approximate "pure profit" margins more accurately than gross margins, as they include the costs of fixed factors. Under the model's assumption of constant returns to scale, wedge margins are theoretically consistent measures of distortions. More generally, the following identity holds:

$$\text{Wedge margin} = 1 - \frac{\text{RS}}{\mu},$$

where RS are the returns to scale.[17]

With constant returns to scale, this implies:

$$\mu_i = \frac{1}{1 - \text{wedge margin}_i}. \tag{C.3}$$

Estimating wedge margins is challenging. It requires producer-level capital stocks disaggregated by asset type, as well as asset-specific depreciation rates and user costs. I use capital data from KLEMS and WIOD, and depreciation rates from the Bureau of Economic Analysis (BEA).[18] I estimate user costs of capital using the method of van Vlokhoven (2022), which uses exploits cross-sectional variation in input choices. Specifically, I estimate the following OLS regression:

$$\frac{p_i y_i}{\text{COGS}_i} = \overline{\psi} + \overline{\psi w^{\text{gross}}} \frac{p_i^K K_i}{\text{COGS}_i} + \varepsilon_i,$$

where COGS_i denotes the costs of goods sold (intermediates plus variable labor), $p_i^K K_i$ is the nominal capital stock, and ε_i is an error term. The slope $\overline{\psi w^{\text{gross}}}$ and intercept $\overline{\psi}$ coefficients yield an estimate of the gross user cost of capital as $\overline{w^{\text{gross}}} = \overline{\psi w^{\text{gross}}}/\overline{\psi}$.

OLS provides unbiased estimates under the assumption of constant marginal cost and equalized user costs across producers—a strong condition, but a useful benchmark.

C.1.1 The Accounting-Profits Approach

The accounting-profits approach can be viewed as a special case of the wedge-margins approach in which net-of-depreciation rental rates of fixed factors are zero.

C.1.2 The Cost-Shares Approach

The cost-shares approach can be considered a special case of the production function approach outlined in Section C.2.2. Under suitable conditions, it yields distortion

[17]This equation can be established under assumptions of cost minimization, and differentiability and quasi-concavity of production functions. (see Hasenzagl and Perez, 2023).

[18]Depreciation rates from the BEA are more reliable than those provided by KLEMS or implied by accounting data. The BEA accounts for tax incentives and accounting practices that may lead firms to overstate depreciation and, unlike KLEMS, it does not back out depreciation rates assuming zero profits.

estimates equivalent to those obtained from wedge margins, provided that the gross-of-depreciation rental rates are constructed using the same data and methodology.[19]

C.2 The Production Function Approach

The production function approach to markup estimation dates back to Hall (1986, 1988), who derived an expression for the markup using the first-order condition for a variable input of a cost-minimizing producer operating under price-taking behavior in that input market. The core insight is that a producer's markup can be expressed as the output elasticity of a variable input multiplied by the inverse of that input's revenue share. To see this, suppose producer i uses technology

$$y_i = F_i(A_i, \mathbf{x}_i, \boldsymbol{\ell}_i),$$

where y denotes output, A is Hicks-neutral productivity, $\mathbf{x}$ is a vector of variable inputs, and $\boldsymbol{\ell}$ is a vector of pre-determined inputs potentially subject to adjustment costs.

The producer minimizes total costs subject to an output constraint:

$$\begin{aligned} \min_{\mathbf{x}_i, \boldsymbol{\ell}_i} \quad & \mathbf{p}_i'\mathbf{x}_i + \mathbf{w}_i'\boldsymbol{\ell}_i + \text{other costs}_i \\ \text{s.t.} \quad & y_i \geq \overline{y}_i. \end{aligned}$$

Let λ_i be the Lagrange multiplier on the constraint. The first-order condition with respect to variable input x_{ij} (with $x_{ij} > 0$) yields

$$p_j = \lambda_i \frac{\partial y_i}{\partial x_{ij}},$$

where λ_i denotes marginal cost. Thus, defining the markup as the ratio of output price to marginal costs,

$$\mu_i := \frac{p_i}{\lambda_i} = \frac{\partial y_i}{\partial x_{ij}} \frac{p_i}{p_j}.$$

Multiplying and dividing by x_{ij}/y_i, we obtain

$$\mu_i = \frac{\partial y_i}{\partial x_{ij}} \frac{x_{ij}}{y_i} \frac{p_i y_i}{p_j x_{ij}} \equiv \epsilon(y_i, x_{ij}) \times \frac{p_i y_i}{p_j x_{ij}}, \tag{C.4}$$

where $\epsilon(y_i, x_{ij})$ is the output elasticity of x_{ij}.

[19] These conditions include constant returns to scale, cost minimization, input market price-taking, full variable input flexibility, and zero non-operating costs.

To implement equation (C.4), one must estimate $\epsilon(y_i, x_{ij})$. Two approaches are widely used: the control-function approach and the cost-shares approach.

C.2.1 The Control-Function Approach

The control-function approach requires specifying a functional form for the production function, typically Cobb-Douglas or translog. Consider the Cobb-Douglas case with one variable input x and one pre-determined input ℓ. The associated log-regression is:

$$\log y_{it} = \log A_{it} + \beta_x \log x_{it} + \beta_\ell \log \ell_{it} + \varepsilon_{it}, \tag{C.5}$$

where $\log A_{it}$ is the (unobserved) productivity term, β_x is the elasticity to be estimated (i.e., $\epsilon(y,x)$), and ε_{it} captures measurement error or unanticipated shocks to output or productivity that are observed neither by the econometrician nor the producer.

Two econometric challenges. First, $\log A_{it}$ is observed by the producer but not by the econometrician, leading to simultaneity bias. Second, most datasets report revenues and expenditures rather than physical quantities, introducing price-related bias.

Following Ackerberg et al. (2015), the solution involves a two-step control-function procedure. The first stage non-parametrically controls for unobserved productivity, and the second stage estimates production-function parameters using moment conditions. This yields a consistent estimate of $\beta_x = \varepsilon(y_i, x_{ij})$, which can be used in equation (C.4) to compute markups.[20]

C.2.2 The Cost-Shares Approach

The cost-shares approach, developed by Foster et al. (2008), offers a fully no-parametric alternative. it avoids estimating a production function by assuming constant returns to scale and that all inputs are variable. Under these assumptions, the elasticity of a variable input is given by its share in total costs:

$$\epsilon(y_i, x_{ij}) = \frac{p_j x_{ij}}{\sum_{j \in \mathcal{I}} p_j x_{ij} + \sum_{f \in \mathcal{F}} w_f \ell_{if}}. \tag{C.6}$$

While more transparent and robust to functional form misspecification, this method requires rental rates for all factors. Once these are estimated (as discussed in previous sections), equation (C.4) can be again used to recover markups or wedges.

[20]Extensions exist to address price biases (see De Loecker et al., 2016).

D Data

This appendix describes the datasets used in the empirical analysis, along with the sample selection, data cleaning, and estimation procedures. The analysis relies primarily on two sources: the KLEMS Growth and Productivity Accounts database and the World Input-Output Database (WIOD). KLEMS provides industry-level data on output and factors of production, while WIOD contains annual time-series data on global input-output linkages, capturing trade flows between producers and both intermediate and final users. Intermediate users are producers that purchase goods to incorporate them as inputs in their own production processes, whereas final users—households, non-profit organizations, governments, and firms—purchase goods for consumption or investment purposes.

D.1 KLEMS

KLEMS offer industry-level data on output, inputs, and productivity starting in 1970 for a range of countries, primarily EU member states but also non-EU economies such as the United States, Japan, and Canada. Coverage varies by release.[21,22] Despite release-specific variation, all KLEMS data are constructed following a harmonized methodology grounded in the neoclassical growth-accounting framework.[23]

The KLEMS data draw on national statistical sources and adhere to the System of National Accounts (SNA) and the European System of Accounts (ESA). A harmonization protocol ensures cross-country comparability through consistent definitions of outputs, inputs, and prices. This one of KLEMS' main contributions. Another important advantage of KLEMS with respect to national sources is its disaggregation of labor and capital.[24] A higher level of granularity is achieved by merging labor surveys, earnings data, establishment surveys, and social security records.

Nonetheless, KLEMS is subject to the usual measurement issues. Reliability may decline at finer levels of disaggregation or over long time periods.[25] Measuring output

[21] Early releases (2007, 2008, 2009) use the ISIC Rev. 3/NACE Rev. 1 industry classification whereas latter releases (2012, 2016, 2017, 2021) use the ISIC Rev. 4/NACE Rev. 2 classification and provide wider country coverage. However, later releases often begin in 1995. For questions requiring long time series, earlier releases are preferable.

[22] In some cases, KLEMS provides more historical disaggregation than national sources. For examples, Spanish industry data in KLEMS begins in 1970, whereas coverage from the Instituto National de Estadística (INE) begins in 2000.

[23] See O'Mahony and Timmer (2009) for a methodological overview and Timmer et al. (2007) for country-level documentation.

[24] Labor is split into 18 categories by education (high, medium, low), gender, and age (15–29, 30–49, 50+). Capital is categorized as ICT and non-ICT, with further breakdowns by asset types. Capital classification evolved with ESA 2010. Starting with the 2016 release, the data begin in 1995.

[25] This is due to reliance on supplementary sources or additional assumptions.

is particularly difficult in services and non-market sectors, where hedonic pricing methods are hard to leverage and many outputs (e.g., public services or imputed rents in real estate) are not priced in markets. As a result, many studies restrict attention to the market economy, excluding real estate, public administration, education, and health. In addition, some forms of capital—especially intangible or organizational capital—are poorly captured in national accounts, which may bias productivity measures.[26]

In this paper, I use the 2007/08 and 2021 KLEMS releases. These are combined with WIOD's Socioeconomic Accounts to construct growth-accounting variables and estimate factor compensation and depreciation rates. Depreciation rates are computed using capital input files from the 2008 and 2021 KLEMS releases, which detail industry-specific capital composition. Labor compensation is inferred from labor compensation to value added ratios in the 2007/08 KLEMS release. For national-level aggregates, I use the 2007/08 and 2021 KLEMS data at the total industry level.

D.2 WIOD

The World Input-Output Database (WIOD) provides annual time series of world input-output tables (WIOTs), which integrate national input-output tables with bilateral trade flows. A WIOT links domestic transactions among households, firms, and governments with international trade, thereby providing a global picture of intermediate and final goods flows.

WIOD includes several releases (e.f., 2013, 2016) and initiatives (e.g., Long-Run WIOD), each with different time spans, country coverage, and industry classifications. I use the WIOD 2013 and Long-Run WIOD datasets, both of which use ISIC Rev. 3 and together span 1965–2011.[27]

The Long-Run WIOD covers 26 countries and a rest-of-world region for 1965–2000. The WIOD 2013 release includes 40 countries and a rest-of-world region for 1995–2011. Since the two datasets cover different groups of countries and industries, I harmonize the data as follows.[28] First, I expand the rest-of-world region by including countries that appear in only one of the datasets (see Table 3 for the final list of countries.) Second, I use the industry groupings for which data are available in both datasets (see Table 4 for a list.) In total, I analyze data for 24 countries and a rest-of-region, each covering 23 industries. Together, these countries account for over 85% of the world's GDP, with the rest-of-world region accounting for the remainder. Each year contains approximately 562,500 observations, yielding roughly 23 million observations over 40 years.

[26]See Oulton (2017).
[27]The 2016 release adds only three years (2012–2014) and uses a different industry classification.
[28]WIOD 2013 release is more granular in that it covers 40 countries (vs. 26) and 35 industries (vs. 23.)

To illustrate the structure of WIOTs, Table 2 presents a two-country, two-industry example. Rows of the industry table represent flows from industries to other users (intermediate or final), while columns represent demands. Entry z_{ij}^{AA} denotes the value of goods from industry i in country A used by industry j in the same country. Diagonal elements represent domestic transactions; off-diagonal ones represent international trade (e.g., z_{ij}^{BA} is the value of goods from industry i in country B used by industry j in A) Final-use columns cover final demands from households (HHs), non-profit organizations (NPOs), governments (GVT), and firms demanding goods for investment (GFCF) or inventory purposes (INVEN). The non-industry rows of Table 2 capture total demand by intermediate and final users (II_FOB), taxes and subsidies on products (TXSP), CIF/FOB adjustments on exports (EXP_ADJ), direct purchases abroad by residents (PURR), purchases on domestic territory by non-residents (PURNR), value added at basic prices (VA), and international transport margins (INTTTM).

Summing all elements within an industry row or column gives gross output at basic prices, which can be computed using either:

$$x_i^r = \underbrace{\sum_{s\in\{A,B\}} \sum_{j=1}^{I_s} z_{ji}^{sr}}_{\text{intermediate consumption}} + \underbrace{\mathrm{VA}_i^r}_{\text{value added}} + \underbrace{\mathrm{tax}_i^r + \mathrm{adj}_i^r + \mathrm{trans}_i^r}_{\text{tax and trade adjustments}}, \qquad \text{(Production approach)}$$

$$x_i^r = \underbrace{\sum_{s\in\{A,B\}} \sum_{j=1}^{I_s} z_{ij}^{rs}}_{\text{sales to intermediate consumers}} + \underbrace{\sum_{s\in\{A,B\}} \sum_{v\in\{C,N,G,K,I\}} f_{i,v}^{rs}}_{\text{sales to final consumers}}. \qquad \text{(Expenditure approach)}$$

These two approaches mirror national accounting conventions.

WIOD vs. other similar datasets. While other datasets provide similar information (e.g., Eora, OECD–ICIO, IDE–JETRO, GTAP), WIOD offers the best balance of time coverage, factor detail, and alignment with KLEMS. Its advantages include longer time series, more consistent treatment of factor inputs, and lower reliance on imputation. Unlike many other datasets, WIOD does not restrict analysis to benchmark years and offers flexibility in modeling trade flows. Its main drawbacks are limited country coverage and a coarser industry classification compared to alternatives like Eora or GTAP. However, for this study's focus on long-run productivity and welfare, WIOD appears as the most suitable source.

Table 2: Two-country input-output table, following the conventions of WIOD's 2013 release.

			INTERMEDIATE USE						FINAL USE										TOTAL USE
			Country A			Country B			Country A					Country B					
			Industries			Industries			Final demand					Final demand					
			1	⋯	I_A	1	⋯	I_B	HHs	NPOs	GVT	GFCF	INVEN	HHs	NPOs	GVT	GFCF	INVEN	GO
SUPPLY COUNTRY-INDUSTRY: Country A	Industries	1																	x_1^A
		⋮		z_{ij}^{AA}			z_{ij}^{AB}		$f_{i,\mathrm{H}}^{AA}$	$f_{i,\mathrm{N}}^{AA}$	$f_{i,\mathrm{G}}^{AA}$	$f_{i,\mathrm{K}}^{AA}$	$f_{i,\mathrm{I}}^{AA}$	$f_{i,\mathrm{H}}^{AB}$	$f_{i,\mathrm{N}}^{AB}$	$f_{i,\mathrm{G}}^{AB}$	$f_{i,\mathrm{K}}^{AB}$	$f_{i,\mathrm{I}}^{AB}$	⋮
		I_A																	$x_{I_A}^A$
Country B	Industries	1																	x_1^B
		⋮		z_{ij}^{BA}			z_{ij}^{BB}		$f_{i,\mathrm{H}}^{BA}$	$f_{i,\mathrm{N}}^{BA}$	$f_{i,\mathrm{G}}^{BA}$	$f_{i,\mathrm{K}}^{BA}$	$f_{i,\mathrm{I}}^{BA}$	$f_{i,\mathrm{H}}^{BB}$	$f_{i,\mathrm{N}}^{BB}$	$f_{i,\mathrm{G}}^{BB}$	$f_{i,\mathrm{K}}^{BB}$	$f_{i,\mathrm{I}}^{BB}$	⋮
		I_B																	$x_{I_B}^B$
II_FOB				z_j^A			z_j^B		f_H^A	f_N^A	f_G^A	f_K^A	f_I^A	f_H^B	f_N^B	f_G^B	f_K^B	f_I^B	
TXSP				tax_j^A			tax_j^B		$\mathrm{tax}_\mathrm{H}^A$	$\mathrm{tax}_\mathrm{N}^A$	$\mathrm{tax}_\mathrm{G}^A$	$\mathrm{tax}_\mathrm{K}^A$	$\mathrm{tax}_\mathrm{I}^A$	$\mathrm{tax}_\mathrm{H}^B$		⋯		$\mathrm{tax}_\mathrm{I}^B$	
EXP_ADJ				adj_j^A			adj_j^B		$\mathrm{adj}_\mathrm{H}^A$	$\mathrm{adj}_\mathrm{N}^A$	$\mathrm{adj}_\mathrm{G}^A$	$\mathrm{adj}_\mathrm{K}^A$	$\mathrm{adj}_\mathrm{I}^A$	$\mathrm{adj}_\mathrm{H}^B$		⋯		$\mathrm{adj}_\mathrm{I}^B$	
PURR									$\mathrm{par}_\mathrm{H}^A$	$\mathrm{par}_\mathrm{N}^A$	$\mathrm{par}_\mathrm{G}^A$	$\mathrm{par}_\mathrm{K}^A$	$\mathrm{par}_\mathrm{I}^A$	$\mathrm{par}_\mathrm{H}^B$		⋯		$\mathrm{par}_\mathrm{I}^B$	
PURNR									$\mathrm{pdn}_\mathrm{H}^A$	$\mathrm{pdn}_\mathrm{N}^A$	$\mathrm{pdn}_\mathrm{G}^A$	$\mathrm{pdn}_\mathrm{K}^A$	$\mathrm{pdn}_\mathrm{I}^A$	$\mathrm{pdn}_\mathrm{H}^B$				$\mathrm{pdn}_\mathrm{I}^B$	
VA				VA_j^A			VA_j^B												
INTTTM				trans_j^A			trans_j^B		$\mathrm{trans}_\mathrm{H}^A$	$\mathrm{trans}_\mathrm{N}^A$	$\mathrm{trans}_\mathrm{G}^A$	$\mathrm{trans}_\mathrm{K}^A$	$\mathrm{trans}_\mathrm{I}^A$	$\mathrm{trans}_\mathrm{H}^B$	$\mathrm{trans}_\mathrm{N}^B$	$\mathrm{trans}_\mathrm{G}^B$	$\mathrm{trans}_\mathrm{K}^B$	$\mathrm{trans}_\mathrm{I}^B$	
GO				x_j^A		x_1^B	⋯	$x_{I_B}^B$											

Table Notes.

- *Abbreviations*. HHs: Households, NPOs: Non-profit organizations, GVT: Government, GFCG: Gross fixed capital formation, INVEN: Inventories, GO: Gross output, II_FOB: Total intermediate consumption, TXSP: Taxes less subsidies on products, EXP_ADJ: CIF/FOB adjustments on exports, PURR: Direct purchases abroad by residents, PURNR: Purchases on the domestic territory by non-residents, VA: Value added at basic prices, INTTTM: International transport margins, I_c: number of industries in country c.

- *Units*. In the WIOTs, entries represent USD millions.

- *Interpretations*. Red shaded cells denote empty cells (or cells populated by zeroes in the WIOTs). z_{ij}^{AA} is a generic entry of the national input-output table of country A, and it captures the demand of goods from industry j by industry i. A similar interpretation applies for z_{ij}^{BB}. z_{ij}^{AB} is the demand of goods i from country A by industry j in country B. Alternatively, one could say that z_{ij}^{AB} is the supply of goods by industry i in country A to industry j in country B. The remaining cells are left blank because their interpretation is straightforward.

D.3 Country Sample

Table 3: Country and Region Sample

Australia (AUS)	Denmark (DNK)	Ireland (IRL)	Sweden (SWE)
Austria (AUT)	Spain (ESP)	Italy (ITA)	Taiwan (TWN)
Belgium (BEL)	Finland (FIN)	Japan (JPN)	United States (USA)
Brazil (BRA)	France (FRA)	South Korea (KOR)	Rest of world (ROW)
Canada (CAN)	United Kingdom (GBR)	Mexico (MEX)	
China (CHN)	Greece (GRC)	Netherlands (NLD)	
Germany (DEU)	India (IND)	Portugal (PRT)	

Table Notes. ISO-3 country codes are listed in parenthesis. The countries listed in this table appear in both the Long-Run and the 2013 WIOD releases. Some countries (e.g., Hong-Kong) may appear in one of the aforementioned WIOD releases, but not in the other. In such cases, countries are included in the "Rest of world" region, which is appropriately harmonized across releases.

D.4 Industry Sample

Table 4: Industry Sample

Code	Name
AtB	Agriculture, Hunting, Forestry and Fishing
C	Mining and Quarrying
D15t16	Food, Beverages and Tobacco
D17t19	Textiles, Textile, Leather, and Footwear
D21t22	Pulp, Paper, Paper, Printing and Publishing
D23	Coke, Refined Petroleum and Nuclear Fuel
D24	Chemicals and Chemical Products
D25	Rubber and Plastics
D26	Other Non-Metallic Mineral
D27t28	Basic Metals and Fabricated Metal
D29	Machinery, Nec
D30t33	Electrical and Optical Equipment
D34t35	Transport Equipment
Dnec	Manufacturing, Nec; Recycling
E	Electricity, Gas and Water Supply
F	Construction
G	Wholesale and Retail Trade
H	Hotels and Restaurants
I60t63	Transport and Storage
I64	Post and Telecommunications
J	Financial Intermediation
K	Real Estate, Renting and Business Activities
LtQ	Community Social and Personal Services

Table Notes. Industry codes and names follow the ISIC Rev. 3.1 Industry Classification.

D.5 Growth-Accounting Variables

Table 5 presents the correspondence between model variables and their empirical counterparts used in the growth-accounting exercise. For each variable, the table lists the data source. Given the long time horizon and the need to implement alternative growth-accounting procedures, I combine data from both KLEMS and WIOD. These two sources are internally consistent: WIOD was constructed using KLEMS data and following its methodology.

The variables in Table 5 fall into three categories. *Common variables* are used in all growth-accounting exercises. *Traditional Solow Residual* variables are those employed by statistical agencies and in much of the literature to estimate TFP based on Solow's framework. In this approach, the capital share is calculated residually as one minus the labor share, implicitly assuming a frictionless economy. *Distorted Solow Residual* variables, by contrast, incorporate distortions. Their construction follows the procedures outlined in Section 3 and requires additional data, including estimates of depreciation, rental rates, and input-output linkages.

Table 5: Growth-Accounting Variables.

Model Variable	Data Counterpart	Source
COMMON VARIABLES		
$d \log Y_t$	$\Delta \ln \text{VA\_QI}_t$	
$d \log L_{Kt}$	$\Delta \ln \text{CAP\_QI}_t$	KLEMS 2007 (1970–2005), KLEMS 2021 (2005–)
$d \log L_{Lt}$	$\Delta \ln \text{LAB\_QI}_t$	
TRADITIONAL SOLOW RESIDUAL		
Λ_{Lt}	$\frac{1}{2}\left(\frac{\text{LAB}_{t-1}}{\text{VA}_{t-1}} + \frac{\text{LAB}_t}{\text{VA}_t}\right)$	KLEMS 2007 (1970–2005), KLEMS 2021 (2005–)
Λ_{Kt}	$1 - \Lambda_{Lt}$	
DISTORTED SOLOW RESIDUAL		
Λ_{Lt}	Revenue-based labor share	
Λ_{Kt}	Revenue-based capital share	WIOD, KLEMS, BEA
$\tilde{\Lambda}_{Lt}$	Cost-based labor share	
$\tilde{\Lambda}_{Kt}$	Cost-based capital share	

Table Notes. This table presents the exact mapping between model variables and data counterparts. Here, $\Delta \ln X_t = \ln X_t - \ln X_{t-1}$. Common variables are those used irrespective of the TFP measure to be constructed. Variables under "Traditional Solow Residual" are the revenue-based factor shares resulting from ignoring distortions and input-output networks. Variables under "Distorted Solow Residual" are revenue- and cost-based factor shares which take both distortions and IO linkages into account.

D.6 Consumption of Fixed Capital

I estimate the consumption of fixed capital using capital stock data from KLEMS and WIOD, combined with asset-specific depreciation rates from the Fixed-Asset Tables published by the U.S. Bureau of Economic Analysis (BEA).

From KLEMS, I use two capital input files: the 2008 release for the period 1970–2005, and the 2021 release for 2005–2010. Both files report eight distinct types of real capital stocks: computing equipment ("`K_IT`"), communications equipment ("`K_CT`"), software ("`K_Soft`"), transport equipment ("`K_TraEq`"), other machinery and equipment ("`K_OMach`"), non-residential investment ("`K_OCon`"), residential structures ("`K_RStruc`"), and other assets ("`K_Other`").[29]

Using these data, I compute the share of each capital type j in the total capital stock of sector i in country c and year t as

$$\text{Share in capital stock}_{jict} = \frac{K_{jict}}{K_{ict}}.$$

Given these shares, I construct the sector-specific depreciation rate δ_{ict} as a weighted average of asset-specific depreciation rates:

$$\delta_{ict} = \sum_j \delta_{jt} \times \text{Share in capital stock}_{jict}.$$

Because the BEA reports depreciation rates at a finer level of disaggregation than the capital types provided in KLEMS, I map the BEA depreciation rates to KLEMS categories. Table 6 documents this mapping and the resulting depreciation rates for each asset type.

When data on asset-specific capital stocks are missing for a given country-sector-year observation, I impute capital shares using the unweighted mean from all other observations. Table 7 illustrates the resulting depreciation rates for a sample of sectors.

[29] KLEMS also divides capital ("`K_GFCF`") into ICT ("`K_ICT`") and non-ICT ("`K_NonICT`") categories.

Table 6: Asset-Specific Depreciation Rates.

ASSET	DESCRIPTION	DEPRECIATION RATE BEFORE 1978	DEPRECIATION RATE AFTER 1978
K_IT	**Computing**	**0.2729**	**0.3119**
Office, computing, and accounting machinery		0.2729	0.3119
K_CT	**Communications**	**0.1438**	**0.1438**
Business services		0.1500	0.1500
Other industries		0.1100	0.1100
Instruments		0.1350	0.1350
Other instruments		0.1800	0.1800
K_Soft	**Software**	**0.1947**	**0.1947**
Video and audio products, computers, etc.		0.1833	0.1833
Electronic countermeasures		0.2357	0.2357
Other		0.1650	0.1650
K_TraEq	**Transport**	**0.1440**	**0.1440**
Local and interurban passenger transit		0.1232	0.1232
Trucking and warehousing		0.1725	0.1725
Transportation by air, depositiory institutions, etc.		0.0825	0.0825
Other industries		0.1100	0.1100
Other motor vehicles		0.2316	0.2316
K_OMach	**Machinery**	**0.1046**	**0.1046**
Other fabricated metal products		0.0917	0.0917
Steam engines and turbines		0.0516	0.0516
Internal combustion engines		0.2063	0.2063
Metalworking machinery		0.1225	0.1225
Special industrial machinery, n.e.c.		0.1031	0.1031
General industrial equipment		0.1072	0.1072
Electrical transmission, distribution, and industrial apparatus		0.0500	0.0500
K_OCon	**Non-residential**	**0.0262**	**0.0262**
Industrial buildings		0.0314	0.0314
Mobile offices		0.0556	0.0556
Office buildings		0.0247	0.0247
Commercial warehouses		0.0222	0.0222
Other commercial buildings		0.0262	0.0262
Educational buildings		0.0188	0.0188
Hospital and institutional buildings		0.0188	0.0188
Hotels and motels		0.0281	0.0281
All other nonfarm buildings		0.0249	0.0249
Railroad replacement track		0.0275	0.0275
Other railroad structures		0.0166	0.0166
Telecommunications		0.0237	0.0237
K_RStruc	**Residential**	**0.0418**	**0.0418**
1-to-4-unit structures-new		0.0114	0.0114
1-to-4-unit structures-additions and alterations		0.0227	0.0227
1-to-4-unit structures-major replacements		0.0364	0.0364
5-or-more-unit structures-new		0.0140	0.0140
5-or-more-unit structures-additions and alterations		0.0284	0.0284
5-or-more-unit structures-major replacements		0.0455	0.0455
Mobile homes		0.0455	0.0455
Other structures		0.0227	0.0227
Equipment		0.1500	0.1500
K_Other	**Other**	**0.1465**	**0.1465**
Medical		0.1834	0.1834
Construction		0.1550	0.1550
Industrial		0.0917	0.0917
General		0.1650	0.1650
Other		0.1375	0.1375

Table Notes. Rows in bold and with description correspond to the capital types provided by KLEMS. The depreciation rates for these stocks are computed as the unweighted mean of the depreciation rates for the assets listed in the rows with indentation below, which display the depreciation rates for the asset types provided by the BEA and which are mapped to KLEMS assets as shown.

Table 7: Illustration of sector-specific depreciation rates for Spain.

Sector	Code	1970	1980	1990	2000	2010
Hotels and Restaurants	H	0.047	0.047	0.049	0.060	0.065
Post and Telecommunications	I64	0.058	0.063	0.068	0.084	0.094

Table Notes. Sector-specific depreciation rates are computed as a weighted average of asset-specific depreciation rates, where the weights are the shares of each type of capital in the total capital of a sector for a particular year.

D.7 Distortions and Markups

This appendix outlines the data processing steps and modeling assumptions used to estimate distortions and markups.

Wedges (baseline measure.) I compute wedge margins using equation (C.2) after estimating each sector's capital consumption and the corresponding net-of-depreciation rental rate. Whenever wedge margins are negative, I set them to zero. I then back out wedges using equation (C.3) and winsorize the resulting distribution at the 1st and 99th percentiles.

Capital consumption is estimated using capital composition data and BEA asset-specific depreciation rates, as described in Section D.6. For Spain, the sales-weighted average depreciation rate increases from approxiamtely 6% in 1970 to 8% in 2010. I compute the net-of-depreciation rental rate using the method ofvan Vlokhoven (2022), applying a three-year rolling window. For year t in country c, I pool sector-level data from years $t-1$, t, and $t+1$ and impose a common user cost of capital across sectors. This assumption could be relaxed by instead pooling by industry across countries, which would imply a common user cost across countries for a given sector.

As an example, Figure 13 shows the unconditional distribution of wedges (left panel) and the evolution of the harmonic sales-weighted wedge for Spain (right panel), which indicates rising distortions over time.

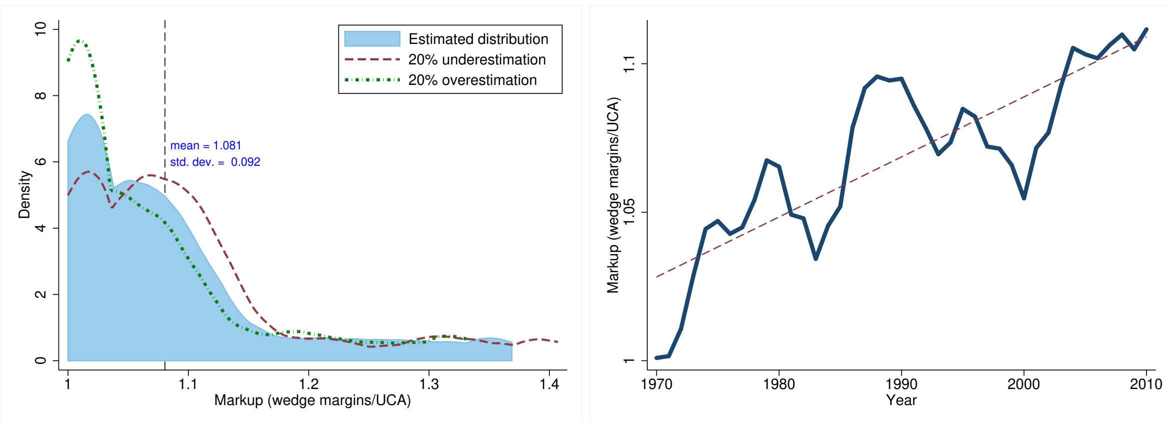


Figure 13: Wedges in Spain, 1970–2010.

Figure Notes. The left panel reports the (unconditional) distribution of wedges in Spain for the period of analysis. The dash- and dash-doted lines show how the distribution would look like if the wedge margin were underestimated or overestimated by 20%, respectively. The right panels displays the evolution of the harmonic sales-weighted wedge, and the dash line provides a linear fit.

Markups using Gross Margins. I calculate gross margins using equation (C.1). Whenever gross margins are negative, I set them to zero. I then apply equation (C.3) and winsorize the resulting markups at the 1st and 99th percentiles.

Figure 14 plots the unconditional distribution of markups (left) and their evolution over time (right). Since gross margins do not deduct capital costs, estimated markups are higher than those based on wedge margins. Consistent with the figure for wedges, the harmonic sales-weighted markup indicates that the Spanish economy has become less competitive over time. While wedge-based distortions increase from 1.00 to 1.12, gross-margin markups remain around 1.20 until 1990, after which they rise sharply to 1.30 by 2010.

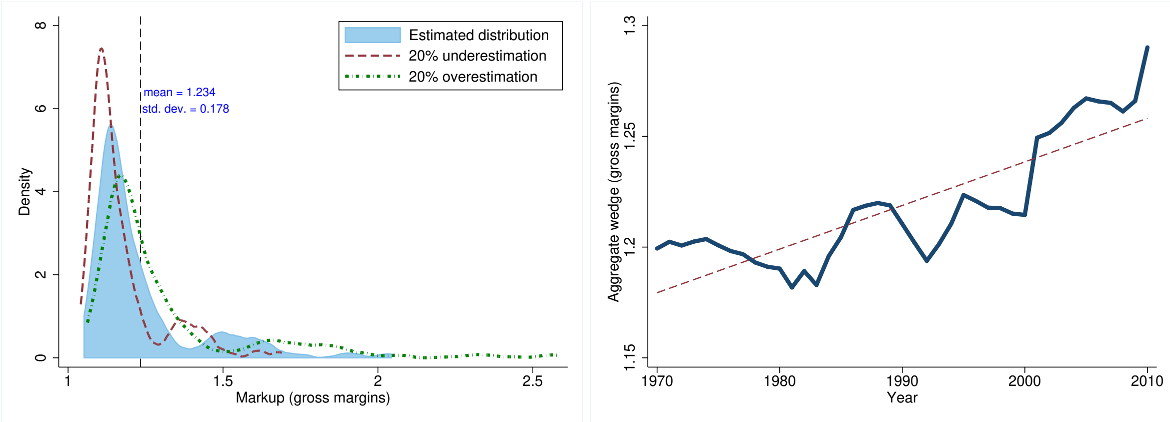


Figure 14: Markups in Spain (gross margins), 1970–2010.

Figure Notes. The left panel report (unconditional) distributions of markups for the period of analysis. The dash- and dash-doted lines show how the distribution would look like if gross margins were underestimated or overestimated by 20%, respectively. The right panel displays the evolution of harmonic sales-weighted markups over time, and the dash line provides a linear fit.

Markups using the Accounting–Profits Approach. This approach mirrors the wedge-margin method but assumes the net-of-depreciation rental rate of capital is zero. Figure 15 shows that the resulting markups also display a secular increase, from 1.00 in 1970 to 1.20 in 2010.

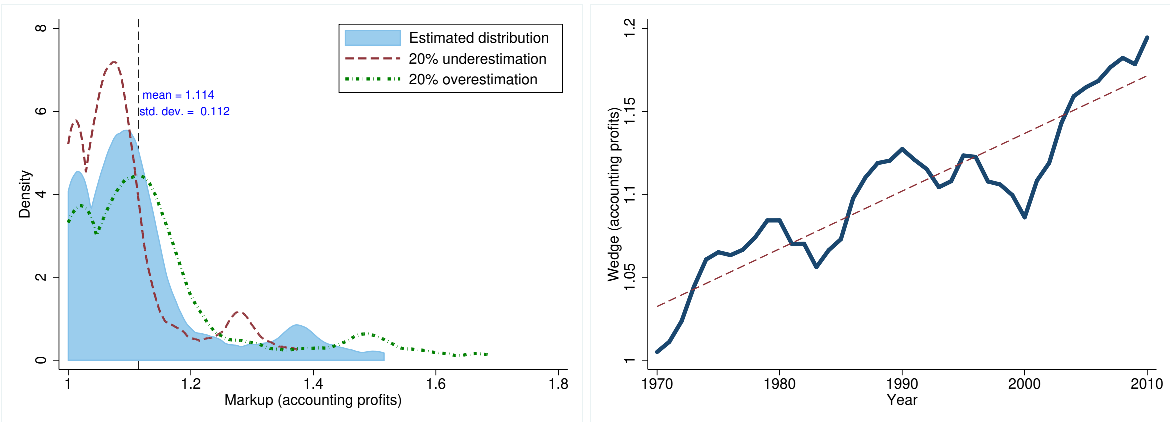


Figure 15: Markups in Spain (accounting profits), 1970–2010.

Figure Notes. The left panel displays the (unconditional) distribution of markups in Spain for the period of analysis. The dash- and dash-doted lines show how the distribution would look like if the wedge margin were underestimated or overestimated by 20%. The right panel shows the evolution of the sales-weighted markup over time, and the dash line provides a linear fit.

Markups using the Control–Function Approach. I estimate the elasticity of labor using the methodology of Olley and Pakes (1996) and the correction of Ackerberg et al. (2015). Estimation is conducted under both Cobb–Douglas and translog technologies, allowing for time-varying elasticities. I impose common elasticities across countries within each industry and estimate them using 3-year rolling windows. See Table 8 for details.

Table 8: Estimation Details in the Application of Control–Function Approach.

	(1)	**(2)**	**(3)**	**(4)**
Technology	CD	CD	TL	TL
Elasticities	Constant	Time-varying	Constant	Time-varying
Method	Olley and Pakes (1996)			
Productivity process	AR(1)			
Degree of polynomial	2nd			
Ackerberg et al. (2015)'s correction	✓			
Volume units	✓			
Outcome	Gross output			
State	Capital			
Free	Labor			
Proxy	Investment			

Table Notes. CD stands for Cobb-Douglas, and TL for translog. When elasticities are permitted to be time-varying, I estimate the elasticity of year t using 3-year rolling windows $(t-1, t, t+1)$.

Because the sample size is small ($N = 25$ sectors per country), elasticities are imprecisely estimated—frequently exceeding one—I discard this approach for computing markups. This method is better suited to firm-level data with large cross-sectional variation.

Markups using the Cost–Shares Approach. As shown in Section C.1.2, this method yields equivalent markups to the wedge-margin approach when using the same user costs of capital. To distinguish it, I compute markups assuming a constant gross rental rate of capital of 10%. Using equation (C.6) for elasticities and equation (C.4) for markups, I cap values below one at unity and winsorize the distribution at the 1st and 99th percentiles.

Figure 16 shows the resulting markup estimates. The sales-weighted average increases from 1.00 in 1970 to approximately 1.15 in 2010.

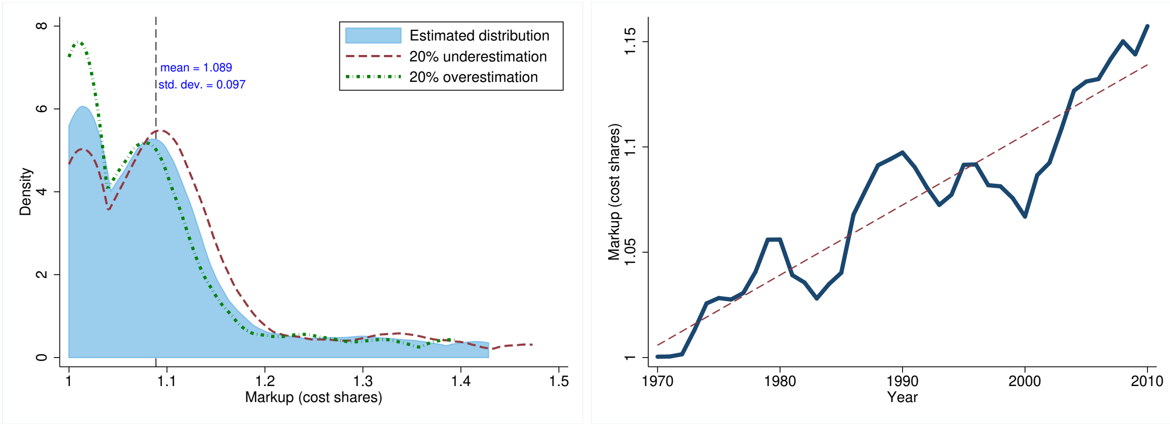


Figure 16: Markups in Spain (costs-shares approach), 1970–2010.

Figure Notes. The left panel displays the (unconditional) distribution of wedges in Spain for the period of analysis. The dash- and dash-doted lines show how the distribution would look like if the gross-of-depreciation rental rate of capital is set to 8% and 12%, respectively. The right panel shows the evolution of the sales-weighted markup over time, and the dash line provides a linear fit.

D.8 Reallocation of Labor and Value Added, and TFP

Here I present evidence supporting the reallocation of labor and value added toward sectors with declining productivity, as measured by the traditional Solow residual. Figure 17 shows the evolution of employment shares in Spain and Italy from 1970 to 2014. In both countries, labor has steadily shifted away from non-service sectors—such as agriculture, manufacturing, and construction—and toward services, including professional services, health care, education, and accommodation and food.

Figure 17: Reallocation of labor in Spain and Italy, 1970–2014.

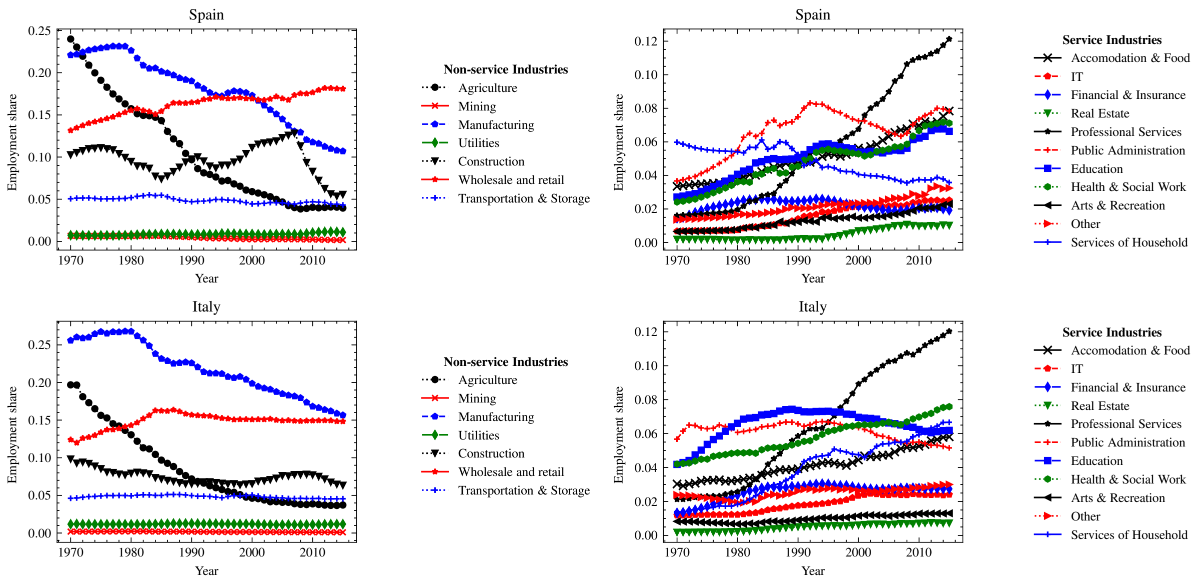


Figure Notes. Employment shares are calculated as the total hours worked by persons engaged in a particular sector ("H_EMP") divided by the economy total. Data comes from KLEMS.

Among non-service sectors, mining stands out as the only industry that experienced substantial employment growth. In contrast, agriculture's employment share fell dramatically—from roughly 20–25% in 1970 to around 5% in 2014. Manufacturing and construction also saw their employment shares halved over this period. On the services side, professional services registered the largest increase, rising from 2% to about 12%. Employment shares in accommodation and food, health care, and education also expanded significantly—doubling or tripling in size. Real estate and IT grew more modestly, while trends in public administration diverged: Spain's share doubled to 8%, whereas Italy's share remained relatively stable.

Figure 18 presents analogous trends in value added. While the patterns largely mirror those in employment, some differences emerge. Notably, real estate's value added share surged despite only modest employment gains—likely reflecting capital deepening or rents.

Figure 18: Reallocation of value added in Spain and Italy, 1970–2014.

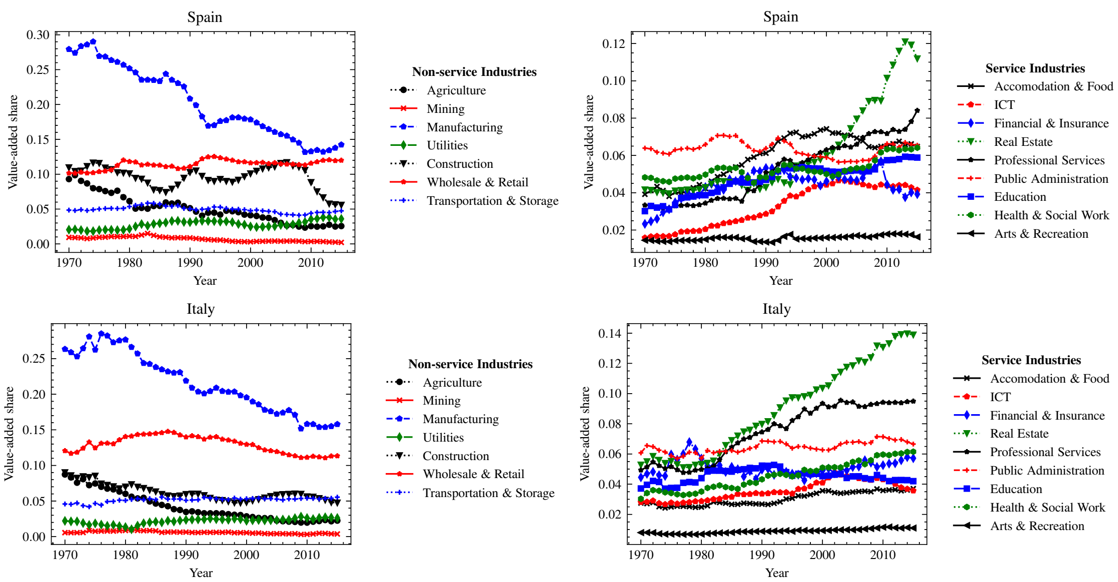


Figure Notes. Value added shares are calculated as the value added ("VA") of a particular industry divided by aggregate value added. Data comes from KLEMS.

Figure 19 complements these results by showing cumulative growth in measured productivity across sectors. Strikingly, industries that shed labor—such as agriculture and manufacturing—exhibited positive TFP growth. In contrast, sectors that expanded—particularly professional services, health care, and accommodation and food—experienced persistent TFP declines. Among non-service sectors, agriculture and manufacturing recorded the strongest productivity gains. Within services, professional services and hospitality saw the largest productivity losses.

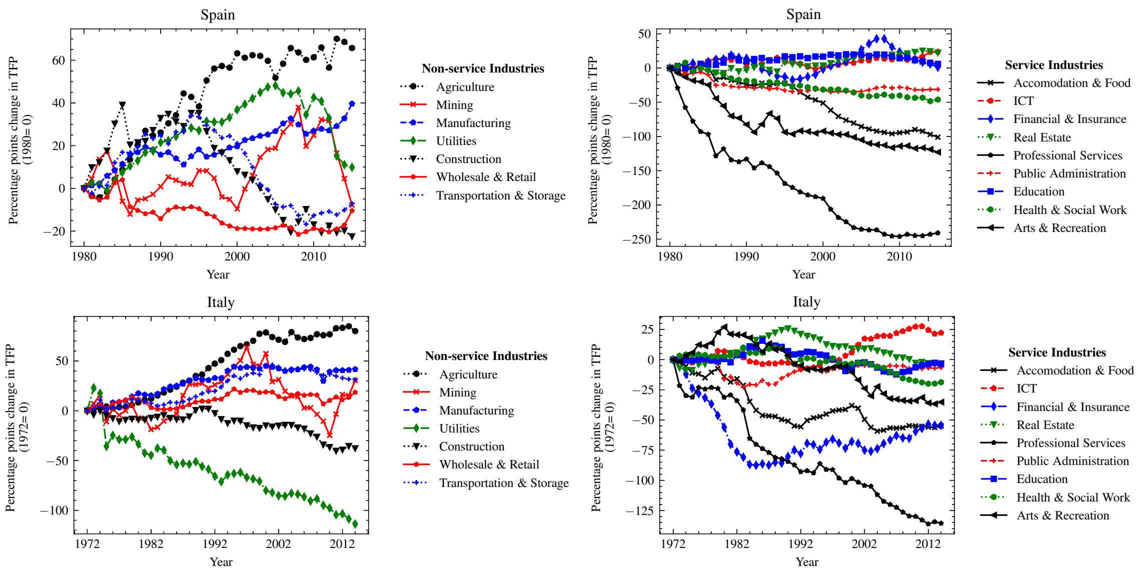


Figure 19: TFP growth in Spain and Italy, 1980–2014.

Figure Notes. TFP is taken from KLEMS ("`TFP_vaI`") and normalized to 100 in 1980.

D.9 Increased Trade Integration

The left panel of Figure 20 shows the share of total household expenditures allocated to foreign goods in Spain and Italy. Over time, imported consumption goods have accounted for a growing portion of final demand. In Spain, the foreign share rose from approximately 2% in 1985 to 13% in 2007. In Italy, it increased from around 4% in 1970 to 11% in 2007. The right panel plots the share of domestic producers' intermediate input expenditures accruing to foreign suppliers. Here too, a rising trend is evident. In Spain, the foreign share of intermediate inputs doubled from about 10% to 20%. In Italy, this share remained relatively flat at 13% through 2000, before climbing to 20%. Taken together, these patterns indicate a growing reliance on foreign goods.

Figure 20: Trade Statistics in Spain and Italy, 1970–2014

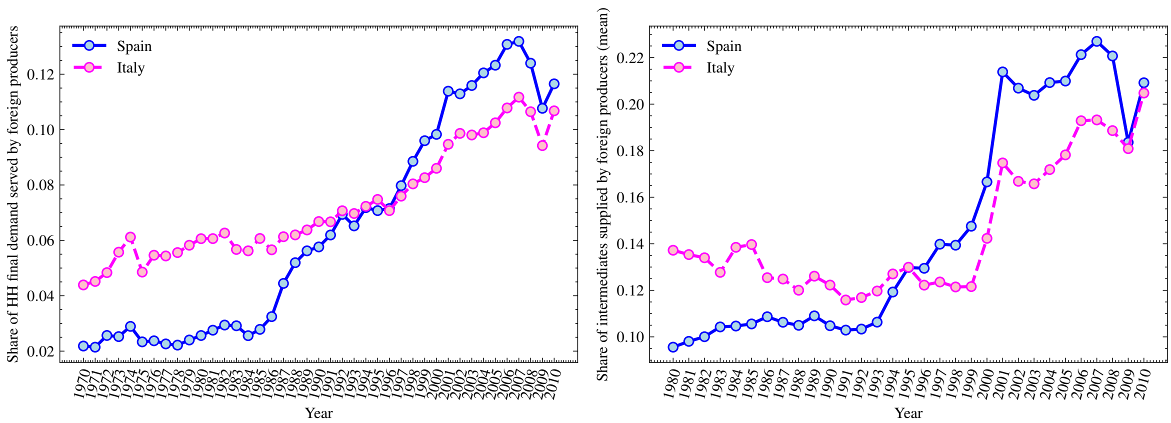


Figure Notes. Data are from WIOD.

D.10 Trade-Induced Factor Reallocation

I examine whether the factor reallocation observed in Southern European countries goes beyond the standard process of structural transformation. In particular, I investigate whether changes in the terms of trade contributed to the observed shifts in employment shares across sectors. To do so, I estimate the following regression:

$$\underbrace{\Delta \log(\text{EMPshare}^{NT})_{ct}}_{\substack{\text{\% Change in employment share} \\ \text{of non-tradable sector}}} = \beta_1 \underbrace{\Delta \log \text{ToT}_{ct}}_{\substack{\text{\% Change} \\ \text{terms of trade}}} + \beta_2 \underbrace{\Delta \log \text{ToT}_{ct} \times D_{SE}}_{\substack{\text{\% Change terms of trade} \\ \times \text{ Southern Europe}}} + \alpha_c + \xi_t + \varepsilon_{ct},$$

where $\text{EMPshare}^{NT}_{ct}$ denotes the employment share of the non-tradable sectors in country c and year t, ToT are the terms of trade (the ratio of exports to imports prices), D_{SE} is a dummy equal to one for Southern European countries (Greece, Italy, Portugal, and Spain), α_c and ξ_t are country and year fixed effects, and ε_{ct} is the error term.[30]

The economic intuition is straightforward: when the price of exports rises relative to imports, tradable sectors become more profitable, and mobile factors such as labor should reallocate toward them. This implies that the employment share of non-tradable sectors should decline following improvements in the terms of trade. Accordingly, a negative β_1 coefficient would confirm this prediction for the average country. A negative and significant β_2 coefficient would suggest that this reallocation effect is stronger in Southern Europe than in the rest of the sample, supporting the hypothesis of trade-induced reallocation above and beyond structural transformation.

Table 9 reports the regression results. In my preferred specification, the coefficient on the interaction term (β_2) is negative and statistically significant at the 5% level. This supports the view that changes in the terms of trade led to a greater reallocation of labor toward tradable sectors in Southern Europe than in the rest of Europe. Quantitatively, the estimates imply that a 10% improvement in the terms of trade is associated with a three pp increase in the employment share of tradable sectors in Southern Europe.

[30] Tradable sectors are identified following De Gregorio et al. (1994). A sector is classified as tradable if its average export-to-value-added ratio for the period 1995–2010 exceeds 10%:

$$\left(\frac{1}{T - t_0 + 1}\right) \sum_{t=t_0}^{T} \frac{\sum_{c \in \mathcal{C}} X^c_{it}}{\sum_{c \in \mathcal{C}} \text{VA}^c_{it}} > 0.10.$$

Tradable sectors include agriculture, mining, all manufacturing industries, wholesale and retail trade, and financial intermediation.

Table 9: Trade-Induced Labor Reallocation in Southern Europe,

Coefficient	(1)	(2)	(3)
$\Delta \log \text{ToT}_{ct}$	0.03	0.07	0.03
$\Delta \log \text{ToT}_{ct} \times D_{SE}$	-0.28^{**}	-0.22^{**}	-0.35^{***}
Country FE	✓	✓	–
Time FE	✓	–	–
Obs.	466	466	466

Table Notes. The regression period is 1995–2010. Terms of trade come from the OECD database, and employment shares from KLEMS and WIOD. Significance levels are denoted as *** if $p < 0.01$, ** if $p < 0.05$, and * if $p < 0.10$.

E Robustness Exercises

Figure 21 displays the evolution of aggregate TFP in Spain from 1970 to 2010 using alternative distortion measures (see Appendices C and D.7 for methodological details). As the figure shows, the main conclusions are robust to these alternative measures: in all cases, TFP peaks in 1995, and the post-peak decline is consistently less pronounced than that suggested by the standard (undistorted) Solow residual.

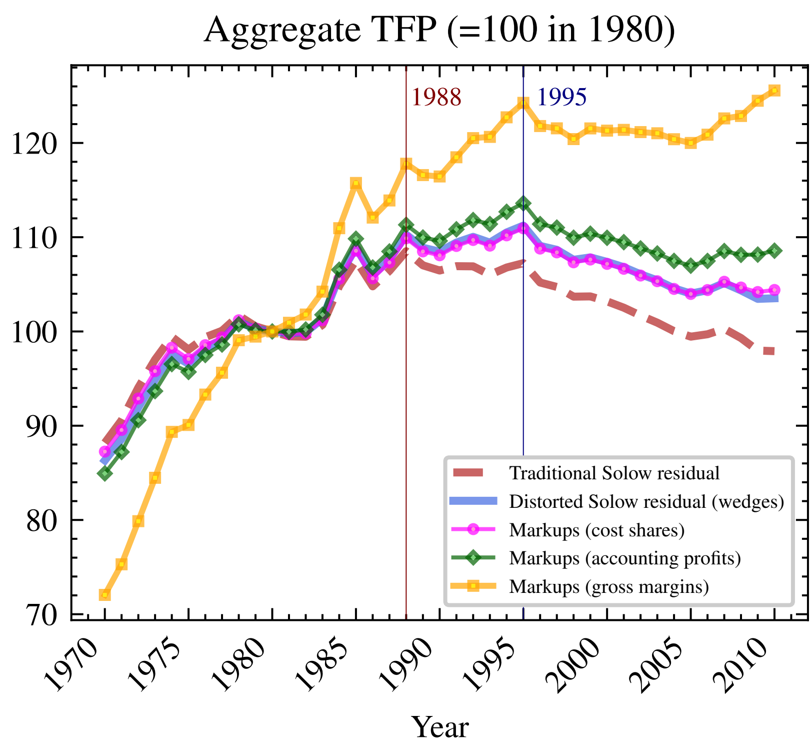


Figure 21: Aggregate TFP in Spain with alternative measures of distortions.

Figure Notes. The index based on the traditional Solow residual does not allow for distortions, while all other indices do. Distortions are estimated using the approaches listed within parenthesis. Indices are normalized to 100 in 1980.

Figure 22 presents robustness checks for the first-order decomposition of TFP growth. Panel (a) shows the baseline results using wedge margins. Panels (b)–(d) report decompositions using alternative methods to compute distortions: cost shares, accounting profits, and gross margins. The qualitative patterns are consistent across all approaches: "technical efficiency" explains between 57% and 90% of aggregate TFP growth; "international trade" accounts for 39% to 44%; and "reallocation" contributes between –1% and –31%. Quantitative differences across methods are modest, with the exception of gross margin, which assumes a zero user cost of capital and thereby understates capital costs.

Figure 22: Robustness of First-Order Decomposition of TFP growth in Spain.

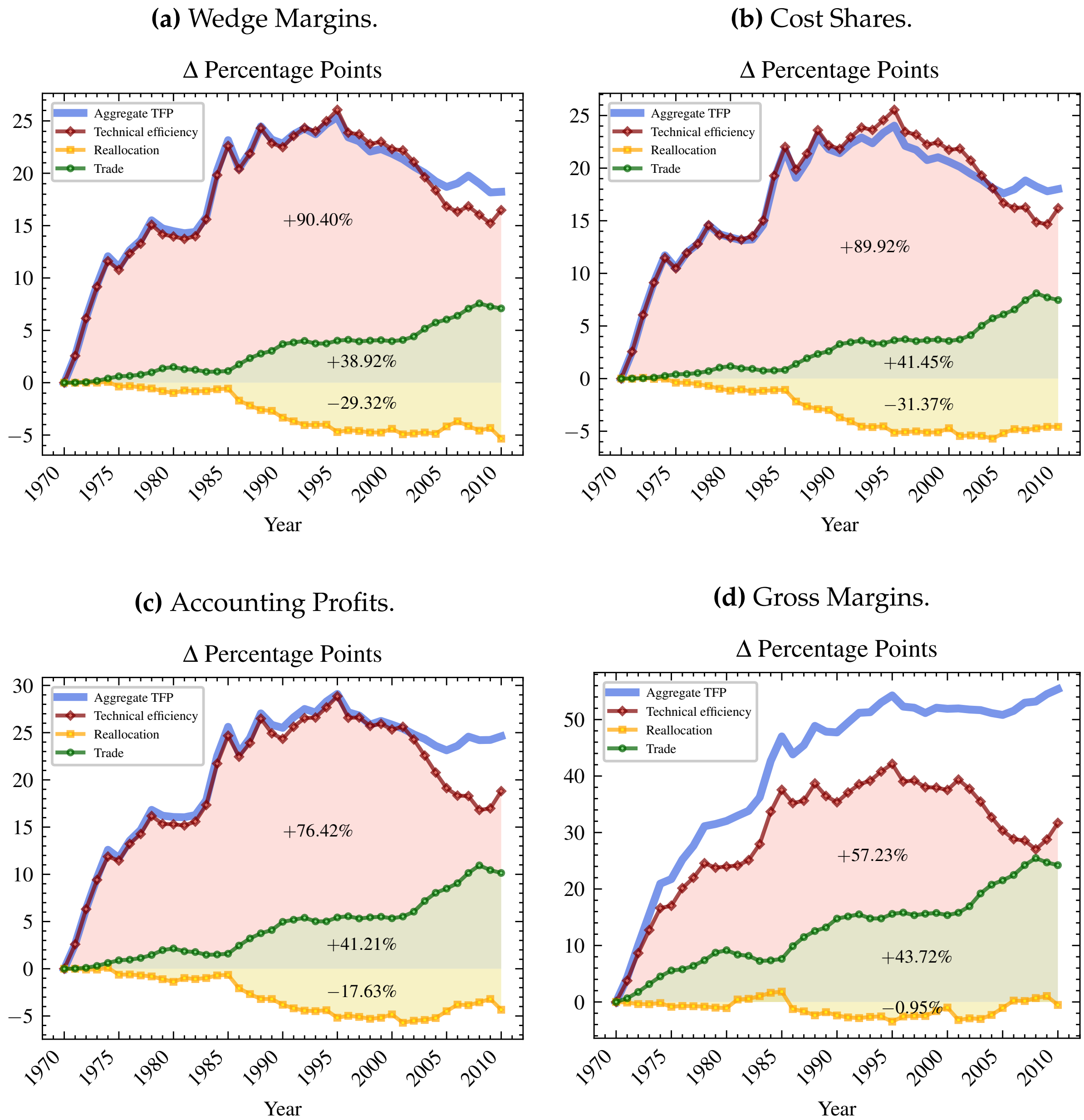


Figure Notes. Each panel offers the results of the first-order decomposition of aggregate TFP growth (6) under several measures of distortions. Distortions as wedges estimated using wedge margins, and distortions as markups estimated using cost shares, accounting profits, and gross margins. The term reallocation is the result of grouping the terms "distortions" and "income shares."

F The Case of Italy

Figure 23 shows various TFP indices for Italy, each constructed using a different distortion measure, alongside the index based on the traditional Solow residual. As in the case of Spain, the trajectory of TFP is less dismal than previously reported. In particular, TFP begins to decline in 2000 rather than 1995, though the peak-to-through decline remains at around 7 percentage points.

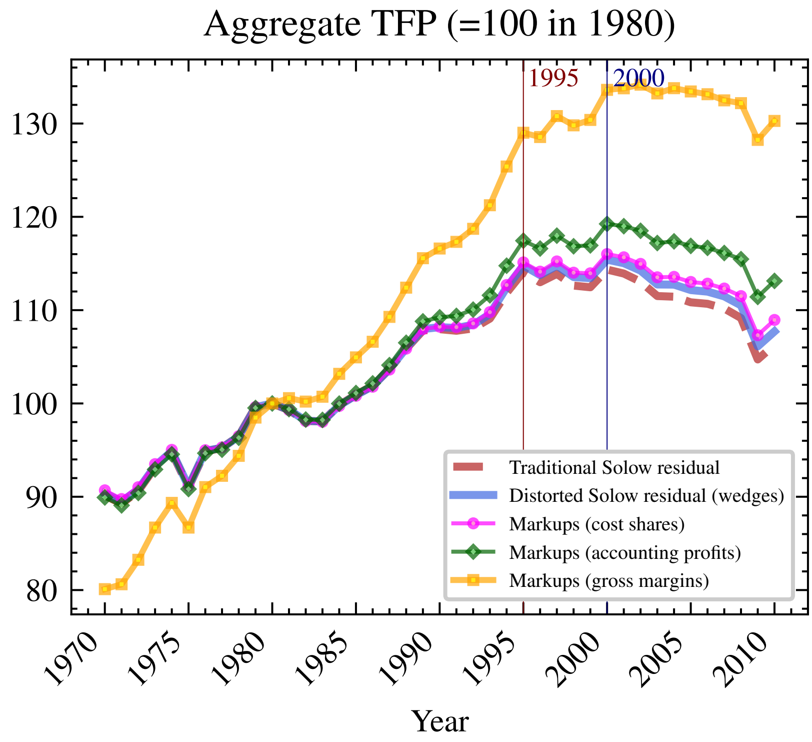


Figure 23: The Evolution of TFP in Italy, 1970–2010.

Figure Notes. The index based on the traditional Solow residual imposes efficiency and ignores production networks. The index based on the distorted Solow residual allows for distortions and global production networks. Distortions are estimated non-parametrically using wedge margins. Indices are normalized to 100 in 1980. Vertical lines indicate TFP peaks.

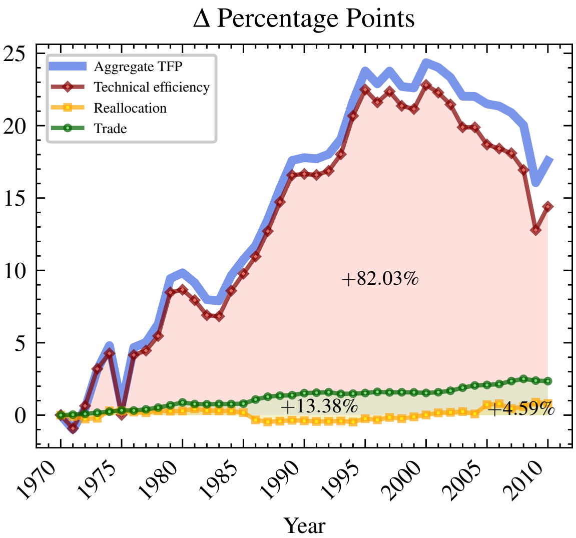
Figure 24 provides cumulative first-order decompositions of aggregate TFP growth using various measures of distortions. Technical efficiency accounts for 35–85% of TFP growth, trade for 13–29%, and reallocation between −2 and 37%. Results are broadly consistent across specifications, with the exception of gross margins, which assume a zero user cost of capital.

Figure 25 zooms into the productivity decline and presents a decomposition from 2000 to 2010. The decline in Italy is more than entirely driven by a deterioration of technical efficiency, as trade and reallocation had a modest positive influence.

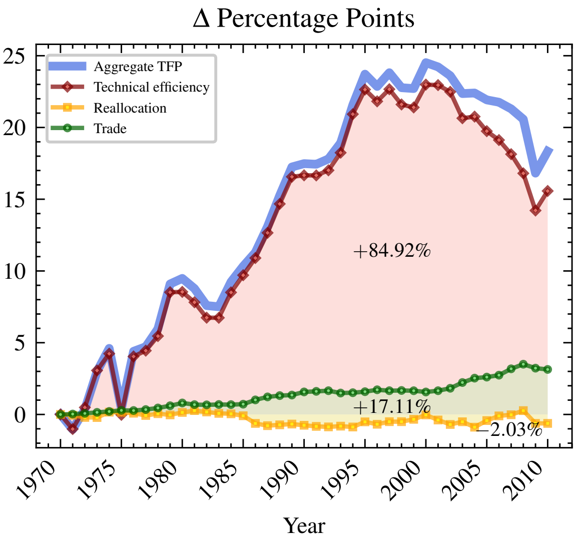
Figure 26 shows the evolution of aggregate productivity and welfare (left panel) and a first-order decomposition of welfare (right panel). As in Spain, productivity and welfare diverge after: while TFP declined, welfare continued to rise. Unlike

Figure 24: Robustness of First-Order Decomposition of TFP growth in Spain.

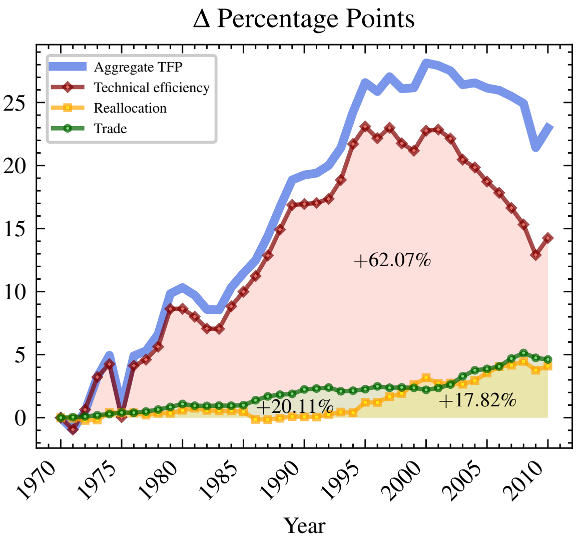
(a) Wedge Margins.



(b) Cost Shares.



(c) Accounting Profits.



(d) Gross Margins.

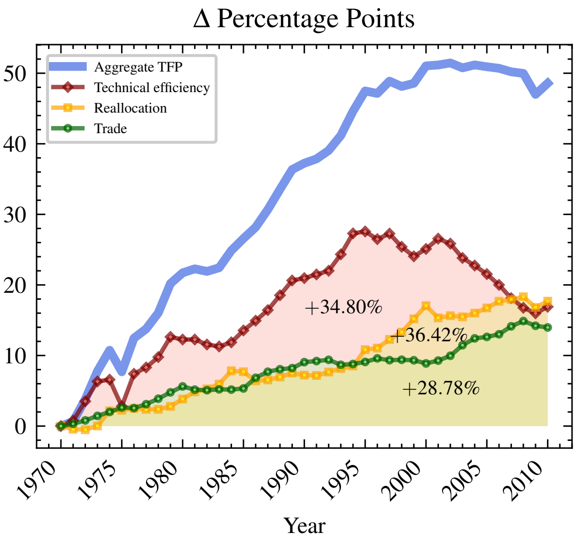


Figure Notes. Each panel offers the results of the first-order decomposition of aggregate TFP growth (6) under several measures of distortions. Distortions as wedges estimated using wedge margins, cost shares, accounting profits, and gross margins. The term reallocation is the result of grouping the terms "distortions" and "income shares."

Spain, where both technology and reallocation contributed positively, Italy's welfare gains were driven entirely by technological improvements. Reallocation had a slightly negative effect.

Figure 27 presents a counterfactual scenario in which producer weights are held fixed at their 2000 levels. The left panel depicts the evolution of aggregate TFP and its first-order decomposition under this scenario. While the overall magnitude of the TFP decline is similar to that observed in the data, the timing differs markedly: the

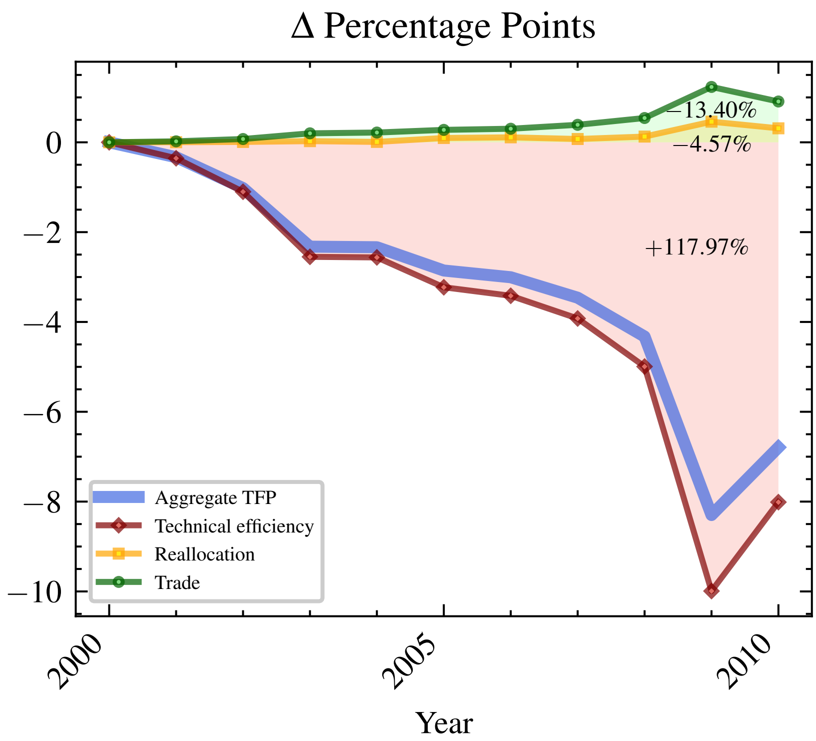


Figure 25: Cumulative First-Order Decomposition of TFP Decline in Italy, 2000–2010.

Figure Notes. Aggregate TFP is computed using the definition 1. Technical efficiency is computed as the residual of TFP minus reallocation and trade terms. Reallocation is the sum of changes in distortions and income shares.

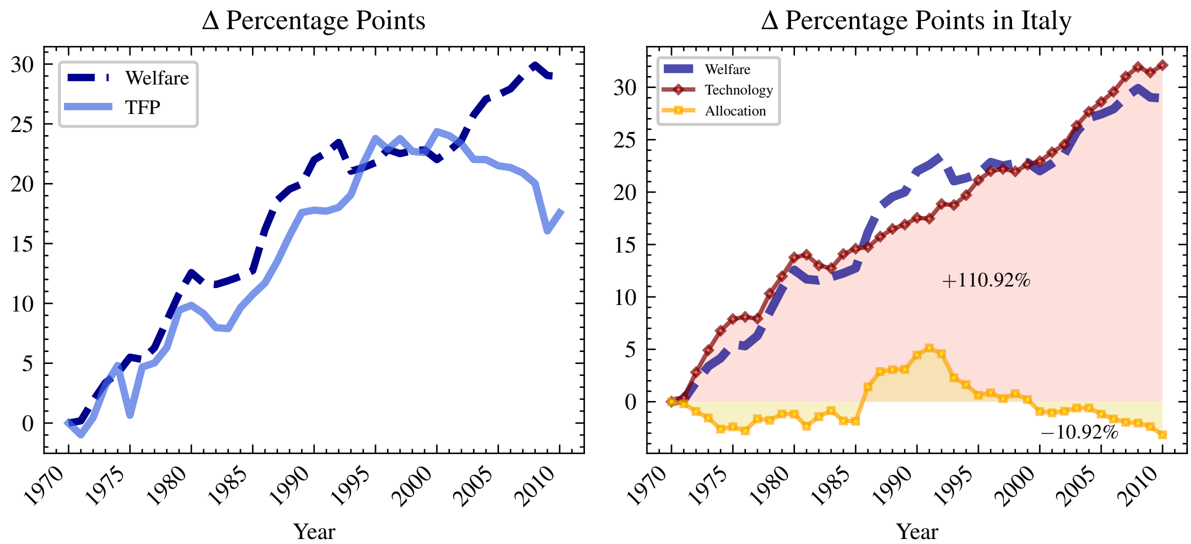


Figure 26: Welfare and TFP in Italy, 1970–2010.

decline occurs exclusively during the 2007 crisis, rather than gradually over time. The right panel compares actual and counterfactual welfare. It shows that, had sectoral composition remained unchanged, aggregate welfare would have been approximately five percentage points lower by the end of the period.

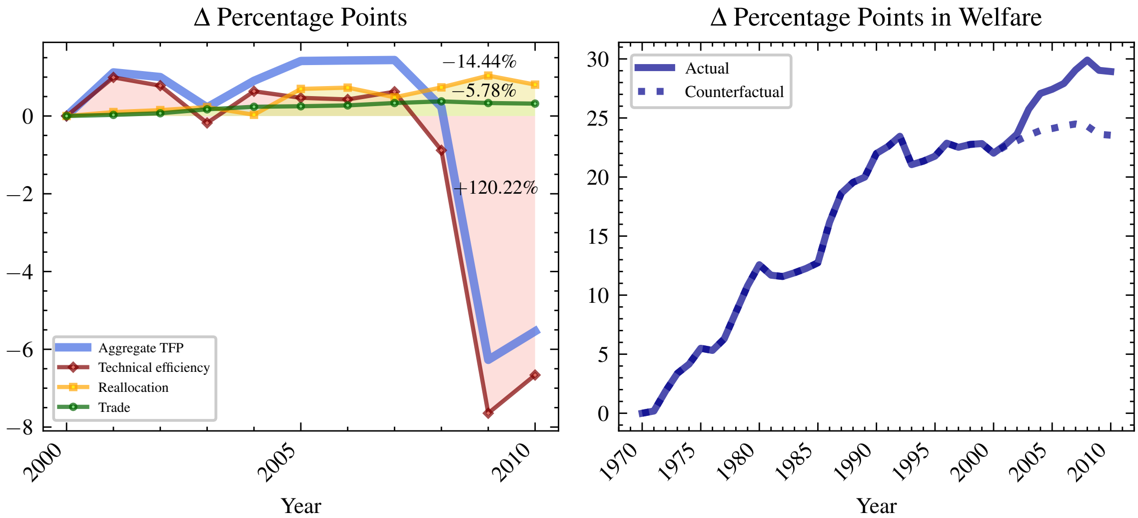


Figure 27: Counterfactual TFP and Welfare in Italy, 1970–2010.

Finally, Figure 28 displays the evolution of income shares in Italy. In contrast to Spain, where the income share accruing to wedges increased steadily over time, Italy's wedge income share remained relatively stable at approximately 4% of GDP throughout the period. The labor share declined from 70% in 1970 to 65% in 2010, and the capital share rose from 25% to 30%.

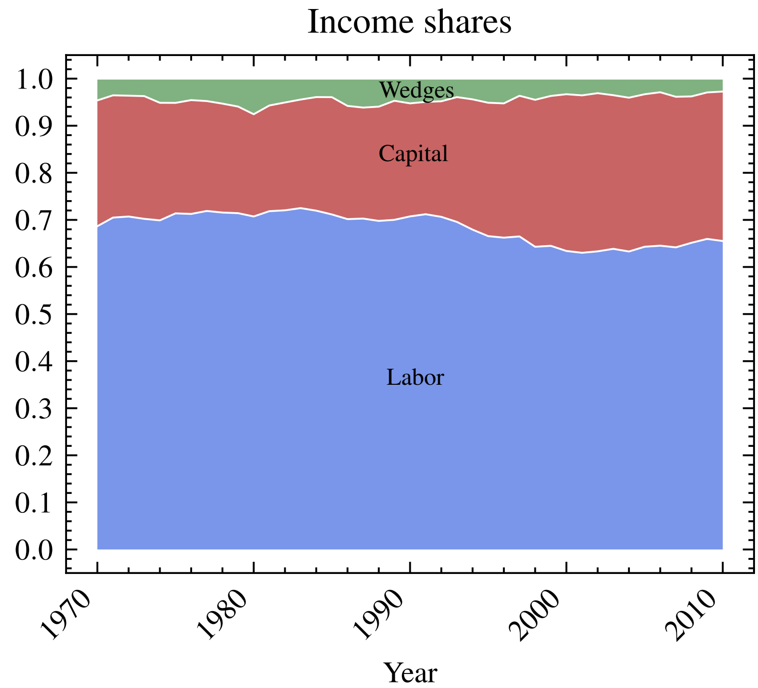


Figure 28: Income Shares in Italy, 1970–2010.

Figure Notes. Income shares are computed after subtracting taxes from total income. That is, I compute the share of labor-, capital-, and wedge income by dividing the income generated by that factor/source over net-of-taxes aggregate value added.