Structural Change under Limited Growth Pass-Through*

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Abstract

I incorporate variable markups into a model of structural change. This separates the canonical price effect into two objects: productivity growth and its *growth pass-through* into the sectoral price index. Growth pass-through is incomplete and depends on the sectoral firm distribution. Consequently, observed price changes do not directly reveal underlying productivity. I quantify the mechanism for the United States from 1980 to 2014 and find that growth pass-through has declined in every sector as markups have risen. In the full pass-through counterfactual, structural change toward Services would have been 31.4% larger, corresponding to a 2.92 percentage-point higher Services expenditure share in 2014. This effect is primarily driven by limited pass-through in Industry.

Keywords: Structural Change; Markups; Growth Pass-Through; Firm Heterogeneity; Growth
JEL classification: O14; O41; L11; D43.

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1 Introduction

Over the last decades, reallocation of expenditure and employment away from goods production and into Services has coincided with changes in market structure: large firms have expanded their market shares and the aggregate markup has risen. This coincidence matters because in the standard interpretation structural change relies on prices reflecting productivity. Rising markups drive a wedge between these two. Changes in market structure can therefore affect both the speed of structural change and how productivity is inferred from observed prices.

This paper connects two largely separate literatures. Models of structural change explain relative price changes through sectoral productivity growth, abstracting from firm heterogeneity and market power. At the same time, a large literature documents heterogeneous and rising markups and incomplete firm-level pass-through. My theory builds on the structural change framework of Comin et al. (2021). I embed an explicit firm distribution into this model and allow firms to charge variable markups through a non-constant price elasticity of demand. This feature separates the classic price effect into two objects: productivity growth, and its *growth pass-through* into the price index. The model preserves tractability: the Pareto shape parameter maps directly into sectoral markup and growth pass-through. Once markups vary across firms, sectoral price changes are no longer sufficient to identify productivity growth. Instead, I use observed markups to discipline growth pass-through and combine them with prices to recover productivity.

I show the quantitative implications in an application to the United States from 1980 to 2014. The calibrated model closely replicates the long-run reallocation of expenditure toward Services and captures the secular increase in the aggregate markup. I then construct a counterfactual with full growth pass-through and find that structural change toward Services would have been 31.4% larger, corresponding to a 2.92 percentage-point higher Services expenditure share in 2014. A sectoral decomposition shows that this effect is driven primarily by Industry: imposing full pass-through in Industry alone accounts for nearly the entire aggregate effect.

The mechanism behind these quantitative results operates through the interaction of non-homothetic demand across sectors and variable-markup firms within sectors. On the demand side, consumers allocate expenditure across a set of sectoral composites using non-homothetic CES preferences. This upper-tier structure yields a decomposition of relative expenditure changes into a relative price effect and an income effect, thus allowing for a clean mapping from sectoral price indices into expenditure shares.

Within each sector, varieties are supplied by monopolistically competitive firms that differ in productivity. I assume a quadratic sub-utility over varieties. This implies a finite choke price and a variable price elasticity of demand at the variety level. These preferences satisfy empirical regularities in firm behaviour: markups are heterogeneous and increasing in firm productivity and size, while cost pass-through into prices is incomplete and lower for large firms. I show that introducing these features changes the mapping from productivity growth to structural change. The productivity distribution determines sectoral markups and growth pass-through, so that identical improvements in underlying productivity generate differential price responses across sectors. This mechanism is absent under CES, where constant elasticities imply constant markups and mechanically complete pass-through. Growth pass-through is a sector-level equilibrium object, distinct from the firm-level pass-through studied in the literature. Firm-level pass-through measures the response of an individual firm's price to marginal cost, holding the sectoral environment fixed. Growth pass-through instead captures the equilibrium response of the sectoral price index to a change in productivity. The latter incorporates the endogenous adjustment of prices and firm selection induced by entry.

Firm productivities are drawn from sector-specific Pareto distributions. Firms enter freely by paying a sunk entry cost, while only sufficiently productive firms produce in equilibrium, generating an endogenous productivity cut-off. A thicker upper tail implies relatively more high-productivity firms among producers, raising cost-weighted sectoral markups and lowering growth pass-through. This links firm entry and selection to aggregate price dynamics: sectors with a thicker upper tail exhibit higher markups and weaker transmission of productivity improvements into sectoral prices.

Empirically, I combine US firm-level data from Compustat with sectoral expenditure and price data from the World Input-Output Database (WIOD). I aggregate the data into three broad sectors: Agriculture, Industry, and Services. The sectoral markups are mapped into the Pareto shape parameter using their model relation. The resulting estimates imply a substantial decline in growth pass-through in all three sectors: from about 90% to 63% in Agriculture, 89% to 79% in Industry, and 87% to 82% in Services. Combining these estimates with WIOD sectoral price changes allows me to recover sectoral productivity growth. In line with the literature, productivity growth is fastest in Agriculture and slowest in Services. On the demand side, estimates of the non-homothetic CES system imply gross complementarity across sectors and substantially different income elasticities, with Agriculture as relative necessity and Services as relative luxury goods.

I then calibrate the model to the observed evolution of U.S. expenditure shares and construct a full-pass-through counterfactual that holds the recovered sectoral technology paths fixed while imposing complete growth pass-through. The calibrated model closely tracks the long-run reallocation of expenditure away from Agriculture and Industry and toward Services. Under full pass-through, the Services expenditure share in 2014 would have been 2.92 percentage points higher and the Industry share 2.67 percentage points lower than under the estimated limited-pass-through paths. The additional increase in the Services share amounts to 31.4% of the structural change toward Services in the baseline model between 1980 and 2014 and corresponds to approximately 4.3 million additional workers in Services. A sectoral decomposition shows that this effect originates almost entirely in Industry: imposing full pass-through in Industry alone raises the Services share by 3.20 percentage points, whereas imposing full pass-through only in Services lowers its own share by 0.63 percentage points. About 63% of the additional reallocation under full pass-through is attributable to price effects, the remainder to income effects. Limited growth pass-through therefore slows structural change primarily by attenuating productivity-driven price declines in Industry.

I consider several extensions to assess the robustness and broader implications of the mechanism. First, replacing WIOD sectoral prices with BEA PCE price indexes, which provide an alternative price concept incorporating quality adjustment, leaves the large Industry to Services productivity gap intact and suggests that differential quality adjustment is unlikely to explain the main productivity pattern. Second, disaggregating the economy into eight sectors reveals substantial heterogeneity within Services: income elasticities, productivity growth, and growth pass-through differ markedly across Service industries, so structural change within Services need not be driven by a common mechanism. Finally, I sketch a dynamic extension with learning-by-imitation following Perla and Tonetti (2014), in which productivity growth is endogenous and itself depends on the firm productivity distribution. A thicker upper tail then not only lowers growth pass-through, but also raises productivity growth. The two effects work in opposite directions: a sector may grow faster technologically while passing a smaller fraction of that growth into lower prices. Hence, differences in the firm productivity distribution can shape structural change through both the pace of technological progress and the extent to which that progress reaches consumers.

1.1 Related Literature

Structural Change. Structural change arises from two distinct mechanisms: income effects and price effects. Income effects arise from non-homothetic preferences, which shift expenditure shares from necessities towards luxuries as income rises (even when relative prices are constant). This is known as Engel's Law. The literature has proposed various preferences, including Stone-Geary (Buera and Kaboski, 2009; Herrendorf et al., 2013; Kongsamut et al., 2001), price independent generalised linearity (PIGL, see Boppart (2014); Herrendorf et al. (2021)), hierarchic preferences (Buera and Kaboski, 2012; Föllmi and Zweimüller, 2006, 2008; Matsuyama, 2002;

Murphy et al., 1989), or non-homothetic CES (Auer et al., 2024; Baqaee and Burstein, 2023; Comin et al., 2021; Fally, 2022; Matsuyama, 2019; Redding and Weinstein, 2020).

Price effects are driven by asymmetric technologies across sectors, causing relative price changes. Baumol (1967) postulated productivity growth differences across sectors as driver of relative price changes. Ngai and Pissarides (2007) and Herrendorf et al. (2015) generate structural change using sectoral productivity growth. Acemoglu and Guerrieri (2008) employ sector-specific capital intensities and capital deepening to achieve price effects.

A growing body of literature combines both mechanisms. Boppart (2014) and Comin et al. (2021) perform a decomposition analysis to assess the relative contribution of income effects and price effects, and conclude that income effects are (at least weakly) more important. Herrendorf et al. (2013) show that the result depends on data: income effects dominate using final expenditure data, while price effects prevail with value-added data. Combinations of income and price effects have been applied to explain increases in the skill premium (Buera et al., 2022), structural change within the investment sector (Herrendorf et al., 2021), aggregate productivity differences across countries (Caselli, 2005; Duarte and Restuccia, 2010), or separating stagnant from progressive services (Duernecker et al., 2024). This paper contributes to this literature by splitting the price effect: productivity growth affects expenditure shares only to the extent that it is passed through into prices. With firm heterogeneity and variable demand elasticities, this pass-through is incomplete and becomes an additional determinant of structural change.

Markups. The measurement of markups using the production approach begins with Hall (1988) and advanced by Basu and Fernald (1997); Klette (1999); De Loecker and Warzynski (2012). The average markup has risen substantially since the 1980s. This is linked to various macroeconomic trends such as a falling labour share, increased market concentration and declining business dynamism (Autor et al., 2020; Barkai, 2020; De Loecker et al., 2020). Structural change itself is a driver of the rise in aggregate markup through compositional changes over time (Marto, 2024). Beyond levels, the distribution of markups is relevant as well. More productive firms charge higher markups (Amiti et al., 2014, 2019; Berman et al., 2012; De Loecker and Warzynski, 2012; De Loecker et al., 2016, 2020), which can be linked to a firm's market power (Burstein et al., 2025). These firms also exhibit lower pass-through of cost-push shocks to prices (Gopinath and Rigobon, 2008; Gopinath, Itskhoki and Rigobon, 2010; Nakamura, 2008; Nakamura and Zerom, 2010; Campa and Goldberg, 2005). Dispersion in markups creates a wedge between the market equilibrium and the social optimum, which is a source of inefficiency. This lowers aggregate productivity, distorts the allocation of resources across firms and hinders firm entry (Baqaee and Farhi, 2020; Behrens et al., 2020; Burstein et al., 2024; Dhingra and Morrow, 2019; Edmond et al., 2023; Zhelobodko et al., 2012). In my theory, markups are pinned down by the price elasticity of demand. Under quadratic preferences, the price elasticity decline as firms become more productive. Because pass-through is incomplete, this (static) markup wedge has dynamic implications: as productivity evolves, the wedge continues to shape relative prices and hence expenditure shares.

Concentration. A large empirical literature documents rising market concentration across U.S. industries (Kwon et al., 2024; Grullon et al., 2019), attributed variously to information-technology-driven increasing returns to scale (Lashkari et al., 2024), the growing importance of intangible capital (De Ridder, 2024), declining investment and business dynamism (Gutiérrez and Philippon, 2016), or a broader shift in the relationship between growth and rents (Aghion et al., 2023; Benkard et al., 2026). In my theory, the Pareto shape parameter plays the role of a concentration index: a thicker upper tail raises the cost-weighted markup. The extension in Section 5.3 allows sectoral markups to rise as technology advances, even with a fixed level of concentration. Rising concentration is therefore one driver of rising markups in this framework, but not the only one.

Technology Adoption. Building on Kortum (1997), who models innovation as an outcome of a research process, Alvarez, Buera and Lucas (2008, 2013) and Buera and Oberfield (2020) capture the idea that agents learn from surrounding agents through an exogenous process of meeting and learning. Lucas and Moll (2014) and Perla and Tonetti (2014) endogenise search effort by making firms actively search for better technology, at the cost of losing production while searching. Akcigit et al. (2018), Bloom, Schankerman and Van Reenen (2013) or Moretti (2021) provide compelling empirical evidence that spillovers and interactions among agents increase future productivity. The extension in Section 5.3 links this technology adoption to structural change by embedding learning-by-imitation into the multi-sector framework as a micro-foundation of the main model. Technology diffusion shifts the sectoral productivity distribution over time, and adoption affects expenditure shares not only through growth, but also through its endogenous effect on markups and the pass-through of growth into prices.

The rest of the paper is structured as follows: In Section 2, I present the model and decompose the price effect into productivity growth and pass-through. In Section 3, I discuss the data and the estimation strategy. In Section 4, I explore the quantitative effects of limited pass-through on structural change. Section 5 shows extensions to model and data. Section 6 concludes.

2 Theoretical Framework

Consider an economy with L homogeneous consumers, who each supply one unit of labour inelastically. They spend all their income on consumption. Labour is the only factor of production, it is perfectly mobile across sectors, and the labour market is perfectly competitive. There are finitely many sectors $\mathcal{S}$, each with a continuum of differentiated varieties. Consumption varieties are supplied by monopolistically competitive firms. Each firm produces exactly one variety under constant returns to scale. The wage rate serves as numéraire. The model characterises the static equilibrium for a given set of sectoral technology parameters. In the quantitative analysis, I apply this static equilibrium repeatedly to the observed evolution of these parameters over time.

This section is structured as follows: 2.1 specifies preferences: an upper-tier non-homothetic CES over sectors and a lower-tier quadratic utility over varieties. 2.2 introduces heterogeneous monopolistic-competition firms and derives pricing. 2.3 characterises the within-sector equilibrium. 2.4 analyses the main results of the equilibrium.

2.1 Consumers and Preferences

2.1.1 Upper-Tier Utility

Consumers have preferences across sectors $\mathcal{S}$ represented by a non-homothetic CES aggregator defined over sectoral composites. Let Q denote the aggregate real consumption index per consumer which aggregates the sectoral consumption bundles $\{Q_s\}_{s=1}^{S}$. Preferences across sectors are implicitly defined by the constraint

$$\sum_{s\in\mathcal{S}} \beta_s^{\frac{1}{\eta}} Q_s^{\frac{\eta-1}{\eta}} Q^{\frac{\epsilon_s-\eta}{\eta}} = 1, \qquad 0<\eta<1, \tag{1}$$

where $\beta_s > 0$ describes the sector-specific demand shifter (with $\sum_{s=1}^{S}\beta_s = 1$), η is the elasticity of substitution across sectors and $\epsilon_s > 0$ governs the income elasticity of demand of sector s.[1]

Let E denote total expenditure per consumer and let E_s denote expenditure on sector s. We

[1]The preferences described here are based on the work of Comin et al. (2021). They have subsequently been applied in various settings, e.g. in Auer et al. (2024); Baqaee and Burstein (2023); Fally (2022); Matsuyama (2019). This utility specification nests several classical utility functions. Setting $\epsilon_s = 1\ \forall s$ yields the standard CES aggregator. Additionally letting $\eta \to 1$ corresponds to Cobb-Douglas preferences. Note that the sector-specific demand-shifters β_s could be time-dependent, which would capture taste shocks to preferences, as applied in Baqaee and Burstein (2023) and Redding and Weinstein (2020) using the nonhomothetic CES preferences.

define a sectoral deflator P_s and a corresponding real composite Q_s such that

$$E_s \equiv P_s Q_s, \qquad \omega_s \equiv \frac{E_s}{E}, \qquad \sum_{s=1}^{S} \omega_s = 1. \tag{2}$$

where we interpret ω_s as the expenditure share of sector s. We further define an aggregate deflator P by $E \equiv PQ$.[2]

Under (1) and (2), the implied demand system yields

$$Q_s = \beta_s \left(\frac{P_s}{P}\right)^{-\eta} Q^{\epsilon_s}, \tag{3}$$

and the associated aggregate price index:

$$P = \left(\sum_s \beta_s P_s^{1-\eta} Q^{(\epsilon_s - 1)}\right)^{\frac{1}{1-\eta}}. \tag{4}$$

Combining (3) with (1), we get the expenditure share of sector s:

$$\omega_s = \beta_s \left(\frac{P_s}{P}\right)^{1-\eta} Q^{(\epsilon_s - 1)} \tag{5}$$

This expression illustrates the effect of the sectoral income elasticity ϵ_i on spending patterns. *Ceteris paribus*, an increase in aggregate consumption will result in a larger spending share of sector s if and only if $\epsilon_s > 1$, and in a smaller spending share if $\epsilon_s < 1$. See Appendix A.1 for details.

With the wage normalised to one, each consumer earns labour income $E = 1$, so aggregate expenditure equals L. Since labour is the only factor of production, aggregate sectoral expenditure equals sectoral labour income:

$$L_s = LE_s = L\omega_s.$$

Properties of Demand System. Having established consumer demand at the sectoral level, we can

[2] With non-homothetic within-sector preferences (as in the quadratic lower tier introduced below), the welfare-relevant sectoral expenditure function takes the form $E_s = e_s(\mathbf{p}_s, U_s)$ and is generally not proportional to the sectoral utility level. Hence, the scalar P_s in (2) should be interpreted as a *measurement* deflator (a unit-value index) associated with the sectoral composite Q_s, rather than as a welfare-consistent cost-of-living index. The closed-form demand system (3)–(5) therefore serves as a tractable representation of expenditure allocation over *measured* sectoral aggregates. Welfare analysis would require a separate money-metric construction based on the sectoral indirect utility or expenditure function.

analyse the properties of this demand system. First, the elasticity of substitution between goods of different sectors is constant and given by:

$$\frac{\partial \log(Q_s/Q_r)}{\partial \log(P_r/P_s)} = \eta, \qquad \forall s, r \in \mathcal{S}$$

This property is identical with the elasticity of substitution in CES preferences. Second, the elasticity of relative demand (and of relative expenditure) with respect to real consumption is also constant and given by:

$$\frac{\partial \log(Q_s/Q_r)}{\partial \log Q} = \frac{\partial \log(\omega_s/\omega_r)}{\partial \log Q} = (\epsilon_s - \epsilon_r), \qquad \forall s, r \in \mathcal{S}$$

This elasticity depends only on the sectoral income elasticities ϵ_s. Suppose that $\epsilon_s < \epsilon_r$, then, as the economy grows, consumption is reallocated from sector s to r, because r is a *relative* luxury good.[3] Hence, the Engel curves are non-linear and the preferences are nonhomothetic. Importantly, this effect does not vanish as income grows (as would be the case with Stone-Geary).

Both properties jointly imply that it is possible to fully separate price effects and income effects when measuring sectoral expenditure shares.[4] Relative consumption expenditure can be expressed as:

$$\log\left(\frac{\omega_s}{\omega_r}\right) = \underbrace{(1-\eta)\log\left(\frac{P_s}{P_r}\right)}_{\text{Price Effect}} + \underbrace{(\epsilon_s - \epsilon_r)\log Q}_{\text{Income Effect}} + \underbrace{\log\left(\frac{\beta_s}{\beta_r}\right)}_{\text{Constant}} \qquad \forall\, s, r \in \mathcal{S},\ \ s \neq r \tag{6}$$

The first term captures price effects and decreases in the degree of substitutability as $\eta \to 1$. The easier it is for consumers to shift consumption across sectors, the less price differences matter for expenditure. The second term encompasses income effects, which are purely determined by income elasticities ϵ_s. As consumers become richer, they shift spending towards the *relative* luxury good. The last term is a constant and captures tastes / demand-shifters.

[3] A similar feature can be achieved with a hierarchy of needs, where consumers start buying new products with high income elasticity as they become richer, while older luxury products become necessity goods over time. Such hierarchic preferences have been studied by e.g. Murphy, Shleifer and Vishny (1989), Föllmi and Zweimüller (2006, 2008) or Buera and Kaboski (2012).

[4] This complete separation of income and price effects is possible because the nonhomothetic CES preferences are *implicitly additively separable*. *Explicitly additively separable* preferences (such as Stone-Geary (e.g. Kongsamut et al. (2001), Herrendorf et al. (2013), Buera and Kaboski (2009)), price independent generalised linearity (PIGL, see Boppart (2014); Herrendorf et al. (2021)), constant ratio of income elasticity (CRIE, see Caron et al. (2014))) do not allow for this clear separation. See Matsuyama (2019) for an excellent discussion on the distinction between explicit and implicit additivity.

2.1.2 Lower-Tier Utility

Conditional on sectoral expenditure E_s chosen at the upper tier, consumers allocate spending across differentiated varieties within sector s according to a quadratic sub-utility. Let Ω_s denote the set of available varieties in sector s. Consumers have preferences over a continuum of differentiated varieties that are represented by the quadratic sub-utility

$$U_s = \int_{i \in \Omega_s} \alpha q_{is} - \frac{\gamma}{2} q_{is}^2 \; di, \qquad \alpha, \gamma > 0 \tag{7}$$

where q_{is} is individual demand for variety i in sector s, and α and γ are demand parameters, assumed to be common across sectors. Quadratic utility is characterised by a variable elasticity of substitution across varieties and a finite marginal utility at zero consumption, i.e. a firm faces a finite choke price above which demand for its variety is zero.[5]

Individuals take prices as given and maximise (7) subject to their sectoral budget constraint:

$$\int_{i \in \Omega_s} p_{is} q_{is} \; di = E_s \tag{8}$$

where p_{is} is the price of variety i in sector s and E_s is expenditure in that sector.

Individual Demand. Each consumer's demand for variety i in sector s follows from maximising the quadratic sub-utility (7) subject to the budget constraint (8):

$$q_{is} = \begin{cases} \dfrac{\alpha}{\gamma}\left(1 - \dfrac{p_{is}}{\bar{p}_s}\right), & p_{is} \leq \bar{p}_s, \\ 0, & p_{is} > \bar{p}_s, \end{cases} \tag{9}$$

where $\bar{p}_s = \alpha/\lambda_s$, with λ_s the Lagrange multiplier on the sectoral budget constraint. The price $\bar{p}_s$ is the sectoral choke price: demand for a variety is zero when its price reaches $\bar{p}_s$ and remains zero for any higher price. For varieties with positive demand, demand is linear in its own price. The relative price (meaning relative to the sectoral choke price) is a sufficient statistic for demand.

[5] Specifically, the elasticity of substitution between varieties within a sector is given by: $\sigma_s = \frac{d\ln(q_{js}/q_{is})}{d\ln MRS_{ijs}}|_{q_{is}=q_{js}} = -\frac{u_s'(q)}{qu_s''(q)}$. Using the demand function implied by quadratic preferences, this can also be expressed as: $\sigma_s = \frac{p_{is}}{\bar{p}_s - p_{is}}$, which is not constant and depends on prices. The marginal utility at zero consumption is given by α. More generally, quadratic preferences imply a subconvex demand curve (see Mrázová and Neary, 2017), thus fulfilling Marshall's Second Law of Demand, and belong to the class of preferences introduced by Pollak (1971). See, *inter alia*, Dhingra (2013); Dixit (1979); Eckel and Neary (2010); Mayer et al. (2014); Melitz and Ottaviano (2008); Parenti et al. (2017); Ottaviano and Suverato (2024) for applications of quadratic utility in various settings.

When the price is zero, demand simplifies to α/γ.

Price Elasticity of Demand. For varieties with strictly positive demand ($p_{is} < \bar{p}_s$), the price elasticity of demand in sector s is defined as:

$$\varepsilon_{is} = -\frac{d\log q_{is}}{d\log p_{is}}.$$

Given the demand function (9), and defining $x_{is} = p_{is}/\bar{p}_s$, we have:

$$\varepsilon_{is} = \frac{p_{is}/\bar{p}_s}{1 - p_{is}/\bar{p}_s} = \frac{x_{is}}{1 - x_{is}}. \tag{10}$$

The elasticity is increasing in the variety's own price p_{is}, implying that consumers become less price sensitive as prices fall (or quantities increase), which is known as Marshall's Second Law of Demand. As shown later, the relevant domain is $x_{is} \in (0.5, 1)$.

2.2 Firms and Production

Firm entry is unrestricted but costly. Each potential producer in sector s must pay an exogenous sunk cost $F > 0$ (in units of labour) to develop a new technology. After paying this cost, the firm learns its idiosyncratic productivity $a_{is} > 0$, drawn from a continuous Pareto distribution with CDF

$$G_s(a) = 1 - \left(\frac{A_s}{a}\right)^{\kappa_s}, \qquad a \geq A_s,$$

where A_s is the sector-specific lower bound of the productivity distribution and $\kappa_s > 1$ its shape parameter. After observing its productivity, the firm produces only if it can generate positive demand; otherwise it exits without producing. Production uses labour as the only input. A firm with productivity a_{is} produces according to $y_{is} = a_{is} l_{is}$, where l_{is} denotes the firm's labour input.

Pricing. Given its productivity and the demand function (9), each firm chooses its price to maximise operating profits. Firm i in sector s solves

$$\max_{p_{is} \leq \bar{p}_s} \ \pi_{is} = \left(p_{is} - \frac{1}{a_{is}}\right) y_{is}, \qquad y_{is} \equiv L q_{is},$$

taking the choke price $\bar{p}_s$ as given. The first-order condition yields the pricing rule:

$$p_{is} = \frac{1}{2}\left(\bar{p}_s + \frac{1}{a_{is}}\right)$$

The optimal price is the arithmetic average between the firm's marginal cost $1/a_{is}$ and the sectoral demand ceiling $\bar{p}_s$. For firms with $1/a_{is} < \bar{p}_s$, this implies that the relative price

$$x_{is} \equiv \frac{p_{is}}{\bar{p}_s} = \frac{1}{2}\left(1 + \frac{1}{a_{is}\bar{p}_s}\right)$$

lies in the interval $x_{is} \in (0.5, 1)$: the relative price of any viable producer cannot be less than one half. Firms with higher productivity set lower prices than low-productivity firms. Let a_s^* denote the productivity of the marginal producer (who is indifferent between producing and not producing), defined by $p_{is} = \bar{p}_s$. Evaluating the pricing rule at $a_{is} = a_s^*$ and imposing $p_{is} = \bar{p}_s$ yields $\bar{p}_s = 1/a_s^*$. Recall that $\bar{p}_s = \alpha/\lambda_s$. Combining both expressions pins down the Lagrange multiplier at $\lambda_s = \alpha a_s^*$.

Firms with productivity $a_{is} < a_s^*$ do not produce in equilibrium, because their productivity is too low to generate positive demand. Since the choke price equals the inverse of the productivity cut-off, we can rewrite the pricing rule in terms of the cut-off level:

$$p_{is} = \frac{1}{2}\left(\frac{1}{a_{is}} + \frac{1}{a_s^*}\right) \tag{11}$$

Markups & Firm Pass-through. The relative price x_{is} is a sufficient statistic to determine a firm's markup, markup elasticity and pass-through (Arkolakis and Morlacco, 2017). The markup rate is fully determined by the price elasticity of demand and given by: [6]

$$\mu_{is} = \frac{\varepsilon_{is}}{\varepsilon_{is} - 1} = \frac{1}{2 - 1/x_{is}} = \frac{1}{2}\left(1 + \frac{a_{is}}{a_s^*}\right) \geq 1. \tag{12}$$

The markup decreases in the relative price. The closer a firm's price to the choke price, the lower its markup. Conversely, high-productivity firms will charge higher markups (Amiti et al., 2014, 2019; Berman et al., 2012; De Loecker and Warzynski, 2012; De Loecker et al., 2016, 2020). Coupled with lower prices, this implies a positive relationship between sales and markups. This result is

[6] To see this, set up a generic profit maximisation problem of a firm. Profits are given by $\pi_{is} = \left(p_{is} - a_{is}^{-1}\right) q_{is}$, where a_{is} denotes firm productivity (so marginal cost is $c_{is} = 1/a_{is}$). Profit maximisation yields $q_{is} + p_{is}\frac{dq_{is}}{dp_{is}} - \frac{1}{a_{is}}\frac{dq_{is}}{dp_{is}} = 0$. Define the markup as price over marginal cost. The first-order condition can be rearranged to $\mu_{is} = \frac{1}{1+\frac{dp_{is}}{dq_{is}}\frac{q_{is}}{p_{is}}} = \frac{\varepsilon_{is}}{\varepsilon_{is}-1}$, which implies the profit-maximising price $p_{is} = \mu_{is}c_{is} = \mu_{is}/a_{is}$.

driven by the variable price elasticity of demand: as quantities increase, consumers become less price sensitive. A high-sales firm exploits this willingness-to-pay by increasing its markup.

Pass-through of marginal costs (i.e. of $1/a_{is}$) into prices is given by:

$$\Phi_{is} = \frac{1}{1+\Gamma_{is}}, \qquad \text{with } \Gamma_{is} = -\frac{d\log \mu_{is}}{d\log x_{is}}$$

where Γ_{is} is the markup elasticity (see Appendix A.1 for a derivation). Using (12), we get:

$$\Gamma_{is} = \frac{\varepsilon_{is}+1}{\varepsilon_{is}-1} = \frac{1}{2x_{is}-1} > 0, \qquad \Gamma'_{is} = -\frac{2}{(2x_{is}-1)^2} < 0, \qquad \Phi_{is} = \frac{2x_{is}-1}{2x_{is}} \in (0, 1/2). \tag{13}$$

Given that $\Gamma_{is} > 0$, we have incomplete pass-through: changes in marginal costs are not fully passed on to consumers, but partly absorbed through markup adjustments. From $\Gamma'_{is} < 0$, we also learn that pass-through decreases in firm size. Large, high-productivity firms have lower pass-through than low-productivity firms operating close to the choke price (Campa and Goldberg, 2005; Gopinath and Rigobon, 2008; Gopinath et al., 2010; Nakamura, 2008; Nakamura and Zerom, 2010). The intuition is simple: low-productivity firms barely have any markup to begin with. Hence, a larger share of marginal-cost changes must be reflected in prices.[7] See Figure 1 for the relationship between prices, markups, and pass-through.

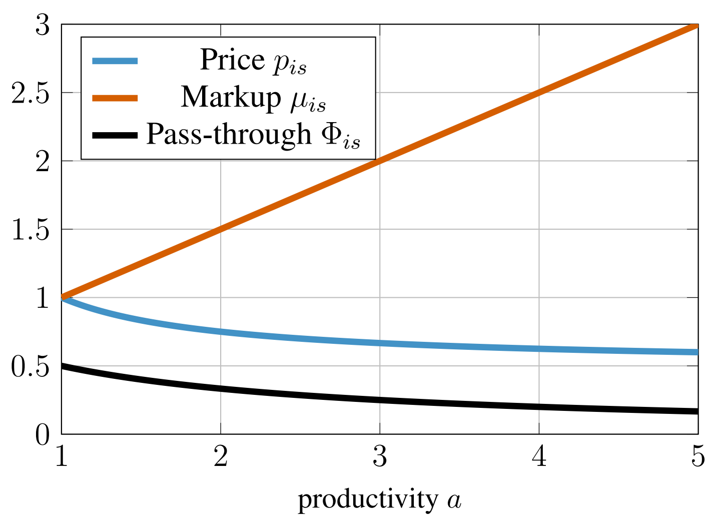


Figure 1: Prices and Markups with Quadratic Utility

[7]A comparison to standard CES preferences may be in order. The elasticity of substitution under CES is constant (hence the name) and given by σ. This implies constant markups for all firms, irrespective of their production possibilities. Thus, the markup elasticity is constant and equal to zero, which leads to constant and complete pass-through of cost-push shocks to prices ($\Phi = 1$).

Firm Output & Profits. With prices, productivity and demand established, we can determine total firm demand and profits. Since consumers are homogenous, aggregate firm demand is given by: $y_{is} = Lq_{is}$. Using Marshallian demand (9) and prices (11), aggregate demand and profits are:

$$y_{is} = L\left(\frac{\alpha}{2\gamma}\right)\left(1-\frac{a_s^*}{a_{is}}\right) \tag{14}$$

$$\pi_{is} = (p_{is}-1/a_{is})y_{is} = L\left(\frac{\alpha}{4\gamma a_s^*}\right)\left(1-\frac{a_s^*}{a_{is}}\right)^2 \tag{15}$$

Firms with higher productivity enjoy both higher quantities and higher markups, and therefore earn higher profits.

2.3 Equilibrium

Under the assumption of free entry, the equilibrium in each sector s is determined by a free-entry condition. Expected operating profits prior to observing the productivity draw equal the sunk cost of entry. Formally, we have:

$$\int_{a_s^*}^{\infty} \pi_{is}(a)dG_s(a) = F \qquad \forall s \in \mathcal{S} \tag{FE}$$

Using profits (15) and the Pareto distribution, we can determine the equilibrium productivity cut-off in terms of the lower bound of the distribution and parameters:

$$a_s^* = \left(\frac{L\delta_\pi(\kappa_s)}{F}\right)^{\frac{1}{1+\kappa_s}} A_s^{\frac{\kappa_s}{1+\kappa_s}}, \qquad \delta_\pi(\kappa_s) = \left(1-\frac{2\kappa_s}{\kappa_s+1}+\frac{\kappa_s}{\kappa_s+2}\right)\frac{\alpha}{4\gamma}. \tag{16}$$

A high value of κ_s lowers the cut-off value. As $\kappa_s \to \infty$, we have $a_s^* \to A_s$. The reason is that a high value of κ_s implies the existence of many low-productivity firms, so it is unlikely to get a good draw upon paying the fixed costs. In order to break even in equilibrium, firms require a lower cut-off level a_s^*. Hence, high κ_s leads to little selection, but it leads to high pass-through, since low-productivity firms have higher pass-through than high-productivity firms. The cut-off decreases in the fixed costs F and rises in the market size L.

Labour market (and goods market) clearing imply that the aggregate sales of producing firms equal expenditure in sector s:

$$N_s\int_{a_s^*}^{\infty} p_{is}y_{is}\frac{dG_s(a)}{1-G_s(a_s^*)} = L_s \tag{LMC}$$

where N_s is the number of producing firms in sector s and y_{is} denotes aggregate demand of variety i in sector s. Solving (LMC) for N_s yields:

$$N_s = \frac{L_s}{F}\frac{\delta_\pi(\kappa_s)}{\delta_x(\kappa_s)}[1 - G_s(a_s^*)] = \frac{L_s}{F}\frac{1}{1+\kappa_s}\left(\frac{A_s}{a_s^*}\right)^{\kappa_s}, \qquad \delta_x(\kappa_s) = \left(1 - \frac{\kappa_s}{\kappa_s+2}\right)\frac{\alpha}{4\gamma}. \tag{17}$$

Finally, we can determine prices and real consumption. Define a real quantity aggregator Q_s over consumed varieties:

$$Q_s = \int_0^{N_s} q_{is}\ di$$

We define P_s as the corresponding unit-value deflator, $P_s \equiv E_s/Q_s$, so that $E_s = P_s Q_s$ holds by construction. Per capita expenditure in sector s, the sectoral quantity index and the sectoral price index are given by:

$$E_s = \int_0^{N_s} p_{is}q_{is}\, di = \frac{\alpha N_s}{2\gamma a_s^*}\frac{1}{\kappa_s+2} \tag{18}$$

$$Q_s = \int_0^{N_s} q_{is} di = \frac{\alpha N_s}{2\gamma}\frac{1}{\kappa_s+1} \tag{19}$$

$$P_s = E_s/Q_s = \frac{(\kappa_s+1)}{(\kappa_s+2)}\frac{1}{a_s^*} \tag{20}$$

See Appendix A.2 for a derivation. The sectoral price index P_s is inversely proportional to the sectoral productivity cut-off a_s^*, so any force that raises a_s^* (e.g. larger market size L or lower fixed costs F) reduces the sectoral price index and, for a given E_s, raises real consumption E_s/P_s. A thicker upper tail of the sectoral productivity distribution (low κ_s) implies tougher selection, more high-productivity firms, a higher a_s^*, and thus a lower price index P_s, whereas a thinner tail (high κ_s) weakens selection and increases P_s. Equations (16)–(20) highlight how sectors differ in equilibrium when the Pareto parameters (κ_s, A_s) are heterogeneous. Sectors with a high lower bound A_s (good underlying technology) or a thick upper tail (low κ_s, many potential low-cost firms) have a high cut-off a_s^* and thus a low sectoral price index P_s. With non-homothetic CES preferences, sectors differ not only in prices P_s but also in income elasticities ϵ_s. A low sectoral price index P_s lowers the expenditure share through the standard substitution channel (governed by $\eta < 1$), while a high income elasticity $\epsilon_s > 1$ makes the sector expand as real consumption Q grows. Sectoral productivity differences thus translate into systematic differences in prices, employment, and the number of firms across sectors.

2.4 Analytical Results

2.4.1 Aggregate Markup

Define the sector-level aggregate markup as the cost-weighted average of firm-level markups. In sector s, a firm with productivity a has marginal cost $c(a) = a^{-1}$, price $p(a)$, and markup $\mu(a) \equiv p(a)c(a)^{-1} = ap(a)$. Its variable cost equals $c(a)y(a) = a^{-1}y(a)$. The cost-weighted sectoral markup is therefore

$$\mu_s^c \equiv \frac{\int_{a_s^*}^{\infty} \mu(a)\, a^{-1}y(a)\, dG_s(a)}{\int_{a_s^*}^{\infty} a^{-1}y(a)\, dG_s(a)} = \frac{\int_{a_s^*}^{\infty} p(a)\, y(a)\, dG_s(a)}{\int_{a_s^*}^{\infty} a^{-1}y(a)\, dG_s(a)},$$

The second equality uses $\mu(a)c(a) = p(a)$. Hence μ_s^c can be written as the ratio of sectoral revenue to sectoral variable cost. Substituting the equilibrium price and quantity schedules, and using the Pareto distribution yields:

$$\mu_s^c = 1 + \frac{1}{\kappa_s} \tag{21}$$

The distortion in sector s depends only on the shape parameter κ_s. Sectors with a thick upper tail have higher cost-weighted markups. This mechanism is consistent with Burstein et al. (2025), who document that sector-level markups rise with concentration.

At the aggregate level, define sectoral variable cost as

$$C_s = N_s \int_{a_s^*}^{\infty} a^{-1}y(a) \frac{dG_s(a)}{1 - G_s(a_s^*)}$$

and let $C = \sum_s C_s$ denote total variable cost in the economy. Aggregate sectoral expenditure is LE_s, and with the wage normalised to one, this equals sectoral labour income L_s, so $LE_s = L_s$. Since the cost-weighted markup satisfies $\mu_s^c = (LE_s)/C_s$ and $\mu_s^c = 1 + 1/\kappa_s$, it follows that variable cost in sector s is a constant fraction of sectoral employment,

$$C_s = \frac{LE_s}{\mu_s^c} = \frac{L_s}{\mu_s^c} = \frac{\kappa_s}{\kappa_s + 1} L_s.$$

Then, the aggregate markup is given by:

$$\mathcal{M} \equiv \frac{\sum_s \mu_s^c C_s}{\sum_s C_s} = \sum_s \mu_s^c \omega_s^c, \qquad \omega_s^c \equiv \frac{C_s}{C} = \frac{\frac{\kappa_s}{\kappa_s + 1} L_s}{\sum_s \frac{\kappa_s}{\kappa_s + 1} L_s}, \tag{22}$$

where ω_s^c is the variable cost share of sector s, such that $\mathcal{M}$ is a cost-weighted average of sectoral markups.[8] With homogeneous technology shapes ($\kappa_s = \kappa$ for all s), the aggregate markup is constant at $\mathcal{M} = 1 + 1/\kappa$. With heterogeneous κ_s, sectors with a thicker upper tail (and hence higher μ_s^c) contribute more to the aggregate distortion. As structural change reallocates employment toward sector i, its labour share—and hence its variable-cost share ω_i^c—naturally rises, so the sectoral markup μ_i^c receives a larger weight in the aggregate markup $\mathcal{M}$. When the shape parameters κ_s differ across sectors, this changes the aggregate markup over time, making structural change itself a driver of economy-wide markup dynamics, as studied by Marto (2024). See Appendix A.3 for a derivation of (21) and the sales-weighted markup as comparison.

2.4.2 Growth Pass-Through

Now, having established the equilibrium allocation across sectors, we can turn to growth. I define (exogenous) productivity growth as an increase in the lower bound of the productivity distribution A_s. The exogenous shift in A_s is the heterogeneous-firms analogue of a sector-specific TFP shock in a representative firm model. The response of the sectoral price index can be summarised by the following proposition:

Proposition 1. *Consider an equilibrium described above (16)–(20) with non-homothetic CES preferences across sectors, $0 < \eta < 1$, and quadratic demand within sectors. Let A_s denote the lower bound of the productivity distribution in sector s, $\kappa_s > 1$ the shape parameter, and P_s the sectoral price index. A sector-specific productivity change in sector s, modelled as a change in the lower bound A_s, affects the sectoral price index according to*

$$-\frac{d \log P_s}{d \log A_s} = \frac{\kappa_s}{1 + \kappa_s} \in (1/2, 1). \tag{23}$$

Define $\rho_s \equiv -d \log P_s / d \log A_s$ as the sectoral growth pass-through. Then a 1% productivity shock induces a ρ_s-percent reduction in the sectoral price index P_s. For any finite $\kappa_s > 1$, pass-through is incomplete, $\rho_s < 1$. In the limiting case of $\kappa_s \to \infty$, $\rho_s \to 1$, corresponding to full pass-through.

The elasticity ρ_s measures how changes in production technology in sector s are transmitted into the sectoral price index. Growth pass-through is incomplete: a fraction of the productivity improvement is absorbed by entry and reallocation toward low-cost, high-markup firms rather than

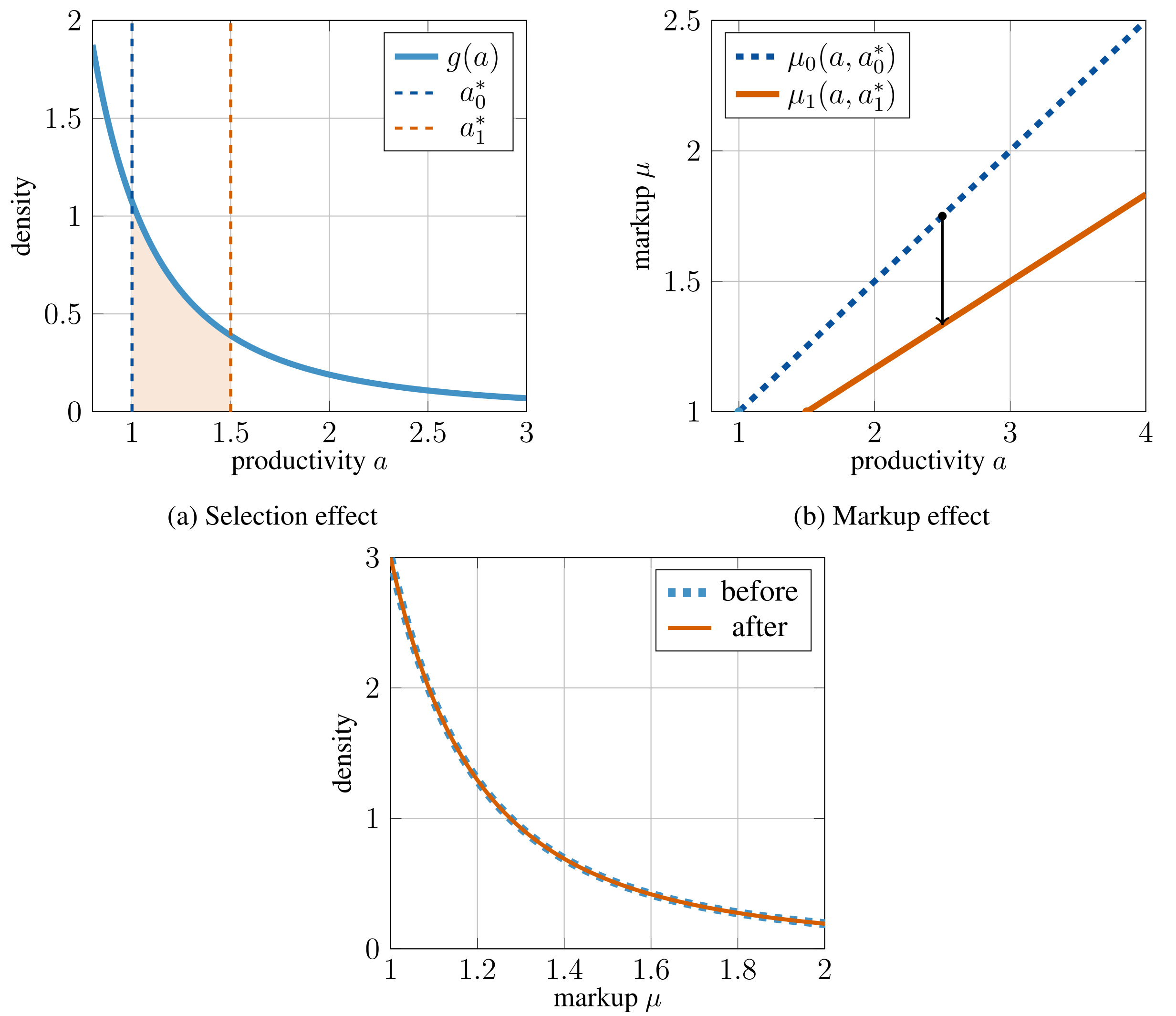
[8] Note that the variable cost share ω_s^c generally does not equal the expenditure share ω_s. They are identical if and only if $\kappa_s = \kappa \quad \forall s \in \mathcal{S}$. To see this, write $\omega_s^c = \frac{C_s}{C} = \frac{L_s/\mu_s^c}{L/\mathcal{M}}$. When κ is identical across sectors, this can be simplified to $\frac{L_s/\mu}{L/\mu} = \frac{L_s}{L} = \omega_s = E_s$.

being fully transmitted into consumer prices. This mechanism relies on the variable elasticity of substitution across varieties and the resulting endogenous markups; it is absent in frameworks with CES and constant markups or in representative-firm model. The parameter κ_s governs the strength of the channel: when κ_s is small (a thick upper tail with many potential high-productivity firms), growth pass-through is weak, whereas for large κ_s (a thin tail with productivity bunched near the lower bound) it approaches one. This elasticity is the key to the structural change results later on: since ρ_s governs how productivity growth passes into the price index, it directly enters the relative price terms when determining expenditure shares across sectors.

A distinction arises between firm-level and sector-level pass-through. Firm-level marginal-cost pass-through is bounded above by one half, $\Phi_{is} \in (0, 1/2]$, with the upper bound attained only by the marginal firm. Growth pass-through, by contrast, is bounded below by one half, $\rho_s \in (1/2, 1)$. The two elasticities describe different adjustment margins. Firm-level pass-through measures the response of an individual firm's price to marginal cost holding the sectoral choke price fixed, whereas growth pass-through captures the equilibrium response of the sectoral price index to a change in production technology. The latter additionally incorporates the endogenous adjustment of the productivity cut-off and firm selection induced by free entry.

An increase in the lower bound of the productivity distribution A_s shifts the entire distribution of potential technologies to the right and raises the equilibrium cut-off a_s^*. Figure 2 illustrates the resulting adjustment in firm selection and markups. As shown in Panel a, the higher cut-off causes low-productivity firms to exit, as represented by the shaded interval $[a_{s,0}^*, a_{s,1}^*)$. Moreover, for a given surviving incumbent with fixed productivity, the increase in a_s^* reduces its productivity relative to the cut-off and therefore lowers its markup. Panel b illustrates this intensive-margin response: the increase in the cut-off shifts the markup schedule downward, reducing the markup of a firm with fixed productivity $\bar{a}$.

At the same time, new firms entering from the new productivity distribution replace exiting low-productivity, low-markup producers. This selection effect shifts the composition of producers towards relatively more productive, higher-markup firms. As Panel c shows, the intensive-margin decline in incumbent markups and the selection effect exactly offset at the sector level. Conditional on producing, the distribution of relative productivity a/a_s^*, and therefore the distribution of firm-level markups, is invariant to a level shift in A_s. Consequently, the cost-weighted sectoral markup remains unchanged at $\mu_s^c = 1 + 1/\kappa_s$. Nevertheless, the endogenous adjustment in firm-level markups and firm composition prevents the productivity improvement from being transmitted fully into lower consumer prices, generating incomplete growth pass-through.



(a) Selection effect

(b) Markup effect

(c) Conditional markup distribution

Figure 2: Productivity Growth and Markup Invariance

Notes: Panel (a) plots the Pareto density of firm productivity together with the equilibrium cut-off before (a_0^*) and after (a_1^*) a productivity improvement; the shaded interval $[a_0^*, a_1^*)$ marks firms that were previously producing and are now below the cut-off. Panel (b) plots the markup schedule $\mu(a; a^*) = \frac{1}{2}(1 + a/a^*)$ before and after the shift; for a fixed incumbent $\bar{a}$ (surviving both regimes) the vertical segment shows the resulting decline in its markup. Panel (c) plots the density of the markup μ conditional on producing, implied by $\Pr(a/a^* \geq z \mid a \geq a^*) = z^{-\kappa_s}$ for $z \geq 1$; this density does not depend on A or a^*, so the curves coincide exactly, which is why the sectoral markup $\mu_s^c = 1 + 1/\kappa_s$ is unaffected by productivity improvements despite every surviving incumbent's markup falling.

2.4.3 Growth & Structural Change

Productivity growth implies falling prices. When $\eta < 1$, sectors are complements: a decline in P_s makes sector s cheaper, shifting relative expenditure to other sectors rather than pulling resources in. In a CES setting, this implies that sectors with faster productivity growth see their expenditure share and labour input L_s fall relative to more "expensive" sectors.

With the nonhomothetic CES preferences, income effects also matter. Consider a one-time sector-specific growth shock that increases productivity from A_s to $A'_s > A_s$, holding A_r in all other sectors $r \neq s$ fixed. From the sectoral cut-off condition, the shock raises the cut-off a_s^* and reduces the sectoral price index P_s. The responses of expenditure share ω_s, employment L_s, and number of producing firms N_s depend on the sector's income elasticity ϵ_s, shape parameter κ_s, and can be summarised by the following proposition:

Proposition 2. *Consider an equilibrium described above (16)–(20) with non-homothetic CES preferences across sectors, $0 < \eta < 1$, and quadratic demand within sectors. Let A_s denote the lower bound of the productivity distribution in sector s, and let ω_s, L_s, and N_s be, respectively, the expenditure share, employment, and number of firms in sector s. Define the expenditure-weighted average income elasticity as $\bar{\epsilon} \equiv \sum_{r \in \mathcal{S}} \omega_r \epsilon_r$ and assume $\bar{\epsilon} > \eta$.*

A sector-specific technology improvement in sector s, modelled as an increase in A_s holding A_r fixed for all $r \neq s$, implies the following changes to expenditure shares and employment:

$$\frac{d \log \omega_s}{d \log A_s} = \frac{d \log L_s}{d \log A_s} = \underbrace{-(1-\eta)(1-\omega_s)\rho_s}_{\textit{relative price effect}} + \underbrace{(\epsilon_s - \bar{\epsilon})\frac{d \log Q}{d \log A_s}}_{\textit{income effect}}$$

$$= -(1-\eta)\rho_s \left[1 - \frac{\omega_s(\epsilon_s - \eta)}{\bar{\epsilon} - \eta}\right] \tag{24}$$

$$\frac{d \log \omega_r}{d \log A_s} = \frac{d \log L_r}{d \log A_s} = \frac{d \log N_r}{d \log A_s} = (1-\eta)\omega_s \rho_s \frac{\epsilon_r - \eta}{\bar{\epsilon} - \eta}, \qquad r \neq s \tag{25}$$

The number of producing firms in the own sector satisfies:

$$\frac{d \log N_s}{d \log A_s} = \frac{d \log \omega_s}{d \log A_s} + \rho_s = \rho_s \left[\eta + (1-\eta)\frac{\omega_s(\epsilon_s - \eta)}{\bar{\epsilon} - \eta}\right] \tag{26}$$

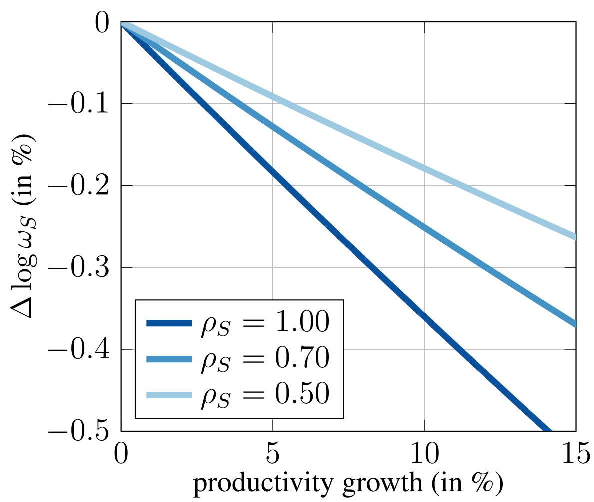
Proof. In Appendix A.3. ■

The change in expenditure shares can be decomposed into a relative price effect and an income effect. For the innovating sector s, the relative price effect is always negative when $\eta < 1$: a decline in the sectoral price index makes sector s relatively cheaper, and under gross complementarity this shifts expenditure towards the other sectors. The strength of this channel depends on growth pass-through ρ_s. The higher the growth pass-through, the larger the induced price movement and hence the stronger the price effect. The income effect depends on whether sector s is a relative necessity or a relative luxury. Since a productivity improvement raises aggregate real consumption, sectors with $\epsilon_r > \bar{\epsilon}$ gain expenditure share through the income channel, whereas sectors with $\epsilon_r < \bar{\epsilon}$ lose expenditure share. Hence, for an innovating necessity sector, both channels reduce its expenditure share, while for an innovating luxury sector the income effect works against the negative relative price effect and may offset it.

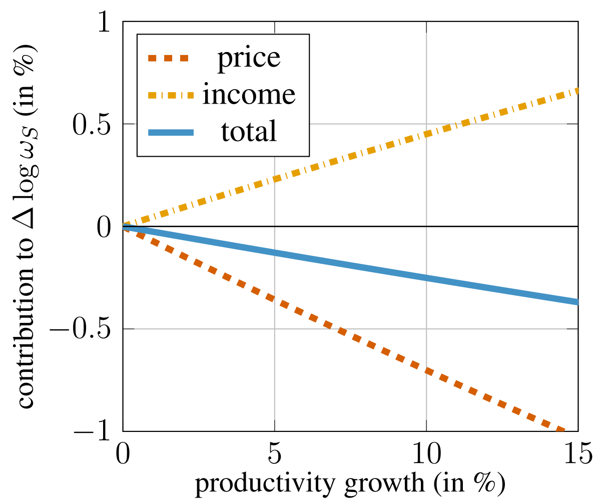
For the non-innovating sectors $r \neq s$, the relative price effect is always positive. Their prices are unchanged while the innovating sector becomes cheaper, so under complementarity expenditure is shifted towards the non-innovating sectors. The income effect is again governed by $\epsilon_r - \bar{\epsilon}$. Combining both channels, the net response is determined by $\epsilon_r - \eta$. The expenditure share of a non-innovating sector increases if $\epsilon_r > \eta$ and decreases if $\epsilon_r < \eta$. In the limiting case of $\eta \to 1$ and $\epsilon_s = 1 \quad \forall s \in S$, we are in the Cobb-Douglas setting and the expenditure shares are constant by construction.

Employment follows expenditure shares because $L_r = L\omega_r$. Hence, $\frac{d \log L_r}{d \log A_s} = \frac{d \log \omega_r}{d \log A_s}$ for all sectors. The response of the number of producing firms differs between the innovating and non-innovating sectors. In sectors $r \neq s$, productivity is unchanged and the number of producing firms therefore moves proportionally with sectoral employment, such that $\frac{d \log N_r}{d \log A_s} = \frac{d \log L_r}{d \log A_s}$. In the innovating sector, productivity growth additionally affects the extensive margin of production. The improvement in the productivity distribution raises the fraction of entrants that exceed the equilibrium productivity cut-off, implying $\frac{d \log N_s}{d \log A_s} = \frac{d \log \omega_s}{d \log A_s} + \rho_s$. Consequently, the number of producing firms in sector s may increase even when its expenditure share and employment decline.

Figure 3 illustrates how the degree of growth pass-through shapes expenditure reallocation following a productivity improvement in the Service sector. Panel 3a plots the total change in the Service expenditure share for three values of pass-through. Under complete pass-through, $\rho_S = 1$, productivity growth generates the largest decline in the Services expenditure share because the fall in the relative price of Services is strongest. Under gross complementarity, this shifts expenditure towards the other sectors. The reallocation shrinks with smaller growth pass-through. Panel 3b decomposes the case $\rho_S = 0.70$ into its two underlying channels. The relative-price effect is negative and increases in magnitude with the size of the productivity improvement, whereas the income effect is positive because Services have an income elasticity above the expenditure-weighted average, $\epsilon_S > \bar{\epsilon}$. The two forces therefore work in opposite directions and partially offset one another, leaving a smaller negative total response. Both the relative price and income channels are proportional to growth pass-through ρ_S. Lower pass-through therefore reduces the magnitude of both channels and, holding the initial allocation fixed, scales down the overall expenditure-share response without changing its sign.



(a) Total response



(b) Decomposition $\rho_S = 0.70$

Figure 3: Services Productivity Growth and Expenditure Reallocation

Notes: The figure illustrates Proposition 2's decomposition of the change in expenditure share following a productivity improvement, at the example of Services. Panel (a) plots the total response $\Delta \log \omega_S$ implied by (24), for three values of the growth pass-through $\rho_S \in \{1.00, 0.70, 0.50\}$. Panel (b) decomposes the $\rho_S = 0.70$ case into its relative-price and income-effect components. The horizontal axis is the percentage increase in A_s. Parameter values are taken from Section 3.

3 Data & Estimation

3.1 Data

World Input-Output Database. The World Input-Output Database (Timmer et al., 2015) provides information on final household consumption per Industry, both in nominal values and previous-year prices.[9] I use this database to construct expenditure shares, relative prices and real consumption, to estimate the cross-sector parameters (ϵ, η). To obtain a long time series, I splice the Long-Run WIOD (1965–2000) with the WIOD 2016 Release (2000–2014). Because the two releases overlap in 2000, I retain the Long-Run WIOD observation in the overlapping year 2000. The industries are aggregated to sectors. A challenge in the aggregation process is the fact that the long-run WIOD and the 2016 release use a different Industry classification system, namely ISIC Rev. 3.1 and ISIC Rev. 4, while also being partially pre-aggregated. I therefore rely on standard ISIC correspondence mappings (obtained from ILO) to align industries across revisions wherever feasible. I split up sector "[J] Information and Communication" (ISIC Rev. 4) and allocate parts of it to "Manufacturing", "Transport & Communication", and "Other Services" to maintain comparability with Rev. 3.1 from the Long-Run WIOD. Table B.1 summarises the aggregation procedure from ISIC

[9]The database is available from World Input-Output Database (2026).

Rev. 3.1 and Rev. 4. This leaves me with 8 consistently defined sectors on the lower level of aggregation. Then, the 8 sectors are further aggregated into 3 broad sectors Agriculture, Industry, and Services. The population data to calculate real consumption per capita comes from the 11th issue of the Penn World Tables (Feenstra et al., 2015).

Compustat. For firm-level data, I use Compustat.[10] Specifically, I employ the Compustat North America Fundamentals Annual file, which contains all US-incorporated publicly listed firms. Compustat provides financial information using balance sheet and income statements. This entails, among other things, information on sales, cost of goods sold (COGS), capital stock, employment, and Industry activity classification.[11] My sample covers all US-domestic firms from 1980-2014 with a unique firm identifier. To select US firms only, I filter on ISO country code and ISO currency code. I drop all observations without Industry assignment (missing NAICS code), as well as missing or negative entries for sales or COGS. Following Traina (2018), I remove big merger and acquisition (M&A) episodes. That is, I drop observations if M&A surpasses 5% of total assets. Following De Loecker et al. (2020), I exclude observations in the top and bottom 1% of COGS-to-sales distribution each year. I assign each observation to a 2-digit NAICS Industry, which leaves 20 distinct industries in the final sample.[12] See Table 1 for summary statistics of the sample. Table C.1 in the appendix shows the mapping from the 2-digit NAICS industries into sectors.

3.2 Estimation

Cross-Sector Parameters. To estimate the cross-sector parameters $(\boldsymbol{\epsilon}, \eta)$, I make use of (6) and the WIOD. Expenditure shares per sector are constructed using final household consumption. The expenditure exists both in nominal terms as well as in previous-year prices. Hence, I can infer implicit deflators per sector as $g^P_{s,t} = E^{\text{nom}}_{s,t}/E^{\text{pyp}}_{s,t}$, where $E^{\text{nom}}_{s,t}$ is nominal final household expenditure

[10] The Compustat data is available from Wharton Research Data Services (2026).

[11] Compustat has two important limitations for markup estimation. First, it covers publicly listed firms rather than the full universe of firms. As emphasized by De Loecker et al. (2020), listed firms are not representative of the overall firm distribution: they are larger, older, more capital- and skill-intensive, and the Industry mix differs from that of the private sector. Traina likewise stresses that public-firm samples can overstate aggregate market power because public firms are larger and their representativeness changes over time with listings, delistings, and mergers (Traina, 2018). Second, Compustat provides revenues and expenditures, but not firm-level prices and quantities. As a result, markup estimation must rely on the production approach using revenue data rather than direct price–quantity information. Recent work highlights that this can be problematic because revenue-based estimates may conflate prices, quantities, quality, and demand shifters, and different flexible inputs need not recover the same markup (Raval, 2023; Bond et al., 2021; De Ridder et al., 2026). By contrast, Burstein et al. (2025) show that using firm-level quantity information instead of revenues can circumvent some of these biases.

[12] I merge NAICS Industry 49 into 48 and 61 into 62 due to limited sample sizes.

Table 1: Summary Statistics Compustat (1980-2014)

Variable	Mean	Median	Observations
Sales	1,291.5	81.6	213,703
COGS	881.9	47.4	213,703
SGA	218.9	18.0	171,613
Employment	5.9	0.5	192,455

Notes: The table reports summary statistics for the cleaned Compustat firm-year sample used in the markup estimation. Sales, COGS, and SG&A are measured in millions of U.S. dollars. Employment is measured in thousands of employees.

and $g^P_{s,t}$ the year-on-year price change in sector s.

WIOD reports final consumption by country of origin, which allows me to construct both domestic and trade-inclusive time series of relative prices and expenditure shares. The trade-inclusive expenditure share is total household spending on a sector regardless of where it was produced, thus giving a more accurate reflection of household consumption patterns. The implicit price deflators can be constructed accordingly. I take the trade-inclusive specification as baseline throughout, and report the domestic-only results as a robustness check.

Appendix B.2 and B.3 show the expenditure shares and relative prices across 3-sector and 8-sector aggregates. In the 3-sector aggregation, the continuation across WIOD releases is very close. In the 8-sector aggregation, there are discontinuities around the splice in some sectors. Therefore, I discard the 2000-2001 first-difference observations in the 8-sector aggregation to avoid contaminating the estimates with these discontinuities.

Following Comin et al. (2021), the estimation procedure requires a base sector b, with the normalisation of $\epsilon_b = 1$, and all other income elasticities are interpreted as relative to the base sector's income elasticity. I use Industry as base sector. Because WIOD does not provide price indices, only price changes, I rewrite (6) in changes rather than levels:

$$\Delta \log \left(\frac{\omega_{s,t}}{\omega_{b,t}} \right) = (1-\eta)\, \Delta \log \left(\frac{P_{s,t}}{P_{b,t}} \right) + (\epsilon_s - 1)\, \Delta \log Q_t \tag{27}$$

Using $g^P_{s,t}$, relative price changes can be expressed as

$$\begin{aligned} \Delta \log \left(\frac{P_{s,t}}{P_{b,t}} \right) &= (\log P_{s,t} - \log P_{s,t-1}) - (\log P_{b,t} - \log P_{b,t-1}) \\ &= \log \left(\frac{g^P_{s,t}}{g^P_{b,t}} \right) = \log \left(\frac{E^{\text{nom}}_{s,t} / E^{\text{pyp}}_{s,t}}{E^{\text{nom}}_{b,t} / E^{\text{pyp}}_{b,t}} \right), \end{aligned}$$

and real consumption is defined as aggregate nominal household consumption deflated by the price level, $Q_t \equiv E_t/P_t$ with $E_t \equiv \sum_r E^{\text{nom}}_{r,t}$. Since the aggregate price level is unobserved, I substitute it with indirect measurement using (5), implying

$$\Delta \log Q_t = \Delta \log E_t - \Delta \log P_{b,t} + \frac{1}{1-\eta}\Delta \log \omega_{b,t} = \Delta \log E_t - \log g^P_{b,t} + \frac{1}{1-\eta}\Delta \log \omega_{b,t}$$

Finally, differencing log relative expenditure shares removes time-invariant sector-specific components, so sector fixed effects cancel mechanically in the transformed equation.

I estimate the differenced cross-sector demand system by non-linear GMM. The estimates are reported in Table 2. The income elasticities are reported as $\epsilon_i - 1$, i.e. relative to the base sector. The results are consistent with the standard structural-change pattern. Agriculture has an income elasticity below that of Industry, with $\epsilon_a - 1 = -0.36$ in the domestic specification and $\epsilon_a - 1 = -0.13$ in the trade-inclusive specification, implying that Agriculture behaves as a relative necessity good. In Services, the point estimates are 1.39 and 0.64, respectively, making Services a relative luxury good. The estimated substitution parameter η lies between 0.33 and 0.53 across specifications, indicating imperfect substitutability across broad sectors, consistent with my assumption in the model. Overall, the estimates support the view that non-homothetic demand is an important force behind structural change, with Agriculture as a necessity sector and Services as a luxury sector.

Table 2: Cross Sector Parameter Estimates: 3-Sector Aggregation

	(1)	(2)
η	0.33	0.53
	[0.27,0.38]	[0.52,0.55]
Agriculture	-0.36	-0.13
	[-0.46,-0.27]	[-0.14,-0.11]
Services	1.39	0.64
	[1.01,1.78]	[0.58,0.70]
Sector FE	N	N
Trade Controls	N	Y
Observations	98	98

Notes: The table reports non-linear GMM estimates of the differenced relative expenditure-share equation. Column (1) uses domestic expenditure shares and domestic implicit deflators only. Column (2) uses trade-inclusive expenditure shares and implicit deflators, i.e. imports are included in household expenditure and price measurement. The base sector is industry, so $\epsilon_b = 1$ by normalisation; hence the reported sector coefficients are estimates of $\epsilon_s - 1$ relative to the base sector. Brackets report 95% confidence intervals. Observations are sector-year cells. Because the estimating equation is written in first differences, time-invariant sector fixed effects difference out mechanically; therefore no sector fixed effects are included.

Markups. I construct firm-level markups following the production approach of De Loecker et al. (2020). Under cost minimization and competitive input markets, a firm's markup can be recovered from the ratio of the output elasticity of a flexible input to that input's revenue share. Let $S_{it} = P_{it}Q_{it}$ denote firm sales and let C_{it} denote expenditure on the variable input bundle. I use cost of goods sold (COGS) as the measure of variable input expenditure. For firm i in Industry j and year t, the markup is then given by

$$\mu_{it} = \theta^V_{jt}\frac{S_{it}}{C_{it}} \tag{28}$$

where θ^V_{jt} is the output elasticity of the variable input bundle (see Appendix C.2 for a derivation of this markup formula).[13] Rather than re-estimating these elasticities, I take the Industry-year output elasticities directly from De Loecker et al. (2020) and merge them to the Compustat firm-year data by year and two-digit NAICS Industry.[14] Firm-level variation in markups therefore comes from differences in firms' inverse variable input shares, S_{it}/C_{it}, while the output elasticity is common within Industry-year cells.

For sector-level markups, I aggregate firm-level markups using variable-cost weights. For sector s, the cost-weighted markup is

$$\mu_{st} = \frac{\sum_{i\in s} C_{it}\mu_{it}}{\sum_{i\in s} C_{it}} \tag{29}$$

I construct this measure both for two-digit NAICS industries and the sector aggregates. The aggregate markup is obtained analogously by applying the same cost-weighted average across all firms in the cleaned Compustat sample. Figure C.1 shows the evolution of the aggregate markup from 1980 to 2014 in the US economy. The aggregate markup increased from 1.13 in 1980 to 1.24 in 2014. Appendix C.4 plots the average markups in the 3 sectors.

Table 3 reports initial and final values of aggregate and sector markups from 1980 to 2014, as well as the percentage change. Across sectors, the largest percentage increase is observed in

[13] The production approach to markup estimation is subject to well-known critiques. Raval (2023) shows that markup estimates differ substantially depending on the input factor used for estimation — COGS, as used here following De Loecker et al. (2020), versus alternatives such as labour or materials. Traina (2018) shows that correctly accounting for indirect costs such as marketing and management substantially reduces the estimated increase in average markups. See Basu (2019) for a general discussion.

[14] De Loecker et al. (2020) estimate the output elasticity of the variable input using Industry-specific production functions. In their benchmark specification, log output is modelled as a Cobb-Douglas function of a variable input bundle and capital, $q_{it} = \beta_v v_{it} + \beta_k k_{it} + \omega_{it} + \varepsilon_{it}$, where output is measured using deflated firm sales and the variable input bundle is proxied by cost of goods sold. To address the simultaneity between input choices and unobserved productivity, they use a control-function approach. In the first stage, they purge measurement error and unanticipated shocks to sales by estimating output as a flexible function of variable inputs, capital, and year effects. Productivity is then assumed to follow an AR(1) process, and the output elasticity of the variable input is identified from moments based on lagged variable input choices. I use their estimated Industry-year elasticities directly rather than re-estimating the production functions.

Agriculture, where the average markup rises from 1.11 to 1.59. Markups in Industry increase by 11.8% from 1.13 to 1.26, whereas Services markups grow by 6.8%, from 1.15 to 1.23.

Table 3: Average Markups by Sector

	Average markup		
Sector	**1980**	**2014**	Δ
Aggregate	1.13	1.24	9.4%
Agriculture	1.11	1.59	43.5%
Industry	1.13	1.26	11.8%
Services	1.15	1.23	6.8%

Notes: Average markups are computed as COGS-weighted averages of firm-level markups, using Compustat data and output elasticities from De Loecker et al. (2020). The table reports initial and final values of sectoral markups, as well as the percentage change. The final value of Agriculture's markup is replaced by the average of its last three values to reduce endpoint volatility.

Using (22), I can decompose the change in aggregate markup into changes in sector sizes and changes in sector markups. Appendix Table C.2 shows that, despite the large increase in agricultural markups, Agriculture is essentially irrelevant for the aggregate markup because its share in aggregate COGS is negligible. Instead, the rise in the aggregate markup is driven primarily by Services. Services contribute through both an increase in the markup and, more importantly, the reallocation of economic activity toward Services, as their COGS share increases to over 50%. The markup increase in Industry is overturned by its declining size. This pattern is in line with Marto (2024), who emphasizes that the rise in aggregate markups is partly driven by structural change itself.

Productivity Growth. The evolution of the sectoral productivity cut-off is backed out from WIOD sectoral price changes and the estimated sectoral markup changes. By (20), sectoral price changes can be decomposed into:

$$\Delta \log P_{s,t} = \Delta \log \left(\frac{\kappa_{s,t} + 1}{\kappa_{s,t} + 2} \right) - \Delta \log a^*_{s,t}$$

Rearranging gives the implied change in the productivity cut-off:

$$\Delta \log a^*_{s,t} = \Delta \log \left(\frac{\kappa_{s,t} + 1}{\kappa_{s,t} + 2} \right) - \Delta \log P^{data}_{s,t} + \Delta \log w_t \tag{30}$$

I adjust prices by aggregate wage growth. This is necessary because the model holds the wage fixed by normalisation, whereas observed price changes in the data reflect both changes in productivity and nominal labour costs. I use the BLS non-farm business hourly compensation index from FRED (*COMPNFB*), to measure $\Delta \log w_t$. This adjustment was not necessary previously, since wages cancel in relative prices, which were used to estimate cross-sector parameters.

The final input required to recover the productivity cut-off is $\kappa_{s,t}$. By (21), the sectoral markup satisfies

$$\mu_{s,t}^c = 1 + \frac{1}{\kappa_{s,t}} \qquad \Leftrightarrow \qquad \kappa_{s,t} = \frac{1}{\mu_{s,t}^c - 1} \tag{31}$$

Thus, changes in sectoral markups are interpreted as changes in the shape of the underlying productivity distribution. The model requires $\kappa_{s,t} > 1$, corresponding to $1 < \mu_{s,t}^c < 2$. Since annual Compustat markups contain substantial short-run variation, I do not use the $\kappa_{s,t}$ series directly. Instead, I construct a smoothed path that exactly matches the values in 1980 and 2014 and assumes that $\kappa_{s,t} - 1$ evolves exponentially between the two endpoints,

$$\kappa_{s,t} = 1 + (\kappa_{s,1980} - 1) \exp\left[-\zeta_s(t - 1980)\right], \tag{32}$$

where ζ_s is the decay rate and chosen such that the path matches $\kappa_{s,2014}$. This preserves the observed long-run change in sectoral markups while abstracting from short-run fluctuations.[15]

Column 1 of Table 4 reports the average annual log change of the productivity cut-off a_s^* over the sample period from 1980 to 2014, using the trade-inclusive price series of the baseline specification. The cut-off increases most rapidly in Agriculture (2.7%) and Industry (2.4%), while the corresponding increase in Services is only 0.6%. These cut-off productivity paths are the empirical productivity objects used in the subsequent calibration.

To get a better sense of the average productivity of producing firms, Table 4 also reports a distributional effect depending on κ_s (Column 2) and the change in the conditional-mean productivity $E[a_{s,t} \mid a_{s,t} \geq a_{s,t}^*]$ (Column 3). The conditional mean of a Pareto distribution is given by:

$$E[a_{s,t} \mid a_{s,t} \geq a_{s,t}^*] = a_{s,t}^* \cdot \frac{\kappa_{s,t}}{\kappa_{s,t} - 1}$$

Hence, growth in mean productivity among producing firms can be decomposed into a cut-off effect and a distributional effect. Average productivity growth rates are 5.0% in Agriculture, 2.9% in Industry, and 0.9% in Services (see Appendix C.6 for the decomposition using domestic values).

[15] Results are robust to alternative paths of $\kappa_{s,t}$. Using linear interpolation between endpoints or the annual markup-implied series instead of the exponential path leaves the effect of full pass-through on structural change unaltered. Naturally, using the annual series reproduces short-run movements in the aggregate markup, as these fluctuations are directly fed into the calibration.

As the distributional effect is determined by the change in κ_s, and hence by markup growth, it is no surprise that the distributional effect is largest in Agriculture and smallest in Services. Low κ_s implies a fat upper tail, hence there are more high-productivity firms among producing firms, raising average productivity.

Table 4: Productivity Growth Decomposition

Sector	**Cut-off a^***	**Distribution**	**Total**
Agriculture	2.7%	2.3%	5.0%
Industry	2.4%	0.5%	2.9%
Services	0.6%	0.3%	0.9%

Notes: Values are average annual log changes. Conditional-mean productivity among producing firms, $E[a_{s,t} \mid a_{s,t} \geq a^*_{s,t}] = a^*_{s,t} \cdot \kappa_{s,t}/(\kappa_{s,t} - 1)$, is decomposed into $\Delta \log E[a_{s,t} \mid a_{s,t} \geq a^*_{s,t}] = \Delta \log a^*_{s,t} + \Delta \log[\kappa_{s,t}/(\kappa_{s,t} - 1)]$. The cut-off effect captures the shift in the productivity threshold of producing firms; the distribution effect captures the change in the shape of the productivity distribution above that threshold. Since this only depends on $\kappa_{s,t}$, it is identical across the domestic and trade-inclusive specifications. The baseline uses the smoothed series for κ.

The distributional term in this decomposition should be distinguished from the κ_s-dependent term in equation (30). The former, $\Delta \log[\kappa_s/(\kappa_s - 1)]$, measures how changes in the shape of the productivity distribution affect mean productivity among producing firms. The latter, $\Delta \log[(\kappa_s + 1)/(\kappa_s + 2)]$, captures the corresponding contribution of κ_s to price growth. Appendix C.7 reports the corresponding price decomposition, while Appendix C.8 plots the evolution of the productivity cut-off a^*_s against the inverse price index per sector.

A decline in κ_s therefore has two related implications. It raises conditional-mean productivity relative to the cut-off by fattening the upper tail of the productivity distribution, while at the same time lowering prices for a given a^*_s through the κ_s-dependent term in the sectoral price index. Additionally, a lower κ_s implies lower growth pass-through ρ_s. Table 5 reports the initial and final values of κ_s together with the corresponding model-implied growth pass-through. Pass-through declines in all three sectors, from 90% to 63% in Agriculture, from 89% to 79% in Industry, and from 87% to 82% in Services. The decline is by far the most pronounced in Agriculture, consistent with its larger fall in κ_s, larger increase in markups, and larger distributional effect on mean producer productivity documented above.

4 Calibration

Section 2 showed that limited growth pass-through weakens the response of prices, and hence expenditure shares, to productivity growth. I now quantify the importance of this mechanism for

Table 5: Growth Pass-Through

Sector	κ_{1980}	κ_{2014}	ρ_{1980}	ρ_{2014}
Agriculture	9.2	1.7	90%	63%
Industry	7.9	3.9	89%	79%
Services	6.7	4.4	87%	82%

Notes: Cost-weighted markups imply $\kappa_{s,t} = 1/(\mu^c_{s,t} - 1)$. The model growth pass-through elasticity is $\rho_{s,t} = \kappa_{s,t}/(1 + \kappa_{s,t})$, holding κ fixed in the comparative static. The baseline uses the smoothed kappa series.

structural change in the US. I combine the estimated demand parameters with the empirically recovered firm-distribution and productivity cut-off paths from Section 3 to calibrate the model. Then, I compare the calibrated limited pass-through baseline to a counterfactual scenario featuring complete growth pass-through.

4.1 Setup

Calibration Parameters. Table 6 reports the calibration parameters identified in the previous section. Since the relative expenditure-share equation (6) is identified in changes, I normalize sectoral relative prices and the aggregate consumption index Q_t to one in the base year. Under this normalization, the model implies $\omega_{s,1980} = \beta_s$, so I calibrate β_s to match the observed 1980 expenditure share of each sector.

Table 6: Calibration Parameters

Parameter	η	ϵ_A	ϵ_I	ϵ_S	ζ_A	ζ_I	ζ_S
Value	0.53	0.87	1.00	1.64	0.073	0.026	0.015

Notes: The table reports the trade-inclusive upper-tier demand parameters and the sector-specific decay rate of the smoothed kappa series. η is the elasticity of substitution across sectors; the sectoral income elasticities ϵ_s are estimated using trade-inclusive expenditure shares and implicit deflators, including imports, with the Industry income elasticity normalized to one. ζ_s is the exponential decay rate of kappa, $\kappa_{s,t} = 1 + (\kappa_{s,1980} - 1)e^{-\zeta_s(t-1980)}$, calibrated so that $\kappa_{s,t}$ matches the markup-implied kappa exactly at the 1980 and 2014 endpoints.

Technology Frontier. The model's free entry condition relates the productivity cut-off $a^*_{s,t}$ to the underlying technology frontier A_s through:

$$\log a^*_{s,t} = \frac{\kappa_{s,t}}{1 + \kappa_{s,t}} \log A_{s,t} - \frac{K + \log[(\kappa_{s,t} + 1)(\kappa_{s,t} + 2)]}{1 + \kappa_{s,t}} \tag{33}$$

where $K \equiv \log(2\gamma F/(L\alpha))$ collects the entry cost, market size, and lower-tier demand parameters. Given the empirically recovered paths of $\kappa_{s,t}$ and $a^*_{s,t}$, (33) can be inverted to recover $A_{s,t}$. As the data identifies changes in $a^*_{s,t}$ but not levels, an additional normalization is required. In the baseline, I normalize $a^*_{s,1980} = 1$ for all sectors. K is not separately identified. I set $K = 0.0$ as my baseline and report the sensitivity of the results to K in Appendix D.4.

Counterfactual. I use the calibrated model to quantify the effect of limited growth pass-through on structural change. The counterfactual imposes full growth pass-through. As $\kappa_{s,t} \to \infty$, the markup converges to one and growth pass-through becomes complete. In this limit, the sectoral price index collapses to $P_{s,t} = 1/A_{s,t}$. Thus, changes in the technology frontier are passed through one-for-one into sectoral prices. I construct the counterfactual by holding fixed the recovered path of $A_{s,t}$, imposing complete pass-through, and re-solving the demand system for the resulting counterfactual prices, aggregate consumption, and expenditure shares. Comparing these counterfactual shares with the baseline isolates the contribution of limited pass-through to sectoral reallocation.

I use full growth pass-through as the counterfactual benchmark because it corresponds to the standard in the structural change literature. In representative firm or constant markup environments, productivity growth is fully passed through into the price index. I implement this in my model by letting $\kappa_{s,t} \to \infty$.

4.2 Results

Figure 4 compares the observed expenditure shares with the calibrated limited pass-through model and the full pass-through counterfactual. The baseline model closely tracks the long-run reallocation of expenditure away from Agriculture and Industry and toward Services. Table D.1 confirms the close fit: the correlations between observed and model-implied expenditure shares are 0.97 in Agriculture, 0.98 in Industry, and 0.98 in Services, while the RMSE amounts to 6.0%, 3.1%, and 0.9% of the respective average sectoral expenditure shares. Figure D.1 shows the aggregate markup in data and calibration. The calibrated markup does not reproduce the fluctuations in the observed series due to the smoothing of κ_s. However, it captures the secular trend over the sample period and matches closely to the observed level at sample end, confirming the close fit between actual and calibrated expenditure shares, as reallocation contributes to markup growth as well.

The full pass-through counterfactual shows that limited pass-through substantially dampens structural change. By 2014, imposing full pass-through lowers the expenditure and employment share of Industry by 2.67 percentage points and raises the corresponding share of Services by 2.92 percentage points relative to the baseline. The additional 2.92pp expansion of Services under full pass-through corresponds to *31.4% of the entire 1980–2014 increase* in the model-implied Services expenditure share. Put differently, structural change toward Services would have been 31.4% larger under full pass-through. Given total US employment of about 146 million workers in 2014, this would correspond to approximately 4.3 million additional workers in Services. The effect on Agriculture is small in absolute terms, at -0.25pp, but sizeable relative to its baseline structural change: under full pass-through, the decline in the Agriculture share would have been 56.1% larger.

Table 7 decomposes the change in relative expenditure shares into price and income effects using (6). In the baseline, income effects account for 27% of the total change in Agriculture relative to Industry and for 41% in Services relative to Industry. Price effects therefore account for the bulk of structural change in both cases, although the two channels are more balanced for Services. This differs from Comin et al. (2021), who find that income effects dominate within-country structural change in their cross-country sample. Their income channel accounts for more than 73% of sectoral reallocation. By contrast, Boppart (2014) finds roughly equally large income and price effects for the US. The price effect column can equivalently be interpreted as the structural change response in a homothetic specification with $\epsilon_s = 1$ for all sectors, holding the estimated elasticity of substitution and sectoral price paths fixed.

Imposing full pass-through strengthens both channels, but the additional structural reallocation operates primarily through relative prices. For Agriculture, the price effect increases sharply in magnitude to -0.45, while the income effect increases only modestly to -0.05, reducing the income contribution to 11%. For Services, the price effect rises to 0.41 and the income effect to 0.28. The stronger income effect reflects the increase in aggregate real consumption under full pass-through. As shown in Appendix D.3, the baseline and counterfactual consumption paths diverge over time, with real consumption reaching about 1.55 under full pass-through compared with 1.39 under limited pass-through by 2014. Nevertheless, the increase in the price effect is quantitatively larger than the increase in the income effect. Hence, limited growth pass-through slows structural change primarily by dampening relative price changes, while the associated reduction in real consumption further weakens the income channel.

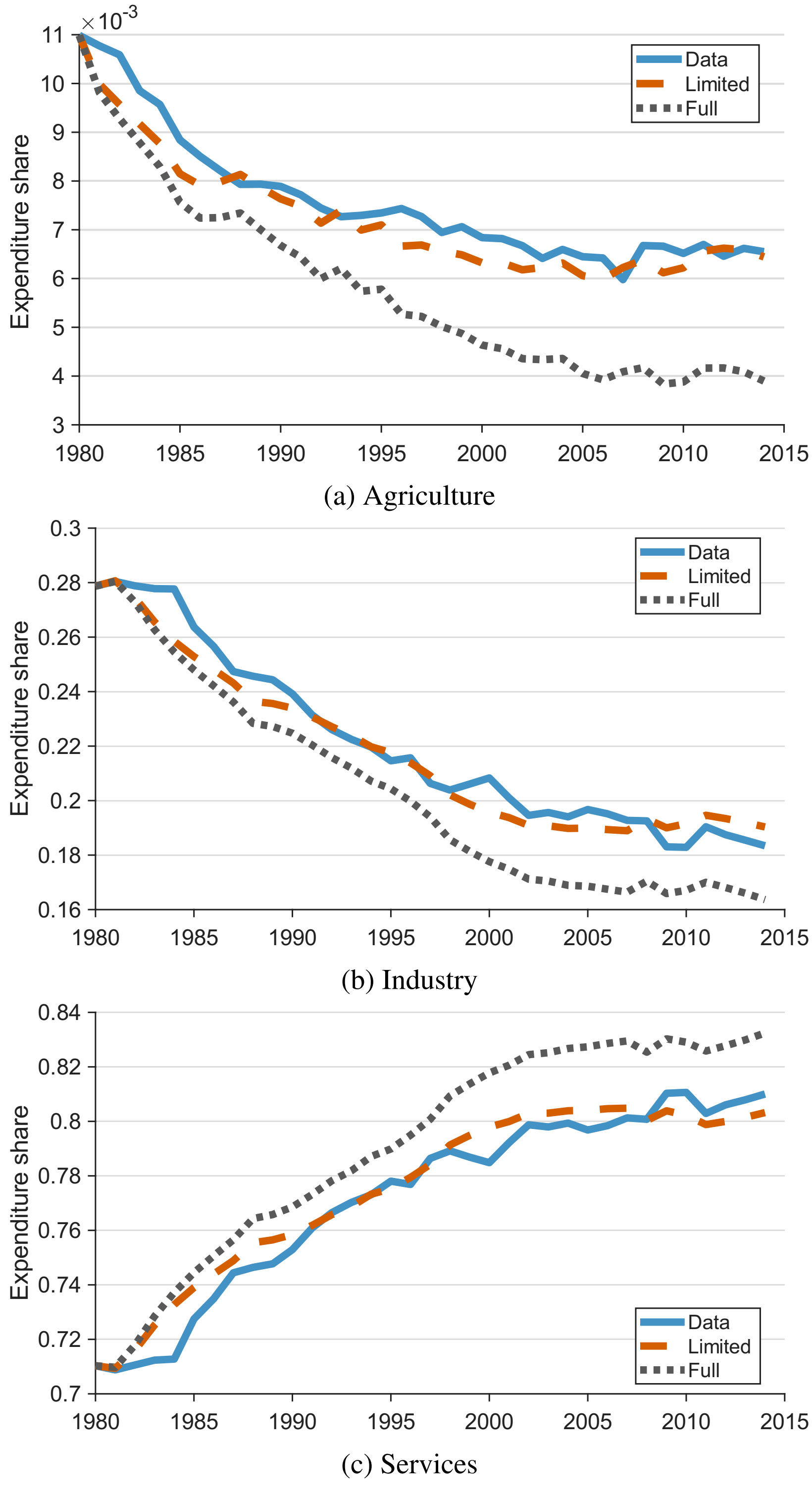


Figure 4: Calibrated Expenditure Shares

Notes: Each panel compares the observed expenditure share with the model-implied share under the limited pass-through baseline and the full pass-through counterfactual. By construction, the baseline matches the observed expenditure shares exactly in 1980.

Table 7: Decomposition: Price vs. Income Effects

	Price effect	**Income effect**	**Income share**
Baseline			
Agriculture vs. Industry	-0.11	-0.04	27%
Services vs. Industry	0.30	0.21	41%
Counterfactual			
Agriculture vs. Industry	-0.45	-0.05	11%
Services vs. Industry	0.41	0.28	40%

Notes: Decomposition of $\Delta \log(\omega_s/\omega_{Industry})$, 1980–2014, into $(1-\eta)\Delta \log(P_s/P_{Industry})$ and $(\epsilon_s - 1)\Delta \log Q$ following (6).

4.3 Sectoral Decomposition

To identify which sectors drive the aggregate effect of limited growth pass-through, I impose full pass-through sector by sector and for all possible combinations. Table 8 Panel A reports the resulting decompositions. The results show that the dampening effect on structural change originates primarily in Industry. Imposing full pass-through in Industry alone lowers its expenditure share by 3.21 percentage points and raises the Services share by 3.20 percentage points by 2014, close to the 2.92 percentage-point increase obtained when full pass-through is imposed in all sectors. In contrast, imposing full pass-through only in Services lowers its share by 0.63 percentage points. This reflects the relative-price mechanism under gross complementarity: stronger pass-through in an innovating sector lowers its relative price and reduces its own expenditure share. The Shapley decomposition in Panel B confirms this result, attributing 3.25 percentage points of the overall Services-share effect to Industry, compared with 0.25 percentage points to Agriculture and -0.58 percentage points to Services. Hence, limited pass-through slows the reallocation toward Services mainly by attenuating price declines in Industry rather than by limiting price declines within Services itself.

5 Extensions

5.1 Disaggregating Sectors

The main analysis studies structural change across three broad sectors. To assess heterogeneity within these aggregates, I disaggregate the economy into eight sectors. Tables E.1 and E.2 report the corresponding estimates of the cross-sector demand parameters, productivity growth, and

Table 8: Sectoral Decomposition of Full Pass-Through Counterfactual

	2014 share gap (in pp)		
Counterfactual	**Agriculture**	**Industry**	**Services**
Panel A: Combinations			
None (baseline)	0.00	0.00	0.00
Agriculture	-0.27	0.02	0.24
Industry	0.01	-3.21	3.20
Services	0.02	0.61	-0.63
Agriculture + Industry	-0.26	-3.19	3.45
Agriculture + Services	-0.26	0.64	-0.38
Industry + Services	0.02	-2.69	2.66
All sectors	-0.25	-2.67	2.92
Panel B: Shapley Attribution			
Agriculture	-0.27	0.02	0.25
Industry	0.01	-3.25	3.25
Services	0.01	0.57	-0.58
Sum	-0.25	-2.67	2.92

Notes: Panel A reports the 2014 expenditure-share gap relative to the limited-pass-through baseline when full growth pass-through is imposed in the indicated sectors. The recovered underlying technology paths $A_{s,t}$ are held fixed, untreated sectors retain their baseline price paths, and aggregate real consumption and expenditure shares are re-solved in each counterfactual. Panel B reports the Shapley decomposition of the all-sector full-pass-through effect, averaging each sector's incremental contribution over all possible orders in which sectors are switched to full pass-through. The Shapley contributions sum to the all-sector effect.

growth pass-through. On the demand side, the high income elasticity of the Service sector is driven primarily by Finance and Transport & Communication, with relative income elasticities near or above 1. Business Services and Other Services are also more income elastic than Manufacturing, although by smaller margins. The relative income elasticity of Other Industry (including Mining, Utilities, and Construction), smaller than Manufacturing. The point estimates for Agriculture are virtually identical to before.

The supply side exhibits equally pronounced heterogeneity. Trade Services combine relatively strong effective-productivity growth of 1.7% per year with essentially unchanged growth pass-through of about 90%. Transport & Communication also experiences strong productivity growth, at 2.0%, but pass-through declines from 92% to 85%. Finance provides a particularly interesting contrast: despite being among the most income-elastic sectors, productivity growth is only 0.5%, while pass-through falls substantially from 88% to 70%. Business Services display similarly modest productivity growth but a much smaller decline in pass-through. At the other end, Other Services experience negative measured productivity growth and persistently low pass-through. This residual category contains many less market-oriented activities, including public administration, education, health, and other social and personal Services. The results do not suggest a simple marketable–non-market Services divide. Instead, substantial heterogeneity exists even among marketable Services: Finance, Transport, Trade, and Business Services differ markedly in both their income elasticities and the extent to which productivity growth is transmitted into prices.

These patterns are consistent with the importance of heterogeneity within Services emphasized by Duernecker et al. (2024). They distinguish between progressive and stagnant Services and show that low-productivity-growth Services tend to be relatively income elastic, so that income growth shifts expenditure toward them, while relative-price changes work in the opposite direction. Importantly, they also show that conventional distinctions such as market versus non-market Services do not align closely with productivity-growth differences. Our results point to an additional source of heterogeneity within Services: even conditional on sectoral productivity growth, differences in growth pass-through determine how strongly productivity improvements translate into relative-price changes. Hence, future structural change within Services depends jointly on income elasticities, productivity growth, and growth pass-through.

5.2 Quality Adjustment in Sectoral Prices

A remaining measurement issue is quality adjustment in sectoral prices. To the extent that WIOD prices do not fully capture quality improvements, recovered productivity growth may be biased. This does not affect estimated growth pass-through, however, since $\rho_{s,t}$ depends only on the markup-implied $\kappa_{s,t}$. If unmeasured quality improvement is denoted by $\Delta \log q_{s,t} \geq 0$, such that $\Delta \log P_{s,t}^{true} = \Delta \log P_{s,t}^{WIOD} - \Delta \log q_{s,t}$, then (30) implies

$$\Delta \log a_{s,t}^{*,true} = \Delta \log a_{s,t}^{*,WIOD} + \Delta \log q_{s,t} \tag{34}$$

Hence, unmeasured quality improvement understates recovered cut-off productivity growth.

As a robustness check, I replace WIOD prices with BEA PCE chain-type price indexes. Agriculture is mapped to food, Services to PCE Services, and Industry approximately to non-food goods, constructed from the goods and food price indexes and their nominal expenditure shares. The mapping is necessarily imperfect because PCE categories are consumption categories rather than production sectors and measure prices paid by consumers. Since PCE does not distinguish domestic from imported consumption, I compare it with the trade-inclusive WIOD baseline.

Table E.3 compares average annual cut-off productivity growth under the two price sources. The Industry estimate changes little, from 2.39% to 2.61%. For Services, estimated growth falls from 0.62% to 0.26%. Consequently, the Industry-Services productivity-growth gap does not narrow under PCE prices, but instead widens from 1.77 to 2.35 percentage points. The larger discrepancy for Agriculture is of limited aggregate importance given the sector's small expenditure share.

This exercise should be interpreted narrowly. Because the same $\kappa_{s,t}$ path is used under both price measures, growth pass-through and the distributional component of conditional mean productivity are unchanged by construction. Moreover, PCE and WIOD differ in their scope and construction beyond quality adjustment alone. Nevertheless, the fact that the Industry–Services productivity gap survives, and if anything increases, under the alternative price source suggests that insufficient quality adjustment in WIOD is unlikely to be the main explanation for the divergence in recovered productivity growth.

5.3 Endogenous Technology Diffusion

The calibration in Section 4 allows the empirically inferred shape parameter $\kappa_{s,t}$ to vary over time. In the baseline model, productivity growth is exogenous. This section sketches a dynamic extension in which growth is generated endogenously through learning-by-imitation. The shape parameter κ_s is a genuine primitive and shapes both productivity growth and growth pass-through. Full derivations are in Appendix A.4.

The static equilibrium of Sections 2.3 closes the model through free entry: a continuum of potential entrants pays a sunk cost F and draw productivity a_{is} from $\mathrm{Pareto}(A_s, \kappa_s)$, and the cut-off a_s^* equates expected profit to F. To generate ongoing productivity growth, this section introduces learning-by-imitation following Perla and Tonetti (2014). Rather than paying a sunk cost to enter, each sector contains a fixed unit measure of firms. In each period, the least productive share $\chi_s \in (0, 1)$ pauses production to imitate a randomly sampled active producer, re-entering next period with the imitated productivity draw. Because there is no sunk-cost margin to select the cut-off, the choke price $\bar{p}_{s,t}$ is instead pinned down by labour-market clearing: the sector's employment share $l_{s,t} \equiv L_{s,t}/L$ must equal labour demand across active producers.

Learning-by-imitation truncates the productivity distribution each period: since imitating firms redraw only from the pool of currently active producers, and producing firms are exactly those with $a \geq A_{s,t+1}$, the time t production cut-off becomes the time $t+1$ lower bound of the distribution, $A_{s,t+1} \geq A_{s,t}$. Defining the productivity-frontier growth rate as $g_s \equiv A_{s,t+1}/A_{s,t}$, the truncation implies

$$g_s = (1 - \chi_s)^{-1/\kappa_s} > 1 \tag{35}$$

The growth rate depends only on the imitation share χ_s and the shape parameter κ_s, and is constant over time.

Let $z_{s,t} \equiv \bar{p}_{s,t} A_{s,t+1} \geq 1$ denote the choke price relative to the production cut-off. The sectoral price index can be written as $P_{s,t} = \frac{1}{2}\bar{p}_{s,t}\, \Lambda_{s,t}(\kappa_s, z_{s,t})$, where $\Lambda_{s,t}$ captures the composition of active firms' markups. Then, the growth pass-through is given by:

$$\rho_{s,t} \equiv -\left.\frac{d\log P_{s,t}}{d\log A_{s,t}}\right|_{l_{s,t}} = 1 - \left(1 + \frac{d\log \Lambda_{s,t}}{d\log z_{s,t}}\right) \frac{d\log z_{s,t}}{d\log A_{s,t}} < 1 \tag{36}$$

As in the static model, growth pass-through is incomplete: part of any technology improvement raises $z_{s,t}$ – pushing the choke price further above the marginal producer's marginal cost – rather than being passed into lower prices. Growth pass-through $\rho_{s,t}$ is state-dependent through $z_{s,t}$, hence endogenously time-varying as the frontier moves, without needing κ_s to change. The productivity distribution shapes both the growth rate and the growth pass-through, and does so in opposite directions. Figure 5 illustrates the mechanism: a thicker upper tail makes imitation draws from high-productivity firms more likely, raising the growth rate. At the same time high-productivity firms have the lowest pass-through, so sector-level pass-through falls.

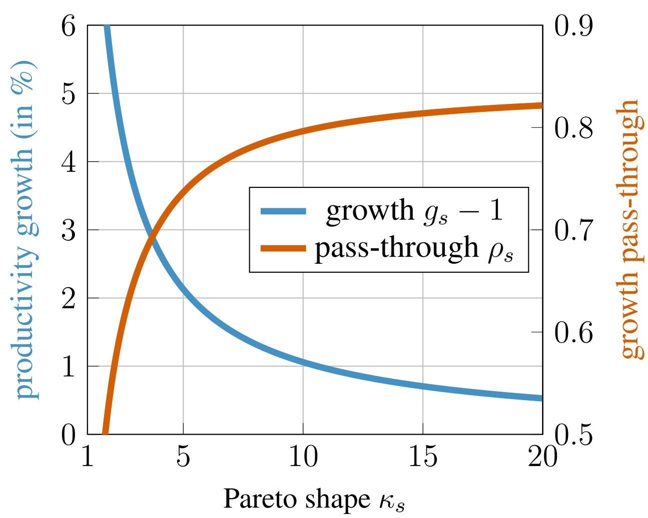


Figure 5: Growth and Pass-Through by Firm Distribution

Notes: The figure illustrates the opposing roles of the Pareto shape parameter. A thicker upper tail raises productivity growth but lowers growth pass-through, and vice versa. The blue line plots the productivity growth rate. The orange line plots the corresponding growth pass-through $\rho(\kappa)$.

The sectoral markup is given by

$$\mu^c_{s,t} = \frac{\kappa_s + 1}{2\kappa_s} \cdot \frac{(\kappa_s + 2)z^2_{s,t} - \kappa_s}{(\kappa_s + 2)z_{s,t} - (\kappa_s + 1)} \tag{37}$$

At $z_{s,t} \to 1$, (37) collapses to $\mu^c_{s,t} \to 1 + 1/\kappa_s$: the markup formula of Section 2.4 emerges as the limiting case in which the choke price approaches the marginal producer's marginal cost. Away from this limit, $\mu^c_{s,t}$ is increasing in $z_{s,t}$. A rise in $A_{s,t}$ increases $z_{s,t}$, so sectoral markups rise *mechanically* as technology advances, without any change in κ_s. Rising concentration is therefore not necessary to generate rising markups within a sector; it is sufficient for the productivity frontier to keep moving. This feature is similar to Marto (2024), who achieves rising markups through income-dependent price elasticity of demand.

6 Conclusion

This paper shows that market structure within sectors matters for structural change. Incorporating heterogeneous firms and variable markups into a structural change framework generates incomplete growth pass-through, whose magnitude depends on the productivity distribution. This separates the canonical price effect into underlying productivity growth and its pass-through into the price index. Quantitatively, limited growth pass-through substantially dampens the speed of structural change. In an application to the US from 1980 to 2014, the service expenditure share would have been 2.92 percentage points higher by 2014 in the full pass-through counterfactual. The effect originates primarily in Industry. Over the sample period, growth pass-through has declined in all sectors. Although markup dynamics cannot by themselves explain the slowdown in structural change, they contributed to it by weakening the transmission of productivity growth into sectoral prices. More broadly, the results imply that observed sectoral price changes need not reveal underlying productivity growth one-for-one. Accounting for market structure is therefore important both for understanding structural transformation and for identifying its technological drivers.

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Appendix

A Theory

A.1 Demand and Preferences

Sectoral Demand and Expenditure Shares. Consider the non-homothetic CES aggregator across sectors

$$\sum_{s=1}^{S} \beta_s^{\frac{1}{\eta}} Q_s^{\frac{\eta-1}{\eta}} Q^{\frac{\epsilon_s-\eta}{\eta}} = 1 \tag{38}$$

with sectoral prices $\{P_s\}_{s=1}^{S}$ and total expenditure $E = \sum_{s=1}^{S} P_s Q_s$ for a given consumer. The consumer chooses $\{Q_s\}_{s=1}^{S}$ and the aggregate real consumption index Q to solve

$$\max_{Q,\{Q_s\}} \; Q + \lambda \left(1 - \sum_{s=1}^{S} \beta_s^{\frac{1}{\eta}} Q_s^{\frac{\eta-1}{\eta}} Q^{\frac{\epsilon_s-\eta}{\eta}}\right) + \mu \left(E - \sum_{s=1}^{S} P_s Q_s\right).$$

The first-order condition with respect to Q_s is

$$\frac{\partial \mathcal{L}}{\partial Q_s} = \lambda \frac{1-\eta}{\eta} \beta_s^{\frac{1}{\eta}} Q_s^{-\frac{1}{\eta}} Q^{\frac{\epsilon_s-\eta}{\eta}} - \mu P_s = 0.$$

Rearranging and multiplying by Q_s gives

$$\lambda \frac{1-\eta}{\eta} \beta_s^{\frac{1}{\eta}} Q_s^{\frac{\eta-1}{\eta}} Q^{\frac{\epsilon_s-\eta}{\eta}} = \mu P_s Q_s.$$

Summing over all sectors and using (38), we obtain

$$\lambda \frac{1-\eta}{\eta} \sum_{s=1}^{S} \beta_s^{\frac{1}{\eta}} Q_s^{\frac{\eta-1}{\eta}} Q^{\frac{\epsilon_s-\eta}{\eta}} = \mu \sum_{s=1}^{S} P_s Q_s \quad \Longrightarrow \quad \lambda \frac{1-\eta}{\eta} = \mu E.$$

Substituting this back into the first-order condition and solving for Q_s delivers sectoral demand

$$Q_s = \beta_s E^{\eta} P_s^{-\eta} Q^{\epsilon_s - \eta} = \beta_s \left(\frac{P_s}{P}\right)^{-\eta} Q^{\epsilon_s}, \tag{39}$$

where we used $E = PQ$. The aggregate price index is then pinned down by the identity $E = PQ = \sum_{s=1}^{S} P_s Q_s$. Substituting (39) into this expression gives

$$P = \left(\sum_{s=1}^{S} \beta_s P_s^{1-\eta} Q^{\epsilon_s - 1}\right)^{\frac{1}{1-\eta}}.$$

Finally, the expenditure share of sector s is

$$\omega_s = \beta_s \left(\frac{P_s}{P}\right)^{1-\eta} Q^{\epsilon_s - 1}.$$

Individual Demand. Using utility (7) and the budget constraint (8), the Lagrangian reads:

$$\mathcal{L} = \int_{i\in\Omega} \alpha q_i - \frac{\gamma}{2} q_i^2 \;\; di - \lambda \left(\int_{i\in\Omega} p_i q_i \;\; di - E \right)$$

The FOC with respect to q_i is:

$$\frac{\partial \mathcal{L}}{\partial q_i} : \alpha - \gamma q_i = \lambda p_i \quad \Leftrightarrow \quad q_i = \frac{\alpha - \lambda p_i}{\gamma}$$

The choke price $\bar{p}$ is by setting demand equal to zero, thus we have $\bar{p} = \alpha/\lambda$. Plugging this back into the FOC, we have:

$$q_i = \frac{\lambda(\bar{p} - p_i)}{\gamma} = \frac{\bar{p}\lambda}{\gamma} \frac{(\bar{p} - p_i)}{\bar{p}} = \frac{\alpha}{\gamma}\left(1 - \frac{p_i}{\bar{p}}\right)$$

which matches (9).

Derive Pass-through. Let $x = p/\bar{p}$ be the relative price. Suppose the firm sets price as a markup over marginal cost $p = \mu(x)\, c$, where the markup $\mu(x)$ depends only on x. Define the markup elasticity and the pass-through as

$$\Gamma(x) \equiv -\frac{d \log \mu(x)}{d \log x}, \qquad \Phi(x) \equiv \frac{d \log p}{d \log c}$$

Because $x = p/\bar{p}$, we have $x\bar{p} = \mu(x)c$. Taking logs,

$$\log x + \log \bar{p} = \log \mu(x) + \log c \quad \Rightarrow \quad \log x = \log c + \log \mu(x) - \log \bar{p}.$$

Differentiating with respect to $\log c$ and using the chain rule,

$$\begin{aligned} \frac{d \log x}{d \log c} &= 1 + \frac{d \log \mu}{d \log c} = 1 + \frac{d \log \mu}{d \log x}\,\frac{d \log x}{d \log c} \\ &= 1 - \Gamma(x)\,\frac{d \log x}{d \log c}. \end{aligned}$$

Hence

$$\big(1 + \Gamma(x)\big)\frac{d \log x}{d \log c} = 1 \quad \Leftrightarrow \quad \frac{d \log x}{d \log c} = \frac{1}{1 + \Gamma(x)}$$

Finally, since $p = x\bar{p}$ and $\bar{p}$ is constant,

$$\Phi(x) = \frac{d \log p}{d \log c} = \frac{d \log x}{d \log c} = \frac{1}{1 + \Gamma(x)}$$

A.2 Equilibrium

This section derives the expressions for sectoral expenditure E_s, the sectoral quantity index Q_s, and the corresponding price index $P_s = E_s/Q_s$ used in the main text.

Expenditure. Sectoral expenditure per consumer is

$$E_s = \int_0^{N_s} p_{is} q_{is} di = N_s \int_{a_s^*}^{\infty} p_s(a) q_s(a)\, g_s(a \mid a \geq a_s^*)\, da.$$

Using the equilibrium price and individual demand schedules $p_s(a) = \frac{1}{2}\left(a^{-1} + (a_s^*)^{-1}\right)$ and $q_s(a) = \frac{\alpha}{2\gamma}\left(1 - \frac{a_s^*}{a}\right)$, sectoral expenditure can be written as

$$\begin{aligned} E_s &= \frac{\alpha N_s}{4\gamma}\left[\frac{1}{a_s^*} - a_s^* \int_{a_s^*}^{\infty} a^{-2} g_s(a \mid a \geq a_s^*)\, da\right] \\ &= \frac{\alpha N_s}{4\gamma a_s^*}\left(1 - \frac{\kappa_s}{\kappa_s + 2}\right) = \frac{\alpha N_s}{2\gamma a_s^*(\kappa_s + 2)}. \end{aligned}$$

Quantity. Sectoral real consumption is defined as the total physical quantity consumed across producing varieties,

$$Q_s = \int_0^{N_s} q_{is} di = N_s \int_{a_s^*}^{\infty} q_s(a)\, g_s(a \mid a \geq a_s^*)\, da.$$

Using $\int_{a_s^*}^{\infty} a^{-1} g_s(a \mid a \geq a_s^*)\, da = \frac{\kappa_s}{\kappa_s+1}(a_s^*)^{-1}$ gives

$$\begin{aligned} Q_s &= \frac{\alpha N_s}{2\gamma}\left[1 - a_s^* \int_{a_s^*}^{\infty} a^{-1} g_s(a \mid a \geq a_s^*)\, da\right] \\ &= \frac{\alpha N_s}{2\gamma}\left(1 - \frac{\kappa_s}{\kappa_s + 1}\right) = \frac{\alpha N_s}{2\gamma(\kappa_s + 1)}. \end{aligned}$$

Sectoral Price Index. Finally, the sectoral unit-value price index is defined as $P_s \equiv E_s/Q_s$. Combining the two expressions above yields

$$P_s = \frac{\kappa_s + 1}{\kappa_s + 2} \frac{1}{a_s^*}. \tag{40}$$

Substituting the equilibrium productivity cut-off a_s^* gives

$$P_s = \frac{\kappa_s + 1}{\kappa_s + 2}\left(\frac{F}{L\delta_\pi(\kappa_s)}\right)^{\frac{1}{1+\kappa_s}} A_s^{-\frac{\kappa_s}{1+\kappa_s}}, \tag{41}$$

which is the expression used in the main text.

A.3 Analytical Results

Cost-Weighted Markups. Recall that the cost-weighted sectoral markup is defined as

$$\mu_s^c \equiv \frac{\int_{a_s^*}^{\infty} \mu_s(a) a^{-1} y_s(a)\, dG_s(a)}{\int_{a_s^*}^{\infty} a^{-1} y_s(a)\, dG_s(a)} = \frac{\int_{a_s^*}^{\infty} p_s(a) y_s(a)\, dG_s(a)}{\int_{a_s^*}^{\infty} a^{-1} y_s(a)\, dG_s(a)}$$

where the second equality follows from $\mu_s(a)a^{-1} = p_s(a)$. Using the equilibrium price and quantity schedules $p_s(a) = \frac{1}{2}\left(a^{-1} + (a_s^*)^{-1}\right)$ and $y_s(a) = L\frac{\alpha}{2\gamma}\left(1 - \frac{a_s^*}{a}\right)$, together with the Pareto density $g_s(a) = \kappa_s A_s^{\kappa_s} a^{-\kappa_s - 1}$, sectoral revenue is

$$\begin{aligned}
\int_{a_s^*}^{\infty} p_s(a) y_s(a)\, dG_s(a) &= \frac{L\alpha}{4\gamma}\left[\frac{1}{a_s^*}\int_{a_s^*}^{\infty} dG_s(a) - a_s^* \int_{a_s^*}^{\infty} a^{-2}\, dG_s(a)\right] \\
&= \frac{L\alpha}{2\gamma} \frac{A_s^{\kappa_s}}{(a_s^*)^{\kappa_s+1}(\kappa_s + 2)}.
\end{aligned}$$

Likewise, sectoral variable cost is

$$\begin{aligned}
\int_{a_s^*}^{\infty} a^{-1} y_s(a)\, dG_s(a) &= \frac{L\alpha}{2\gamma}\left[\int_{a_s^*}^{\infty} a^{-1}\, dG_s(a) - a_s^* \int_{a_s^*}^{\infty} a^{-2}\, dG_s(a)\right] \\
&= \frac{L\alpha}{2\gamma} \frac{\kappa_s A_s^{\kappa_s}}{(a_s^*)^{\kappa_s+1}(\kappa_s + 1)(\kappa_s + 2)}.
\end{aligned}$$

Taking the ratio gives

$$\mu_s^c = \frac{\kappa_s + 1}{\kappa_s} = 1 + \frac{1}{\kappa_s},$$

which is equation (21) in the main text.

Sales-Weighted Markups. For comparison to the cost-weighted markups derived in the main text, consider now the sales-weighted sectoral markup, which weights firms by their revenue shares rather than their cost shares. In sector s, define

$$\mu_s^R \equiv \frac{\int_{a_s^*}^{\infty} \mu_{is}(a)\, p_{is}(a)\, y_{is}(a)\, dG_s(a)}{\int_{a_s^*}^{\infty} p_{is}(a)\, y_{is}(a)\, dG_s(a)},$$

so the weight of firm i is its share in total sales $p_{is}y_{is}$. Using the equilibrium price and quantity schedules, $p_{is}(a) = \frac{1}{2}\left(a^{-1} + (a_s^*)^{-1}\right)$ and $y_{is}(a) = L\frac{\alpha}{2\gamma}\left(1 - a_s^*/a\right)$, together with the Pareto density $g_s(a) = \kappa_s A_s^{\kappa_s} a^{-\kappa_s - 1}$, we obtain

$$\int_{a_s^*}^{\infty} p_{is}(a)\, q_{is}(a)\, g_s(a)\, da = \frac{\alpha}{2\gamma} \frac{A_s^{\kappa_s}}{(a_s^*)^{\kappa_s+1}(\kappa_s + 2)},$$

$$\int_{a_s^*}^{\infty} \mu_{is}(a)\, p_{is}(a)\, q_{is}(a)\, g_s(a)\, da = \frac{\alpha}{2\gamma} \frac{A_s^{\kappa_s}}{(a_s^*)^{\kappa_s+1}} \frac{2\kappa_s^2 + 2\kappa_s - 1}{4(\kappa_s + 2)(\kappa_s^2 - 1)}.$$

Dividing the two expressions yields the sales-weighted sectoral markup

$$\mu_s^R = \frac{\kappa_s^2 + \kappa_s - \frac{1}{2}}{\kappa_s^2 - 1} = \left(1 + \frac{1}{\kappa_s}\right) + \frac{\kappa_s + 2}{2\kappa_s(\kappa_s^2 - 1)} = \mu_s^c + \frac{\kappa_s + 2}{2\kappa_s(\kappa_s^2 - 1)} > \mu_s^c \tag{42}$$

Sales weights put more emphasis on high-productivity, high-markup firms, so μ_s^R exceeds the cost-weighted markup μ_s^c in every sector. Both measures fall with κ_s and converge to one as the productivity distribution becomes more concentrated near the lower bound (i.e. as $\kappa_s \to \infty$). As $\kappa_s \to 1$ the sales-weighted markup diverges while the cost-weighted markup remains finite at $\mu_s^c \to 2$, reflecting the increasing dominance of extremely productive, high-markup firms in sectoral sales.

Proof of Proposition 2: Growth & Structural Change. Recall the expenditure share implied by the non-homothetic CES aggregator:

$$\begin{aligned} \omega_r &= \beta_r \left(\frac{P_r}{P}\right)^{1-\eta} Q^{\epsilon_r - 1}, \\ \Leftrightarrow \qquad \log \omega_r &= \log \beta_r + (1-\eta)\big(\log P_r - \log P\big) + (\epsilon_r - 1)\log Q, \end{aligned}$$

where $E = PQ$ and $\bar{\epsilon} \equiv \sum_{j\in\mathcal{S}} \omega_j \epsilon_j$ denotes the expenditure-weighted average income elasticity.

Consider a sector-specific technology improvement in sector s, modelled as an increase in A_s, holding A_r fixed for all $r \neq s$. Differentiating $\log \omega_r$ with respect to $\log A_s$ gives, for any r,

$$\frac{d\log \omega_r}{d\log A_s} = (1-\eta)\left(\frac{d\log P_r}{d\log A_s} - \frac{d\log P}{d\log A_s}\right) + (\epsilon_r - 1)\frac{d\log Q}{d\log A_s}. \tag{43}$$

From the aggregate price deflator (4), total differentiation yields

$$(1-\eta)\, d\log P = (1-\eta)\sum_{j\in\mathcal{S}} \omega_j \, d\log P_j + (\bar{\epsilon} - 1)\, d\log Q. \tag{44}$$

Equivalently,

$$d\log P = \sum_{j\in\mathcal{S}} \omega_j \, d\log P_j + \frac{\bar{\epsilon} - 1}{1-\eta}\, d\log Q. \tag{45}$$

Since the sectoral price index P_r depends on the technology level A_r of sector r, a technology change in sector s leaves the price indices of all other sectors unchanged. Hence $\frac{d\log P_r}{d\log A_s} = 0$ for all $r \neq s$, while Proposition 1 implies $\frac{d\log P_s}{d\log A_s} = -\rho_s$. It follows that

$$\sum_{j\in\mathcal{S}} \omega_j \frac{d\log P_j}{d\log A_s} = -\omega_s \rho_s. \tag{46}$$

Using (45), we therefore obtain

$$\frac{d\log P}{d\log A_s} = -\omega_s\rho_s + \frac{\bar{\epsilon} - 1}{1-\eta}\frac{d\log Q}{d\log A_s}. \tag{47}$$

Under free entry, expected net profits are zero and nominal expenditure per consumer is fixed at $E = 1$. Since $E = PQ$, this implies $d\log Q = -d\log P$. Combining this result with (47) gives

$$-\frac{d\log Q}{d\log A_s} = -\omega_s\rho_s + \frac{\bar{\epsilon} - 1}{1-\eta}\frac{d\log Q}{d\log A_s},$$

and therefore

$$\frac{d\log Q}{d\log A_s} = \frac{(1-\eta)\omega_s\rho_s}{\bar{\epsilon} - \eta} > 0, \tag{48}$$

where the inequality follows from $\bar{\epsilon} > \eta$.

Now plug (47) into (43). First consider $r = s$. Using $\frac{d \log P_s}{d \log A_s} = -\rho_s$, we obtain

$$\begin{aligned} \frac{d \log \omega_s}{d \log A_s} &= (1-\eta)\left[-\rho_s + \omega_s \rho_s - \frac{\bar{\epsilon}-1}{1-\eta}\frac{d \log Q}{d \log A_s}\right] + (\epsilon_s - 1)\frac{d \log Q}{d \log A_s} \\ &= -(1-\eta)(1-\omega_s)\rho_s + (\epsilon_s - \bar{\epsilon})\frac{d \log Q}{d \log A_s}. \end{aligned} \tag{49}$$

Substituting (48) into (49) yields

$$\frac{d \log \omega_s}{d \log A_s} = -(1-\eta)\rho_s \left[1 - \frac{\omega_s(\epsilon_s - \eta)}{\bar{\epsilon} - \eta}\right], \tag{50}$$

which gives (24).

Next consider any sector $r \neq s$. Since $\frac{d \log P_r}{d \log A_s} = 0$, the same substitutions yield

$$\begin{aligned} \frac{d \log \omega_r}{d \log A_s} &= (1-\eta)\left[\omega_s \rho_s - \frac{\bar{\epsilon}-1}{1-\eta}\frac{d \log Q}{d \log A_s}\right] + (\epsilon_r - 1)\frac{d \log Q}{d \log A_s} \\ &= (1-\eta)\omega_s \rho_s + (\epsilon_r - \bar{\epsilon})\frac{d \log Q}{d \log A_s} \\ &= (1-\eta)\omega_s \rho_s \frac{\epsilon_r - \eta}{\bar{\epsilon} - \eta}, \qquad r \neq s. \end{aligned} \tag{51}$$

This gives (25).

Since sectoral employment satisfies $L_r = L\omega_r$ and aggregate labour supply L is fixed, expenditure shares and employment have identical elasticities:

$$\frac{d \log L_r}{d \log A_s} = \frac{d \log \omega_r}{d \log A_s}, \qquad \forall r \in \mathcal{S}. \tag{52}$$

Finally, consider the number of producing firms. Recall that

$$N_r = \frac{L_r}{F(1+\kappa_r)}\left(\frac{A_r}{a_r^*}\right)^{\kappa_r}.$$

For any non-innovating sector $r \neq s$, both A_r and a_r^* are unaffected by the technology change in sector s. Hence

$$\frac{d \log N_r}{d \log A_s} = \frac{d \log L_r}{d \log A_s} = \frac{d \log \omega_r}{d \log A_s}, \qquad r \neq s. \tag{53}$$

For the innovating sector, differentiating the expression for N_s gives

$$\frac{d \log N_s}{d \log A_s} = \frac{d \log L_s}{d \log A_s} + \kappa_s \left(1 - \frac{d \log a_s^*}{d \log A_s}\right).$$

From the equilibrium cut-off, $\frac{d\log a_s^*}{d\log A_s} = \frac{\kappa_s}{1+\kappa_s} = \rho_s$, so $\kappa_s(1-\rho_s) = \rho_s$. Therefore,

$$\begin{aligned} \frac{d\log N_s}{d\log A_s} &= \frac{d\log \omega_s}{d\log A_s} + \rho_s \\ &= \rho_s \left[\eta + (1-\eta)\frac{\omega_s(\epsilon_s - \eta)}{\bar{\epsilon} - \eta} \right], \end{aligned} \tag{54}$$

which gives (26). This completes the proof. ■

A.4 Endogenous Technology Diffusion

Truncation & Law of Motion. Let $G_{s,t}(a)$ denote the distribution of productivity draws across the unit mass of potential firms in sector s at date t, with support $[A_{s,t}, \infty)$. A constant share $\chi_s \in (0,1)$ of firms is engaged in learning-by-imitation and does not produce, so the mass of producing firms is $1-\chi_s$. Denote by $A_{s,t+1} \geq A_{s,t}$ the productivity cut-off of the marginal active producer. Since firms produce if and only if $a \geq A_{s,t+1}$, this implies

$$1 - \chi_s = 1 - G_{s,t}(A_{s,t+1}). \tag{55}$$

Imitating firms redraw from the cross-section of active producers, so the relevant sampling distribution is the distribution conditional on producing,

$$G^P_{s,t}(a) \equiv \Pr(\tilde{a} \leq a \mid \tilde{a} \geq A_{s,t+1}) = \frac{G_{s,t}(a) - G_{s,t}(A_{s,t+1})}{1 - G_{s,t}(A_{s,t+1})}, \qquad a \in [A_{s,t+1}, \infty),$$

with density $g^P_{s,t}(a) = g_{s,t}(a)/(1 - G_{s,t}(A_{s,t+1}))$ on $[A_{s,t+1}, \infty)$. This implies that the productivity distribution is truncated at the producer cut-off: after imitation and updating, the next period density is a renormalized truncation of the current density,

$$g_{s,t+1}(a) = \frac{g_{s,t}(a)}{1 - G_{s,t}(A_{s,t+1})}, \qquad a \in [A_{s,t+1}, \infty), \tag{56}$$

and zero otherwise. Iterating (56) forward, the cross-sectional distribution at any date is fully characterized by the initial distribution and the current truncation point: the density remains Pareto with shape κ_s and lower bound $A_{s,t}$ at every date t. Using the Pareto distribution, (55), and defining the growth rate as the change in the productivity frontier $g_s \equiv A_{s,t+1}/A_{s,t}$, we get

$$1 - \chi_s = \left(\frac{A_{s,t}}{A_{s,t+1}}\right)^{\kappa_s} = g_s^{-\kappa_s} \quad \Longleftrightarrow \quad g_s = (1-\chi_s)^{-1/\kappa_s} > 1, \tag{57}$$

which is the growth rate equation stated in the main text. The imitation share χ_s pins down the rate at which the productivity frontier expands over time: a larger share of imitators implies a faster expansion, while a larger shape parameter κ_s lowers the growth rate for a given imitation share, because the productivity distribution is more concentrated near its lower bound. Combining (57) with the definition of g_s yields the law of motion for the productivity frontier:

$$A_{s,t+1} = g_s A_{s,t} = (1 - s_s)^{-1/\kappa_s} A_{s,t}$$

Equilibrium. At any date t, an active firm with productivity $a \geq A_{s,t+1}$ sets price and quantity

$$p(a) = \tfrac{1}{2}\left(\bar{p}_{s,t} + \tfrac{1}{a}\right), \qquad q(a) = \frac{\alpha}{2\gamma}\left(1 - \frac{1}{a\bar{p}_{s,t}}\right).$$

Since the mass of firms in sector s is fixed at one, sectoral expenditure and real consumption are obtained by integrating the unconditional Pareto density over the active region $[A_{s,t+1}, \infty)$:

$$E_{s,t} = \int_{A_{s,t+1}}^{\infty} p(a)q(a)\, g_{s,t}(a)\, da, \qquad Q_{s,t} = \int_{A_{s,t+1}}^{\infty} q(a)\, g_{s,t}(a)\, da.$$

The two integrands yield.

$$\begin{aligned} p(a)q(a) &= \frac{\alpha}{4\gamma}\left(\bar{p}_{s,t} + \frac{1}{a}\right)\left(1 - \frac{1}{a\bar{p}_{s,t}}\right) = \frac{\alpha}{4\gamma}\left[\bar{p}_{s,t} - \frac{1}{a^2\bar{p}_{s,t}}\right], \\ q(a) &= \frac{\alpha}{2\gamma}\left[1 - \frac{1}{a\bar{p}_{s,t}}\right] \end{aligned}$$

The three Pareto moments thus required satisfy:

$$\begin{aligned} \int_{A_{s,t+1}}^{\infty} g_{s,t}(a)\, da &= \left(\frac{A_{s,t}}{A_{s,t+1}}\right)^{\kappa_s} = 1 - G_{s,t}(A_{s,t+1}), \\ \int_{A_{s,t+1}}^{\infty} a^{-1} g_{s,t}(a)\, da &= \frac{\kappa_s}{\kappa_s + 1}\big(1 - G_{s,t}(A_{s,t+1})\big) A_{s,t+1}^{-1}, \\ \int_{A_{s,t+1}}^{\infty} a^{-2} g_{s,t}(a)\, da &= \frac{\kappa_s}{\kappa_s + 2}\big(1 - G_{s,t}(A_{s,t+1})\big) A_{s,t+1}^{-2}, \end{aligned}$$

Substituting these into the definitions of $Q_{s,t}$ and $E_{s,t}$ gives:

$$E_{s,t} = \frac{\alpha\bar{p}_{s,t}\big(1 - G_{s,t}(A_{s,t+1})\big)}{4\gamma}\left[1 - \frac{\kappa_s}{\kappa_s + 2}\big(A_{s,t+1}\bar{p}_{s,t}\big)^{-2}\right], \tag{58}$$

$$Q_{s,t} = \frac{\alpha\big(1 - G_{s,t}(A_{s,t+1})\big)}{2\gamma}\left[1 - \frac{\kappa_s}{\kappa_s + 1}\big(A_{s,t+1}\bar{p}_{s,t}\big)^{-1}\right] \tag{59}$$

Dividing (58) by (59) and defining $z_{s,t} = A_{s,t+1}\bar{p}_{s,t}$ leaves

$$P_{s,t} \equiv \frac{E_{s,t}}{Q_{s,t}} = \frac{\bar{p}_{s,t}}{2}\frac{1 - \frac{\kappa_s}{\kappa_s+2}\big(A_{s,t+1}\bar{p}_{s,t}\big)^{-2}}{1 - \frac{\kappa_s}{\kappa_s+1}\big(A_{s,t+1}\bar{p}_{s,t}\big)^{-1}} = \frac{\bar{p}_{s,t}}{2}\frac{1 - \frac{\kappa_s}{\kappa_s+2}\big(z_{s,t}\big)^{-2}}{1 - \frac{\kappa_s}{\kappa_s+1}\big(z_{s,t}\big)^{-1}} = \frac{\bar{p}_{s,t}}{2}\Lambda_{s,t}(\kappa_s, z_{s,t}) \tag{60}$$

which is the price-index decomposition used in the main text.

Labour market clearing requires that labour demand across active producers, $\int_{A_{s,t+1}}^{\infty} a^{-1}q(a)\, dG_{s,t}(a)$, equal the sector's employment share $l_{s,t}$:

$$l_{s,t} = \frac{\alpha\big(1 - G_{s,t}(A_{s,t+1})\big)}{2\gamma}\left[\frac{\kappa_s}{\kappa_s + 1}A_{s,t+1}^{-1} - \frac{1}{\bar{p}_{s,t}} \cdot \frac{\kappa_s}{\kappa_s + 2}A_{s,t+1}^{-2}\right] \tag{61}$$

Rearranging (61) allows us to solve explicitly for the equilibrium choke price $\bar{p}_{s,t}$. Starting from the labour market clearing condition, define $B_s \equiv \frac{\alpha\kappa_s(1-s_s)}{2\gamma}$. Then the two terms in (61) simplify to

$$\frac{\alpha}{2\gamma}\frac{\kappa_s}{\kappa_s+1}(1-s_s)A_{s,t+1}^{-1} = \frac{B_s}{\kappa_s+1}A_{s,t+1}^{-1}, \qquad \frac{\alpha}{2\gamma}\frac{\kappa_s}{\kappa_s+2}(1-s_s)A_{s,t+1}^{-2} = \frac{B_s A_{s,t+1}^{-2}}{\kappa_s+2}.$$

Substituting into (61) yields

$$l_{s,t} = \frac{B_s A_{s,t+1}^{-1}}{\kappa_s+1} - \frac{1}{\bar{p}_{s,t}}\frac{B_s A_{s,t+1}^{-2}}{\kappa_s+2} \tag{62}$$

Rearranging (62) gives

$$\frac{1}{\bar{p}_{s,t}}\frac{B_s A_{s,t+1}^{-2}}{\kappa_s+2} = \frac{B_s A_{s,t+1}^{-1}}{\kappa_s+1} - l_{s,t} \quad \Longrightarrow \quad \frac{1}{\bar{p}_{s,t}} = \frac{\kappa_s+2}{B_s A_{s,t+1}^{-2}}\left(\frac{B_s A_{s,t+1}^{-1}}{\kappa_s+1} - l_{s,t}\right)$$

Inverting and simplifying implies the closed form for the choke price:

$$\bar{p}_{s,t} = \frac{\kappa_s+1}{\kappa_s+2}\left[\frac{A_{s,t+1}^{-1}}{1-(\kappa_s+1)l_{s,t}A_{s,t+1}/B_s}\right] \tag{63}$$

Growth Pass-Through. Taking logs of (60) and using $\bar{p}_{s,t} = z_{s,t}/(g_s A_{s,t})$,

$$\log P_{s,t} = \log z_{s,t} - \log g_s - \log A_{s,t} - \log 2 + \log \Lambda_{s,t}. \tag{64}$$

Holding $l_{s,t}$ fixed, g_s is a constant so $\log g_s$ drops out under differentiation. Differentiating (64) with respect to $\log A_{s,t}$ and defining $\rho_{s,t} \equiv -d\log P_{s,t}/d\log A_{s,t}$ gives

$$\rho_{s,t} = 1 - \left(1 + \frac{d\log \Lambda_{s,t}}{d\log z_{s,t}}\right)\frac{d\log z_{s,t}}{d\log A_{s,t}} \tag{65}$$

the formula stated in the main text. Writing $a_s \equiv \kappa_s/(\kappa_s+2)$, $b_s \equiv \kappa_s/(\kappa_s+1)$,

$$\frac{d\log \Lambda_{s,t}}{d\log z_{s,t}} = \frac{2a_s z_{s,t}^{-2}}{1-a_s z_{s,t}^{-2}} - \frac{b_s z_{s,t}^{-1}}{1-b_s z_{s,t}^{-1}} = \frac{-b_s(z_{s,t}-1)(z_{s,t}-a_s)}{z_{s,t}^3(1-a_s z_{s,t}^{-2})(1-b_s z_{s,t}^{-1})} \leq 0, \tag{66}$$

$$\frac{d\log z_{s,t}}{d\log A_{s,t}} = \frac{(\kappa_s+1)\, g_s\, l_{s,t}\, A_{s,t}}{B_s - (\kappa_s+1)\, g_s\, l_{s,t}\, A_{s,t}} > 0, \tag{67}$$

positive provided $B_s > (\kappa_s+1)g_s l_{s,t} A_{s,t}$, i.e. in any interior equilibrium. Clearing denominators in (66),

$$1 + \frac{d\log \Lambda_{s,t}}{d\log z_{s,t}} = \frac{z_{s,t}^3 - 2b_s z_{s,t}^2 + a_s z_{s,t}}{z_{s,t}^3 - b_s z_{s,t}^2 - a_s z_{s,t} + a_s b_s} = \frac{z_{s,t}\left[(z_{s,t}-b_s)^2 + (a_s - b_s^2)\right]}{z_{s,t}^3 - b_s z_{s,t}^2 - a_s z_{s,t} + a_s b_s} > 0 \tag{68}$$

Combining this with (67) in (65), growth pass-through is incomplete in any interior equilibrium.

Comparative Statics. Fix $(g_s, l_{s,t}, A_{s,t}, \alpha, \gamma, \chi_s)$ and a value $z_{s,t} \geq 1$. Write

$$\rho_{s,t} = 1 - \underbrace{\left(1 + \frac{d\log \Lambda_{s,t}}{d\log z_{s,t}}\right)}_{\equiv A(\kappa_s, z_{s,t})>0} \underbrace{\frac{(\kappa_s+1)\, g_s\, l_{s,t}\, A_{s,t}}{B_s - (\kappa_s+1)\, g_s\, l_{s,t}\, A_{s,t}}}_{\equiv B(\kappa_s)>0}, \qquad B_s \equiv \frac{\alpha\kappa_s(1-\chi_s)}{2\gamma}. \tag{69}$$

Step 1 (B decreasing in κ_s). Write $B(\kappa_s) = N(\kappa_s)/D(\kappa_s)$ with $N(\kappa_s) = (\kappa_s+1)g_s l_{s,t} A_{s,t}$ and $D(\kappa_s) = B_s - (\kappa_s+1)g_s l_{s,t} A_{s,t}$; both $g_s, l_{s,t}, A_{s,t}, \alpha, \gamma, \chi_s$ are held fixed, so $N'(\kappa_s) = g_s l_{s,t} A_{s,t}$ and $D'(\kappa_s) = (1-\chi_s)\alpha/(2\gamma) - g_s l_{s,t} A_{s,t}$. By the quotient rule,

$$\frac{dB}{d\kappa_s} = \frac{N'D - ND'}{D^2}, \qquad N'D - ND' = g_s l_{s,t} A_{s,t}\big[D - (\kappa_s+1)D'\big].$$

Substituting D and D', the $(\kappa_s+1)g_s l_{s,t} A_{s,t}$ terms cancel exactly, leaving

$$D - (\kappa_s+1)D' = -\frac{(1-\chi_s)\alpha}{2\gamma} < 0 \quad \Longrightarrow \quad N'D - ND' = -\frac{g_s l_{s,t} A_{s,t}(1-\chi_s)\alpha}{2\gamma} < 0.$$

Since $D(\kappa_s) > 0$, $D^2 > 0$, so $dB/d\kappa_s < 0$: $B(\kappa_s)$ is strictly decreasing.

Step 2 (A non-increasing in κ_s). From $\Lambda_{s,t} = (1-a_s z^{-2})/(1-b_s z^{-1})$ with $a_s \equiv \kappa_s/(\kappa_s+2)$, $b_s \equiv \kappa_s/(\kappa_s+1)$, some algebra gives the closed form

$$A(\kappa_s, z) = \frac{z\big[(z-b_s)^2 + (a_s - b_s^2)\big]}{z^3 - b_s z^2 - a_s z + a_s b_s},$$

consistent with the incomplete-pass-through step earlier. Differentiating with respect to κ_s holding z fixed yields

$$\frac{\partial \mathcal{A}(\kappa, z)}{\partial \kappa} = -\frac{z(z-1)\left[\kappa^2(z-1)^3 + 4\kappa z^2(z-1) + 4z^3\right]}{(\kappa z - \kappa + z)^2(\kappa z^2 - \kappa + 2z^2)^2} \leq 0. \tag{70}$$

with strict inequality for $z > 1$.

Step 3. Differentiating (69) with respect to κ_s,

$$\frac{\partial \rho_{s,t}}{\partial \kappa_s} = -\frac{\partial A}{\partial \kappa_s} B - A\frac{\partial B}{\partial \kappa_s}.$$

For $z_{s,t} \geq 1$: $A > 0$, $B > 0$, $\partial B/\partial\kappa_s < 0$ (Step 1), and $\partial A/\partial\kappa_s \leq 0$ (Step 2), so $\partial\rho_{s,t}/\partial\kappa_s > 0$.

Endogenous Markup Growth. Active producers have $a \geq A_{s,t+1}$. Using $p(a) = \frac{1}{2}(\bar{p}_{s,t} + 1/a)$ and $q(a) = \frac{\alpha}{2\gamma}(1 - 1/(a\bar{p}_{s,t}))$, revenue and variable-cost integrands simplify to

$$p(a)q(a) = \frac{\alpha}{4\gamma}\left[\bar{p}_{s,t} - \frac{1}{a^2\bar{p}_{s,t}}\right], \qquad a^{-1}q(a) = \frac{\alpha}{2\gamma}\left[\frac{1}{a} - \frac{1}{a^2\bar{p}_{s,t}}\right].$$

The cost-weighted sectoral markup is thus given by:

$$\mu_{s,t}^c = \frac{\int p(a)q(a)\, g_{s,t}(a)\, da}{\int a^{-1}q(a)\, g_{s,t}(a)\, da} = \frac{z_{s,t}\left(1 - \dfrac{\kappa_s}{(\kappa_s+2)z_{s,t}^2}\right)}{2\kappa_s\left(\dfrac{1}{\kappa_s+1} - \dfrac{1}{(\kappa_s+2)z_{s,t}}\right)}.$$

Multiplying numerator and denominator by $(\kappa_s + 2)z_{s,t}$ and simplifying,

$$\mu_{s,t}^c = \frac{\kappa_s+1}{2\kappa_s}\frac{(\kappa_s+2)z_{s,t}^2 - \kappa_s}{(\kappa_s+2)z_{s,t} - (\kappa_s+1)} \tag{71}$$

which is the markup formula stated in the main text. At $z_{s,t} \to 1$ this reduces to $\mu_{s,t}^c \to (\kappa_s+1)/\kappa_s = 1 + 1/\kappa_s$, recovering the level-shift markup formula of the static (free-entry) model as the special case in which the choke price equals the marginal producer's marginal cost. Over time, as technology progresses, we have increasing markups even with constant κ_s since

$$\frac{\partial \mu_{s,t}^c}{\partial z_{s,t}} = \frac{(\kappa_s+1)(\kappa_s+2)(z_{s,t}-1)\left[\kappa_s(z_{s,t}-1) + 2z_{s,t}\right]}{2\kappa_s\left[(\kappa_s+2)z_{s,t} - \kappa_s + 1)\right]^2} \geq 0. \tag{72}$$

B Data: WIOD

B.1 Sector Aggregation

Table B.1: WIOD Rev. 3.1 and Rev. 4 Aggregation into Sectors

3-sector	**8-sector**	**ISIC Rev. 3.1**	**ISIC Rev. 4**
Agriculture	Agriculture	**A** Agriculture **B** Fishing	**A** Agriculture, Forestry & Fishing
Industry	Manufacturing	**D** Manufacturing	**C** Manufacturing **J58** Publishing Activities
	Other Industry	**C** Mining & Quarrying **E** Electricity, Gas & Water **F** Construction	**B** Mining & Quarrying **D** Electricity, Gas, Steam & Air Conditioning Supply **E36** Water Collection & Supply **F** Construction
Services	Trade Services	**G** Wholesale & Retail Trade **H** Accommodation and Food	**G** Wholesale & Retail Trade **I** Accommodation and Food
	Transport & Communication	**I** Transport & Storage **I64** Post & Telecom	**H** Transport, Storage and Post **J61** Telecom
	Finance	**J** Financial and Insurance	**K** Financial and Insurance
	Business Services	**K** Real Estate, Renting & Business Activities	**L68** Real Estate **M** Professional, Scientific & Technical Activities **N** Administrative & Support Service Activities
	Other Services	**L–Q** Public Administration and Defence; Education; Health and Social Work; Other Community, Social and Personal Service Activities; Private Households; Extraterritorial Organizations	**E37–E39** Sewerage, Waste management and remediation **J59–J60** Motion picture, sound recording, broadcasting **J62–J63** Computer programming, consultancy, information Services **O–U** Public Administration and Defence; Education; Health and Social Work; Arts, Entertainment and Recreation; Other Service Activities; Private Households; Extraterritorial Organizations

B.2 Expenditure Shares

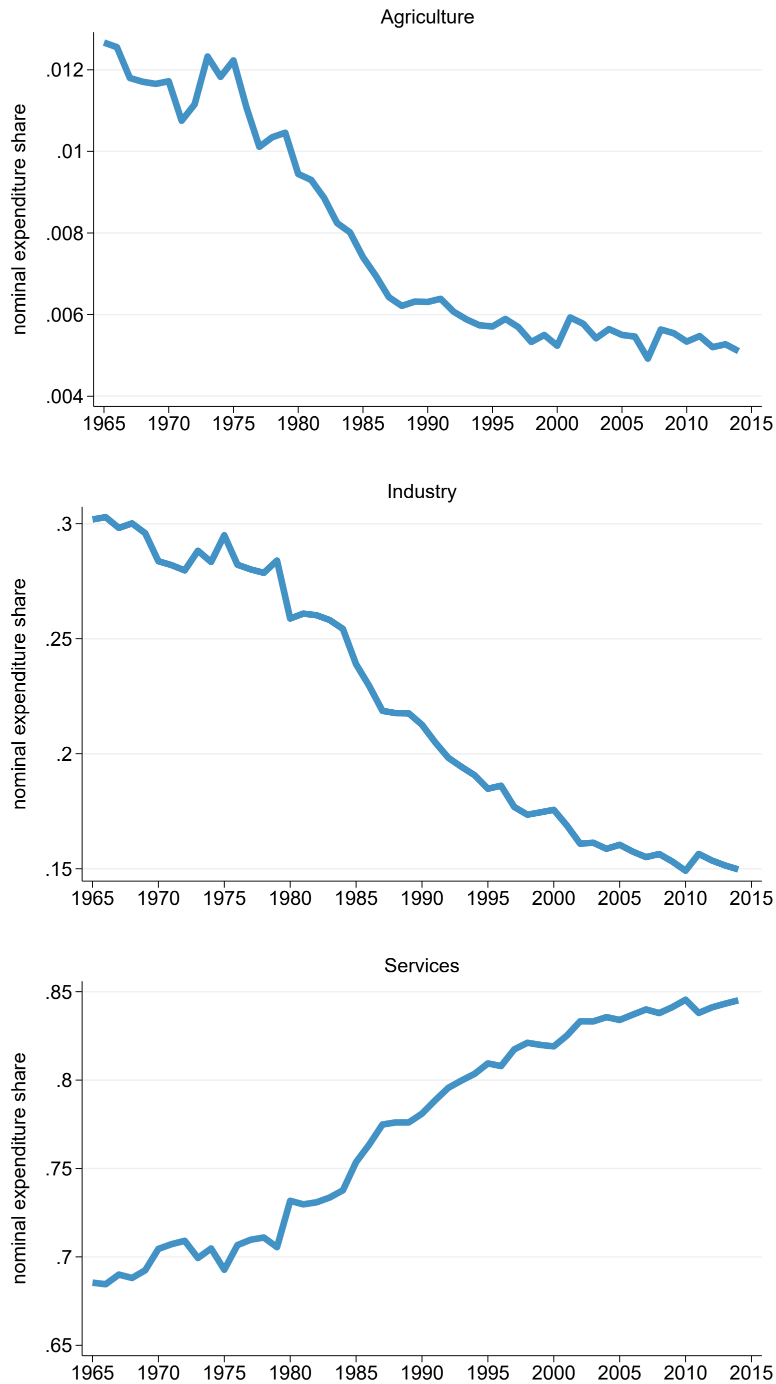
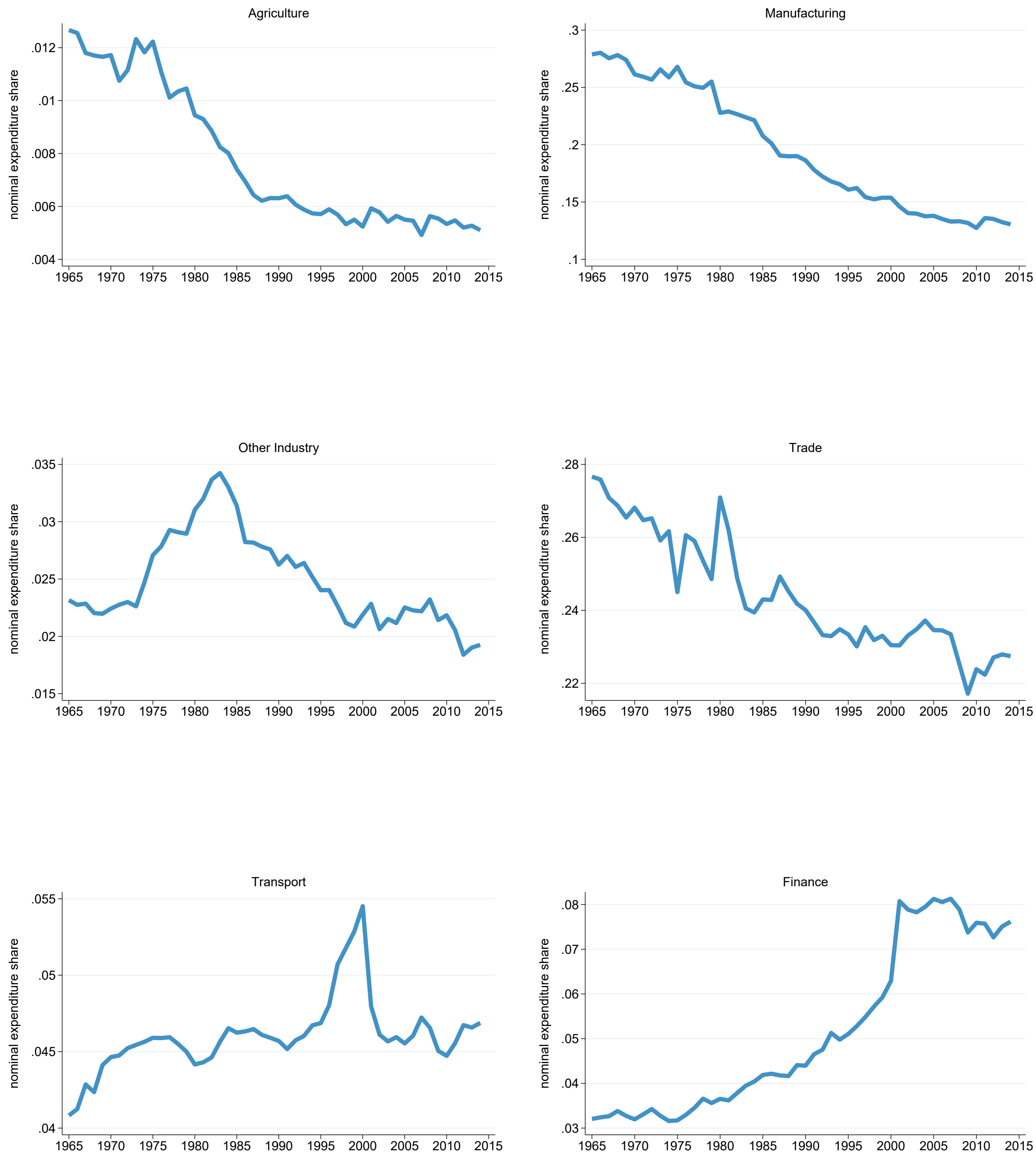


Figure B.1: Expenditure Shares across 3 Sectors

Notes: Own calculations based on WIOD. Expenditure shares are constructed using final household consumption and then aggregated into 3 broad economic sectors: Agriculture, Industry, and Services.


Agriculture
nominal expenditure share
.004
.006
.008
.01
.012
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Manufacturing
nominal expenditure share
.1
.15
.2
.25
.3
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Other Industry
nominal expenditure share
.015
.02
.025
.03
.035
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Trade
nominal expenditure share
.22
.24
.26
.28
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Transport
nominal expenditure share
.04
.045
.05
.055
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Finance
nominal expenditure share
.03
.04
.05
.06
.07
.08
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015

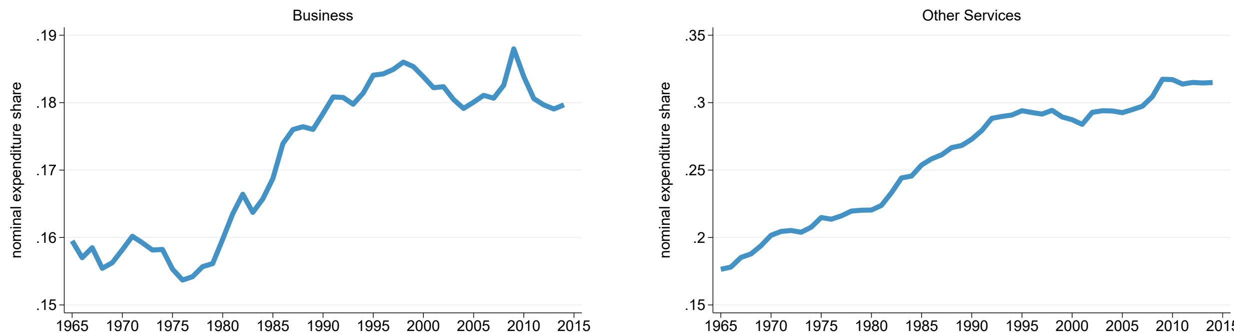


Figure B.2: Expenditure Shares across 8 Sectors

Notes: Own calculations based on WIOD. Expenditure shares are constructed using final household consumption and then aggregated into 8 sectors: Agriculture, manufacturing, other Industry, trade Services, transport Services, finance, business Services, and other Services.

B.3 Relative Prices

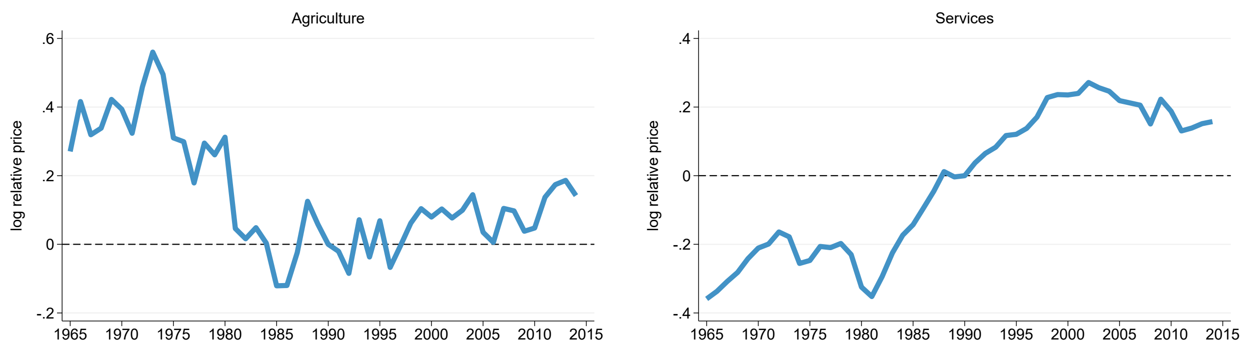


Figure B.3: Sectoral Prices relative to Industry (3-sectors)

Notes: Own calculations based on WIOD. The figure plots sectoral relative price levels for Agriculture and Services relative to Industry. Sectoral gross price changes are measured using the implicit deflator $g^P_{s,t} \equiv E^{\text{nom}}_{s,t}/E^{\text{pyp}}_{s,t}$ (nominal expenditure divided by previous-year-price expenditure). A chained log price index is constructed as $\log P_{s,t} - \log P_{s,t_0} = \sum_{\tau=t_0+1}^{t} \log(g^P_{s,\tau})$. Displayed is the log relative price index, $\log(P_{s,t}/P_{b,t}) - \log(P_{s,t_0}/P_{b,t_0})$, with normalization year $t_0 = 1990$.

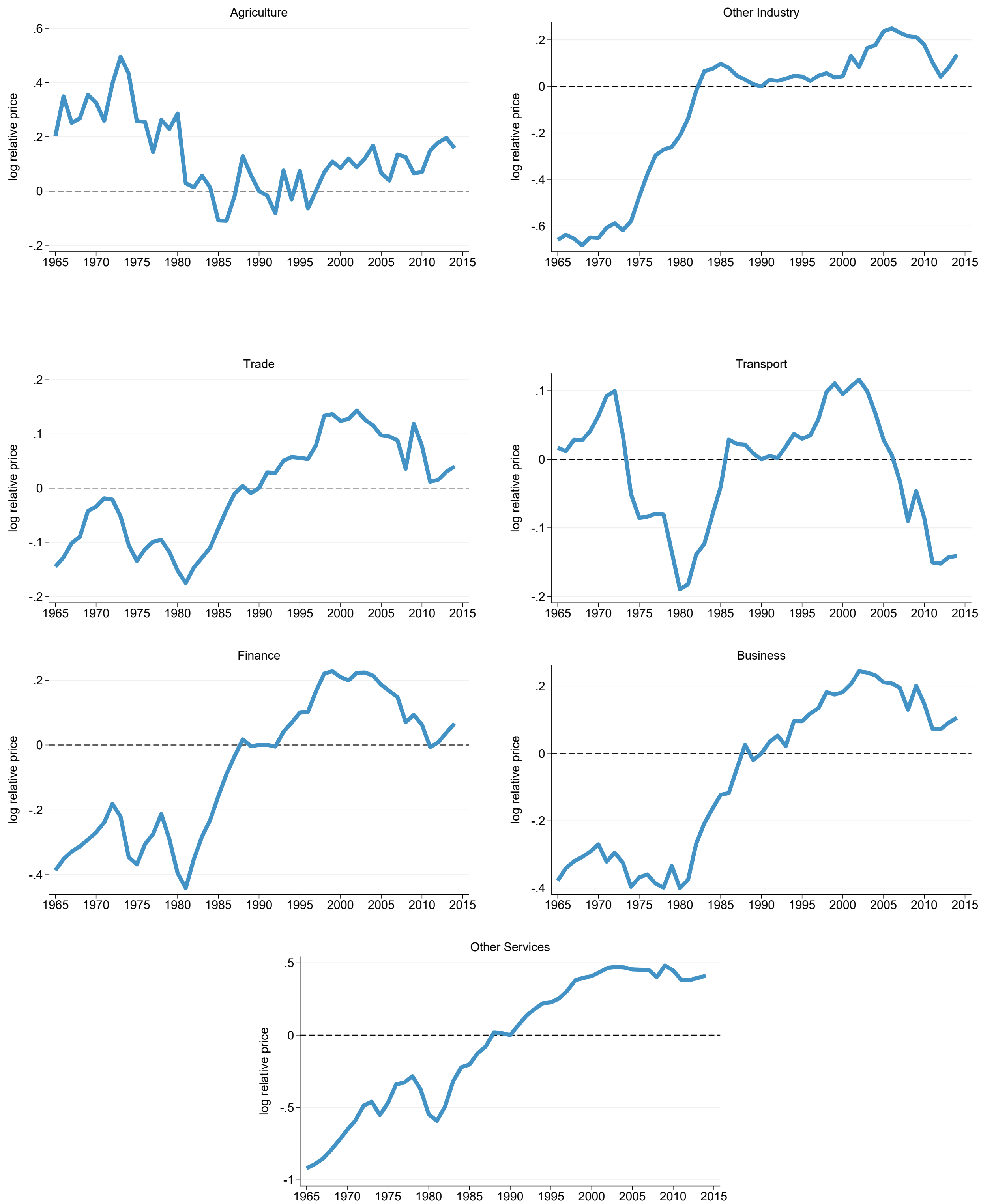


Figure B.4: Sectoral Prices relative to Manufacturing (8-sectors)

Notes: Own calculations based on WIOD. The figure plots sectoral relative price levels for all other sectors relative to Manufacturing. Sectoral gross price changes are measured using the implicit deflator $g^P_{s,t} \equiv E^{\text{nom}}_{s,t}/E^{\text{pyp}}_{s,t}$ (nominal expenditure divided by previous-year-price expenditure). A chained log price index is constructed as $\log P_{s,t} - \log P_{s,t_0} = \sum_{\tau=t_0+1}^{t} \log(g^P_{s,\tau})$. Displayed is the log relative price index, $\log(P_{s,t}/P_{b,t}) - \log(P_{s,t_0}/P_{b,t_0})$, with normalization year $t_0 = 1990$.

C Data: Compustat

C.1 Sector Aggregation

Table C.1: Compustat NAICS 2-Digit Aggregation into 3 Sectors

3-sector	**NAICS 2-Digit Industry**	
Agriculture	11	Agriculture
Industry	21	Mining
	22	Utilities
	23	Construction
	31	Manufacturing non-durables
	32	Manufacturing durables
	33	Manufacturing misc
Services	42	Wholesale Trade
	44	Retail Trade
	45	Retail Trade
	48	Transport, Warehouse
	51	Information
	52	Finance and Insurance
	53	Real Estate
	54	Professional Services
	56	Administrative Support
	62	Education, Health Care
	71	Arts and Recreation
	72	Accommodation and Food
	81	Other Services

C.2 Derivation Markup Estimation Equation

To see where equation (28) comes from, consider a firm that minimizes variable and fixed input costs subject to producing Q_{it}:

$$\min_{V_{it},K_{it}} P_{it}^V V_{it} + R_{it}K_{it} \quad \text{s.t.} \quad Q_{it} \leq F(V_{it}, K_{it}, \Omega_{it}). \tag{73}$$

Let λ_{it} denote the Lagrange multiplier on the production constraint. This multiplier is marginal cost. The first-order condition for the variable input is

$$P_{it}^V = \lambda_{it} \frac{\partial F(\cdot)}{\partial V_{it}}. \tag{74}$$

Multiplying both sides by V_{it}/Q_{it} gives

$$\frac{\partial F(\cdot)}{\partial V_{it}} \frac{V_{it}}{Q_{it}} = \frac{P_{it}^V V_{it}}{\lambda_{it} Q_{it}}. \tag{75}$$

The left-hand side is the output elasticity of the variable input, denoted θ_{it}^V. Using the definition of the markup, $\mu_{it} = P_{it}/\lambda_{it}$, we obtain

$$\theta_{it}^V = \frac{P_{it}^V V_{it}}{P_{it} Q_{it}} \mu_{it}. \tag{76}$$

Solving for the markup yields

$$\mu_{it} = \theta_{it}^V \frac{P_{it} Q_{it}}{P_{it}^V V_{it}} = \theta_{it}^V \frac{S_{it}}{C_{it}}. \tag{77}$$

C.3 Aggregate Markup

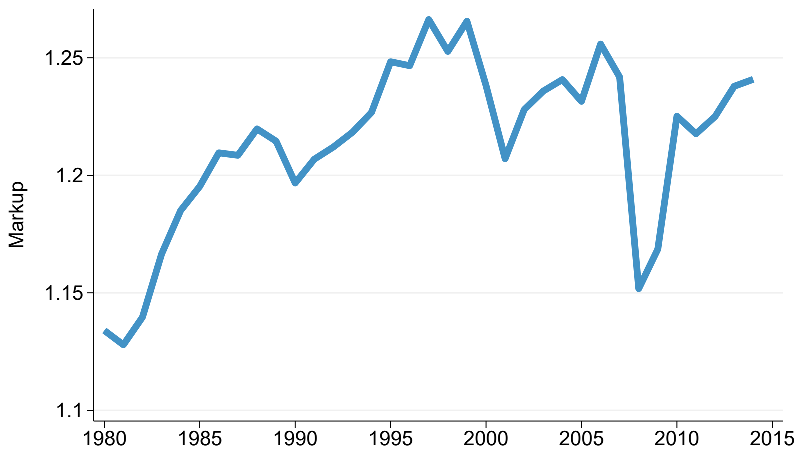
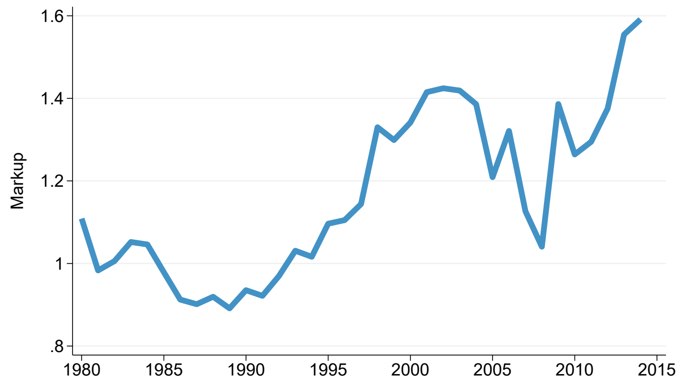


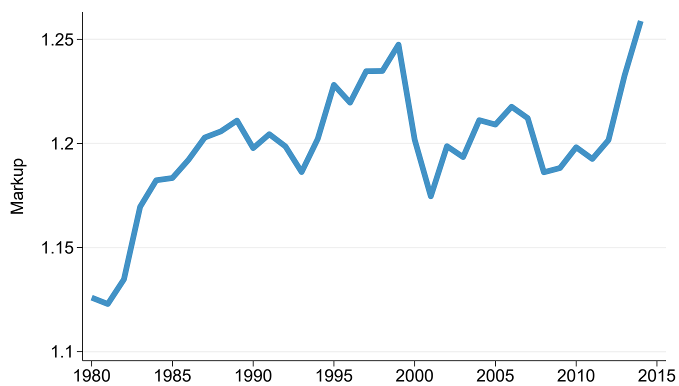
Figure C.1: Aggregate Markup

Notes: The figure shows the aggregate cost-weighted markup for the cleaned Compustat firm-year sample after applying the 1% trimming procedure described in the text. Firm-level markups are constructed as the product of the output elasticity of the variable input and the inverse COGS share of sales. The aggregate markup is computed as the COGS-weighted average.

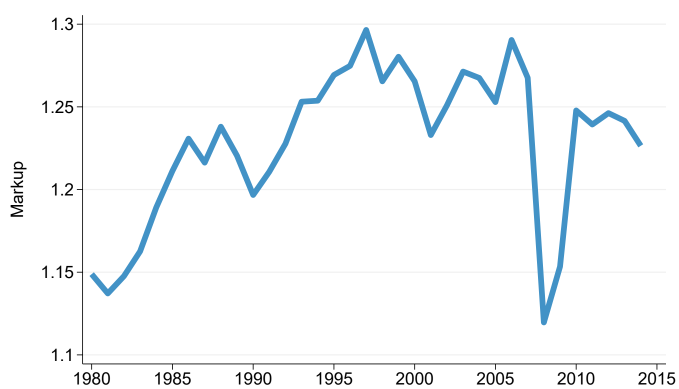
C.4 Sectoral Markups



(a) Agriculture



(b) Industry



(c) Services

Figure C.2: Sectoral Aggregate Markups

Notes: The figures show the aggregate cost-weighted markup within each sector for the cleaned Compustat firm-year sample after applying the 1% trimming procedure described in the text. Firm-level markups are constructed as the product of the output elasticity of the variable input and the inverse COGS share of sales. The sectoral aggregate markup is computed as the COGS-weighted average of all firms in the sector.

C.5 Decomposition of Aggregate Markup Change

Table C.2: Decomposition of Aggregate Markup Change

	COGS share		Contribution to ΔM		
Sector	**1980**	**2014**	**Markup**	**Share**	**Total**
Agriculture	0.4%	0.1%	0.001	-0.004	-0.003
Industry	64.2%	42.6%	0.071	-0.258	-0.187
Services	35.4%	57.3%	0.036	0.261	0.297
Total change			0.108	-0.001	0.107

Notes: The left part reports each sector's share in aggregate COGS, which is used as the aggregation weight for sectoral markups. The right part decomposes the change in the aggregate markup between 1980 and 2014 into two components: a within-sector markup effect, capturing changes in average sectoral markups holding sector size fixed, and a sector-size effect, capturing changes in sectoral COGS shares holding markups fixed. Sector markups are COGS-weighted averages of firm-level markups. The decomposition is $\Delta M = \sum_s \bar{\omega}_s \Delta m_s + \sum_s \bar{m}_s \Delta \omega_s$, where m_s denotes the sectoral markup, ω_s denotes the sectoral COGS share, and bars denote averages of initial and final values.

C.6 Productivity Growth Decomposition

Table C.3: Productivity Growth Decomposition: Domestic

Sector	**Cut-off a^***	**Distribution**	**Total**
Agriculture	2.0%	2.3%	4.3%
Industry	1.9%	0.5%	2.4%
Services	0.6%	0.3%	0.9%

Notes: Values are average annual log changes. Conditional-mean productivity among producing firms, $E[a_{s,t} \mid a_{s,t} \geq a^*_{s,t}] = a^*_{s,t} \cdot \kappa_{s,t}/(\kappa_{s,t} - 1)$, is decomposed into $\Delta \log E[a_{s,t} \mid a_{s,t} \geq a^*_{s,t}] = \Delta \log a^*_{s,t} + \Delta \log[\kappa_{s,t}/(\kappa_{s,t} - 1)]$. The cut-off effect captures the shift in the productivity threshold of producing firms; the distribution effect captures the change in the shape of the productivity distribution above that threshold. Since this only depends on $\kappa_{s,t}$, it is identical across the domestic and trade-inclusive specifications. The baseline uses the smoothed series for κ.

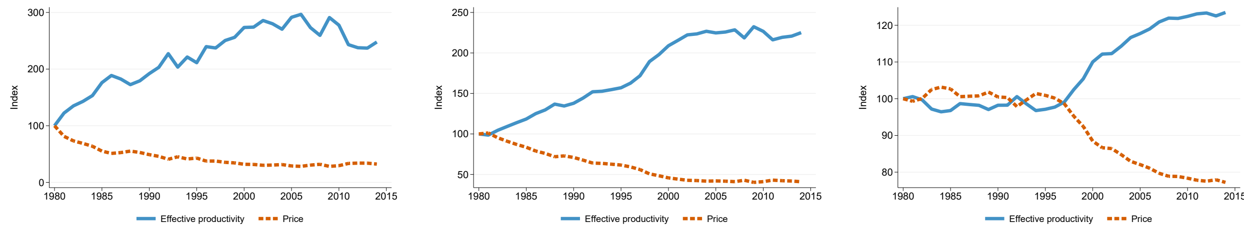
C.7 Price Index Decomposition

Table C.4: Decomposition of Price Growth: Trade-inclusive

Sector	**Cut-off**	**Selection Effect**	**Price**
Agriculture	2.67%	0.65%	3.32%
Industry	2.39%	0.24%	2.62%
Services	0.62%	0.14%	0.76%

Notes: Values are average annual log changes. Wage-adjusted price growth is decomposed according to $\Delta \log(P_{s,t}/w_t)^{-1} = \Delta \log a^*_{s,t} + \Delta \log[(\kappa_{s,t} + 2)/(\kappa_{s,t} + 1)]$. The selection effect can equivalently be written as $\Delta \log[(2\mu^c_{s,t} - 1)/\mu^c_{s,t}]$.

C.8 Prices & Productivity



(a) Agriculture (b) Industry (c) Services

Figure C.3: TFP and Price Indices

Notes: The solid line plots the constructed TFP index, while the dashed line plots the wage-adjusted price index, $P_{s,t}/w_t$. Both series are normalized to 100 in the first year. The discrepancies between TFP growth and price growth reflect markup growth.

D Calibration

D.1 Model Fit

Table D.1: Entry Model: Baseline Fit of Expenditure Shares, 1980–2014

Sector	RMSE	% of share	Correlation
Agriculture	0.0005	6.0%	0.97
Industry	0.0069	3.1%	0.98
Services	0.0071	0.9%	0.98

Notes: Baseline of the entry model. Stata supplies the empirical $\kappa_{s,t}$ and effective-productivity $a^*_{s,t}$ paths. MATLAB recovers the underlying technology shifter $A_{s,t}$ from free entry and solves the upper-tier demand system. Baseline sectoral prices are observed, so residual share error reflects the demand calibration rather than a price-fit residual.

D.2 Aggregate Markup

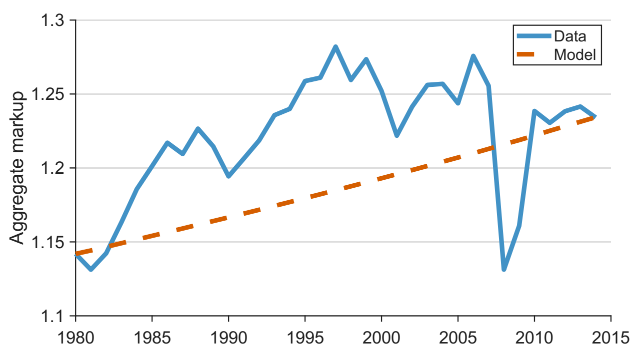


Figure D.1: Calibrated Aggregate Markup

Notes: The solid line plots the observed aggregate markup, using actual expenditure shares and actual sectoral markups. The dashed line plots the calibrated aggregate markup using calibrated expenditure shares and the smoothed sectoral markups implied by (32).

D.3 Real Consumption

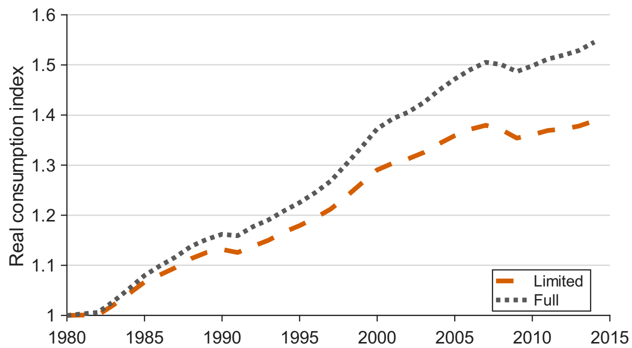


Figure D.2: Real Consumption Index

Notes: The figure plots aggregate real consumption under the limited pass-through baseline and the full pass-through counterfactual, normalized to one in 1980. Changes in aggregate real consumption generate the income-effect in the changing expenditure shares,

D.4 Sensitivity to K

Table D.2: Sensitivity to K

	2014 share gap (in pp)		
K	**Agriculture**	**Industry**	**Services**
-2.0	-0.050	-1.218	1.268
-1.0	-0.163	-1.955	2.118
0.0	-0.255	-2.667	2.921
1.0	-0.329	-3.352	3.681
2.0	-0.389	-4.013	4.402

Notes: full-pass-through counterfactual minus baseline expenditure share in 2014. K enters through the structural recovery of $A_{s,t}$ from $a^*_{s,t}$.

E Extensions

E.1 8-Sector Aggregation

Table E.1: Cross Sector Parameter Estimates: 8-Sector Aggregation

	(1)	(2)
η	0.11	0.51
	[-0.14,0.36]	[0.05,0.97]
Agriculture	-0.36	-0.13
	[-0.59,-0.13]	[-0.42,0.16]
Other Industry	-0.23	-0.27
	[-0.40,-0.05]	[-0.51,-0.03]
Trade	0.48	0.08
	[0.19,0.76]	[-0.24,0.40]
Transport	1.55	0.90
	[0.88,2.21]	[-0.11,1.91]
Finance	1.23	0.93
	[0.48,1.99]	[-0.49,2.36]
Business	0.57	0.31
	[0.13,1.01]	[-0.43,1.05]
Other Services	0.12	0.34
	[-0.47,0.71]	[-0.92,1.60]
Sector FE	N	N
Trade Controls	N	Y
Observations	336	336

Notes: The table reports non-linear GMM estimates of the differenced relative expenditure-share equation. Column (1) uses domestic expenditure shares and domestic implicit deflators only. Column (2) uses trade-inclusive expenditure shares and implicit deflators, i.e. imports are included in household expenditure and price measurement. The base sector is manufacturing, so $\epsilon_b = 1$ by normalisation; hence the reported sector coefficients are estimates of $\epsilon_s - 1$ relative to the base sector. Brackets report 95% confidence intervals. Observations are sector-year cells. Because the estimating equation is written in first differences, time-invariant sector fixed effects difference out mechanically; therefore no sector fixed effects are included.

Table E.2: Productivity and Pass-Through: 8-Sector Aggregation

Sector	**Cut-off** a^*	ρ_{1980}	ρ_{2014}
Agriculture	2.7%	90%	63%
Manufacturing	2.5%	87%	77%
Other Industry	1.1%	96%	87%
Trade	1.7%	90%	90%
Transport	2.0%	92%	85%
Finance	0.5%	88%	70%
Business	0.7%	85%	81%
Other Services	-0.4%	70%	74%

Notes: Productivity growth is the average annual log change of $a^*_{s,t}$, the productivity cut-off of producing firms, using the trade-inclusive specification. Cost-weighted markups imply $\kappa_{s,t} = 1/(\mu^c_{s,t} - 1)$. The baseline uses the smoothed kappa series.

E.2 PCE Price Data

Table E.3: Cut-off Growth: WIOD vs. PCE Prices

Sector	**WIOD**	**PCE**	**Difference**
Agriculture	2.67%	0.73%	-1.94pp
Industry	2.39%	2.61%	0.22pp
Services	0.62%	0.26%	-0.36pp

Notes: Values are average annual log changes, 1980–2014. Both columns are computed as $\Delta \log a^*_{s,t} = \Delta \log[(\kappa_{s,t}+1)/(\kappa_{s,t}+2)] - \Delta \log P_{s,t} + \Delta \log w_t$, using the identical smoothed $\kappa_{s,t}$ path and BLS COMPNFB wage series in both columns; only the price source $P_{s,t}$ differs. WIOD uses the trade-inclusive (baseline) specification. PCE maps Agriculture to PCE food, Services to PCE services, and Industry to PCE goods excluding food. Difference is PCE minus WIOD, in percentage points.