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Intangibles, Knowledge-Intensive Services and Labour Productivity Growth

A Sectoral Analysis of Sweden and Comparable European Economies, 1995-2021

By

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Keywords: Labour productivity; Intangible assets; Knowledge-intensive services; Structural change; Growth accounting; Shift-share analysis; Fixed-effects panel regression; EU KLEMS; INTANProd

Abstract: This thesis examines the coexistence of continued structural change toward more knowledge- and intangible-intensive economic activity with the simultaneous slowdown in labour productivity growth across advanced European economies since the early 2000s. Using Sweden and four comparable European economies over 1995-2021, the thesis investigates three sectoral mechanisms linking the knowledge-economy transition to labour productivity growth, namely within-sector intangible deepening, structural reallocation toward knowledge-intensive services, and the timing of intangible investment effects. Using the EU KLEMS and INTANProd 2025 database, the analysis combines growth-accounting decomposition, shift-share analysis and panel regression methods. The findings show that all three mechanisms are identifiable and largely operate in the predicted direction, but unevenly and at magnitudes insufficient to generate correspondingly strong aggregate productivity growth. The findings, therefore, refine rather than reject the knowledge-economy narrative, pointing toward a conditional reading in which structural depth supports productivity growth without being equivalent to it, and shifting emphasis from the presence of knowledge-economy assets toward their productivity consequences.

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List of Abbreviations

CHS - Corrado, Hulten and Sichel
EU - European Union
EU KLEMS - European Union KLEMS (Capital, Labour, Energy, Materials, Services)
FE - Fixed Effects
GDP - Gross Domestic Product
GFC - Global Financial Crisis
GVA - Gross Value Added
GVCs - Global Value Chains
ICT - Information and Communication Technology
INTANProd - Intangibles and Productivity database
KIBS - Knowledge-Intensive Business Services
KIS - Knowledge-Intensive Services
LP - Labour Productivity
MARKT - Market Economy (sectoral aggregate)
NA - National Accounts
NACE - Nomenclature of Economic Activities (statistical classification)
OECD - Organisation for Economic Co-operation and Development
R&D - Research and Development
TFP - Total Factor Productivity

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1. Introduction

For much of the past three decades, the prevailing account of where growth in advanced economies would come from appeared largely settled. As traditional manufacturing receded, the productive core of these economies moved toward knowledge-intensive activities and the intangible assets that underpin them, with this shift most visible in the rise of knowledge-intensive services (KIS). Investment, policy and academic attention followed accordingly, and innovation and knowledge came to be treated as the foundations of long-run competitiveness.

This conviction is reflected in the institutional record. The Lisbon Strategy staked European competitiveness on becoming the world's leading knowledge-based economy (European Council, 2000). Europe 2020 placed innovation, digitalisation and smart growth at the centre of the Union's economic agenda (European Commission, 2010). The Draghi Report, more recently, argues that Europe's widening productivity gap with the United States reflects precisely the failure to invest enough in these areas (European Commission, 2024a, 2024b). Sweden's Productivity Commission frames the country's economic future in similar terms, emphasising digitalisation, intangible capital and knowledge-intensive activity as the conditions for sustained productivity performance (Produktivitetskommissionen, 2024; 2025). The underlying expectation has been straightforward. Economies that invest more in knowledge, employ more skilled workers and concentrate activity in the most innovation-intensive sectors should, over time, also grow more productive.

The aggregate productivity record has not lived up to these expectations. Labour productivity (LP) growth has slowed across advanced economies since the early 2000s, exacerbated further by the global financial crisis (GFC) of 2008, and recovered unevenly across countries, without returning to the pre-crisis level. Meanwhile, the structural shift toward knowledge-intensive activity has continued, with intangible investment rising further and KIS expanding. This coexistence has created a tension between the continued expansion of knowledge-intensive and intangible-based activity on the one hand, and comparatively weak aggregate productivity outcomes on the other.

Sweden provides one of the clearest settings in which to examine these dynamics. On most indicators associated with the knowledge economy, it sits at, or near, the top of Europe, with the highest intangible investment intensity in the European Union, the largest KIS employment share outside Luxembourg, and the top overall position on the European Innovation Scoreboard. Yet Swedish LP growth has followed the same broad pattern as the rest of advanced Europe, with the same slowdown after the early 2000s and the same incomplete recovery after 2008. The combination of pronounced structural conditions and a typical productivity trajectory makes Sweden a particularly informative case for this kind of investigation.

The relevant question is therefore no longer whether advanced economies have become more knowledge-intensive, as they clearly have. The question is whether the mechanisms through which this structural shift was expected to translate into productivity growth are visible in the data, and at what magnitude. Answering it matters beyond the immediate empirical record. European competitiveness strategies, national productivity commissions and forward-looking debates about the future of the knowledge economy, including artificial intelligence and value-chain reorganisation, all rest on a particular reading of what this transition delivers in productivity terms. Whether that reading holds against the evidence is part of what is at stake in examining the mechanisms directly, and it is the starting point this thesis takes.

1.1 Aim, Scope and Approach

This thesis evaluates three theoretically distinct mechanisms through which intangible-intensive and knowledge-intensive structural change is expected to affect LP. The first is within-sector intangible capital deepening, the productivity contribution of intangible investment within the sectors where it occurs. The second is structural reallocation, the aggregate productivity consequence of labour shifting between sectors of different productivity, particularly toward KIS. The third is the systematic relationship between intangible investment intensity and subsequent LP growth, including whether this relationship appears contemporaneously or with a lag.

The analysis operates at the sector level using the EU KLEMS and INTANProd 2025 dataset, with Sweden as the primary case and Denmark, Finland, the Netherlands and Germany as structurally comparable economies over 1995-2021. Three empirical components are employed.

A growth accounting decomposition addresses the within-sector mechanism, a shift-share analysis addresses the reallocation mechanism, and a panel regression addresses the intensity-and-timing mechanism. KIS is the focal sectoral setting of the thesis, as the largest market-economy sector grouping carrying the structural shift toward knowledge-intensive activity, combining significant intangible-investment intensity with the share of activity that matters for aggregate productivity dynamics.

The contribution is integrative rather than mechanism-discovering. The thesis does not aim to identify a new driver of productivity growth, establish causal effects, or resolve the productivity slowdown. Each of the three mechanisms examined here has been studied in prior work, typically in isolation. What this thesis adds is a joint and internally consistent evaluation of how these mechanisms compare in magnitude, consistency and timing within a common dataset, sector classification, and empirical framework, which has not previously been done for Sweden and structurally similar European economies. Read together, the three mechanisms generate a more complete picture of how the knowledge-economy transition translates into productivity than any one of them produces in isolation, with implications for the Swedish sectoral story, for the treatment of the capital boundary, and for the timing horizon over which the intangibles-productivity relationship is observed.

1.2 Research Questions

Main research question:
Are the sectoral mechanisms through which intangible investment and knowledge-intensive activity are expected to support labour productivity growth observable in the data for Sweden and structurally similar European economies over 1995-2021, and at what magnitude?

Sub-question:
How do these mechanisms appear across within-sector intangible deepening, structural reallocation toward knowledge-intensive services, and the timing of intangible investment effects?

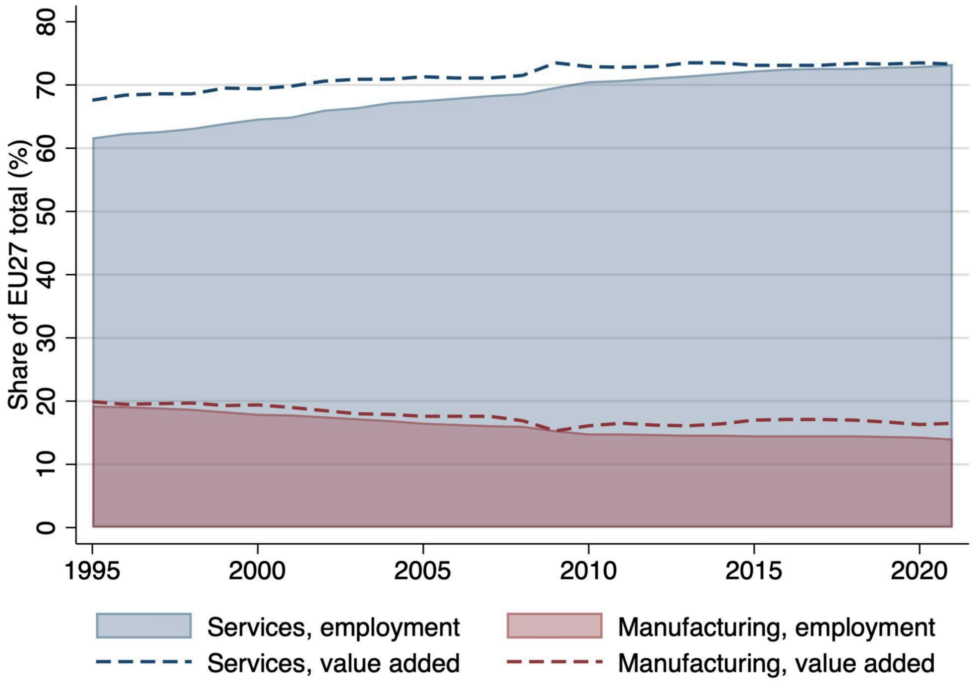
2. Background & Context

This chapter develops the empirical and structural context for the productivity puzzle outlined in the introduction. It traces the rise of KIS and intangible investment across advanced European economies, situates Sweden within this transition, examines the main drivers behind these changes, and outlines the post-2000 productivity slowdown underlying the empirical analysis.

2.1 The Rise of the Knowledge-Intensive Economy

The structural transformation of advanced economies toward more knowledge-intensive forms of production has been one of the major economic developments of the late twentieth and early twenty-first centuries. The decline of the traditional manufacturing base for both employment and output, alongside the expansion of the service sector to take its place (O'Mahony & Timmer, 2009; van Neuss, 2018), predates the period examined in this thesis, but the same pattern remained visible throughout 2021. In the EU27, manufacturing's share of total employment fell from 19.3% in 1995 to 14.1% in 2021, while broad service-sector activities increased from 60.8% to 72.2%. The same pattern is visible in value-added shares, with manufacturing falling from 19.9% to 16.5% and services rising from 67.6% to 73.3% over the same period (see Figure 1). This shift has partly materialised through the growing importance of activities described in the literature as knowledge-intensive, with KIS forming a central component of this transition (Powell & Snellman, 2004). While definitions for KIS vary somewhat across studies and statistical frameworks, these activities are generally organised around the production, application and exchange of knowledge rather than routine labour inputs (Castells, 2010, p.77), and are supported by digital technologies, highly skilled labour, innovation and intangible assets (Dugo et al. 2025; Miles, 2005; Muller & Doloreux, 2009). KIS commonly include activities such as ICT services, finance, professional and technical services, research and engineering, with parts of this literature also discussed under the related concept of knowledge-intensive business services (KIBS), particularly in firm- and innovation-oriented studies. The exact classification for KIS is outlined in Section 5.3.2. Together, these features make KIS the empirical setting where the knowledge-economy transition is most visible in scale terms, and why KIS serves as the focal sectoral lens throughout this thesis.

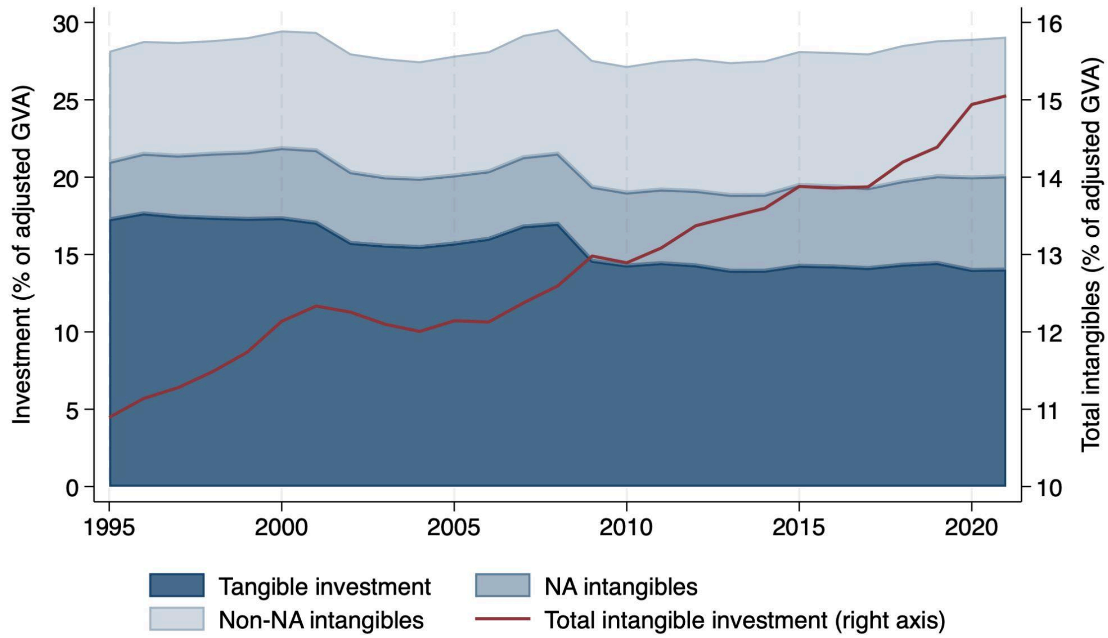
Figure 1. Manufacturing and services shares of employment and value added in the EU27, 1995-2021



Source: Eurostat (2026a), author's calculations.

Expanding on one of the aforementioned supporting pillars of KIS and the knowledge economy in general, intangible assets refer to non-physical, knowledge-based resources that firms accumulate and deploy in production, including software and databases, research and development, design, branding, training and organisational capital (Corrado et al. 2005; 2009; 2022). Investment in these assets has grown significantly over recent decades with the move toward knowledge-intensive activity, where firms no longer only accumulate productive capacity through machinery, buildings and equipment, but also through these intangible forms of capital. Across many advanced economies, this compositional shift has been large enough that intangible investment now exceeds tangible investment as a share of adjusted gross value added (GVA) (Figure 2). The rise of intangible investment is closely connected to the expansion of KIS, with a substantial share of intangible investment concentrated in precisely the sectors where KIS have grown most rapidly (Miles, 2005). The two thus reflect different dimensions of the same larger structural transformation.

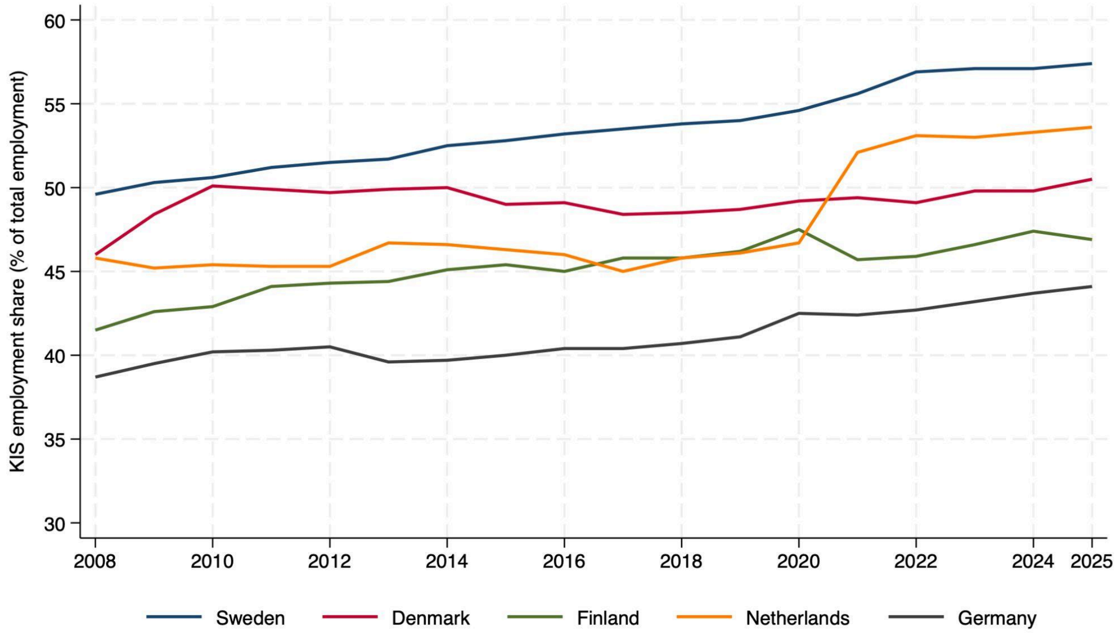
Figure 2. Investment composition in the EU27, 1995-2021



Note: EU27 aggregate based on the 19 EU member states with available data in EU KLEMS & INTANProd 2025, namely Austria, Bulgaria, Czechia, Denmark, Finland, France, Germany, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden. Portugal is covered only from 2010 onwards. Values expressed as shares of adjusted GVA for the market economy aggregate.
Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations.

These broad EU27 patterns are mirrored across the five economies examined in this thesis. The KIS share of total employment has continued to expand throughout the available period in all five countries, with Sweden leading the panel and the other economies on similarly upward trajectories (Figure 3). Real GDP per capita grew across all five economies and the EU27 over the same period (Eurostat, 2026d), though with the post-2008 slowdown discussed in Section 2.4.

Figure 3. KIS employment share, 2008-2025

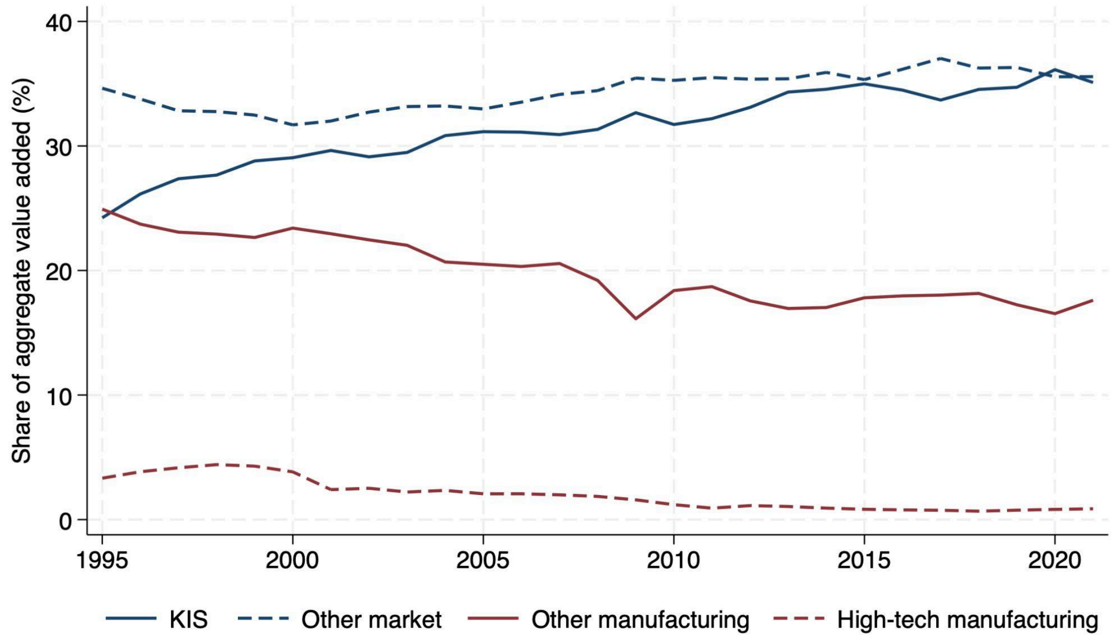


Note: KIS measured on Eurostat's broad knowledge-intensive services classification, consistent with Table 1. Includes both market and non-market knowledge-intensive activities such as health, education and public administration. The narrower market-economy KIS scope used in the empirical chapters is documented in Section 5.3.2.
Source: Eurostat (2026b), author's calculations.

2.2 Sweden at the Frontier of the Knowledge-intensive Economy

Sweden represents one of, if not the clearest, examples of the structural and investment-side shifts described in the previous section. By 2021, the endpoint of the analytical period of this thesis, KIS accounted for 35% of Swedish market-sector value added, nearly twice the combined contribution of manufacturing and roughly equal in size to the residual category of other market activities. KIS therefore stands as the largest coherent sector grouping in the Swedish market economy, contributing more to value creation than the entire industrial base.

Figure 4. Sector shares of Swedish market-sector value added, 1995-2021



Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations.

Sweden's position as a leading knowledge-intensive economy is further reflected in its engagement with international markets. While trade in goods has largely stagnated relative to GDP since the GFC, trade in services has continued to expand substantially, with service exports and imports together corresponding to roughly one-fifth of Swedish GDP by 2024 (Camacho et al. 2025). KIBS, in particular, accounted for roughly a quarter of Swedish GDP growth between 2010 and 2022 despite representing only around 12% of GDP (Jagrén, 2024). Much of this activity is concentrated in technologically intensive multinational firms and headquarters functions linked to software, engineering, branding, R&D and other intangible assets (Camacho et al. 2025). Within the Swedish economy, firms strongly tied to these kinds of knowledge-intensive activities are concentrated primarily in KIS industries (Andersson et al. 2019). Recent analyses further emphasise the growing importance of digital services, business services and increasingly service-intensive manufacturing business models organised around intellectual property and multinational production networks (Business Sweden, 2025a; 2025b).

These structural characteristics are also reflected in a range of comparative indicators associated with the knowledge economy. As shown in Table 1, KIS accounted for 57.4% of total Swedish employment in 2025, the highest share in the European Union outside Luxembourg, whose specialised cross-border financial structure makes direct comparison with larger European economies difficult. Intangible investment intensity averaged 17.2% of adjusted GVA between 1995 and 2021, the highest in the European Union and ahead of France, the UK, the US, and Japan. Sweden also ranks first overall on the European Innovation Scoreboard, with consistently strong performance across R&D, digitalisation, human capital and innovation capacity (European Commission, 2025). Sweden is examined throughout the thesis alongside a small group of structurally comparable Northern European economies, with the rationale for this comparative framework outlined in Section 5.2.

2.3 Drivers of the Knowledge-intensive Transition

The rise of the knowledge-intensive economy did not proceed uniformly across countries. It reflected several structural drivers, whose uneven strength helps explain why knowledge-intensive sectors became larger in some economies than in others. The most direct driver was technological change, particularly the expansion of information and communication technologies (ICTs) from the 1980s onward (Castells, 2010, pp. 95-97). ICT lowered the cost of coordinating economic activity across firms, sectors and borders, making specialised information-based services viable on a larger scale (Castells, 2010, pp. 185-187). Software, data processing, telecommunications and IT services emerged as substantial sectors in their own right, while existing professional services were reshaped by the same technologies.

A second driver is the outsourcing of activities previously carried out within manufacturing and other industries. As firms increasingly concentrated on core production, support functions such as IT, design, legal services, accounting, marketing, research and engineering were spun out into independent service providers. This dynamic is central to the rise of KIBS as a distinct sub-category of KIS (Miles, 2005; Muller & Doloreux, 2009). Part of the measured growth in KIS employment, therefore, reflects activities previously performed inside manufacturing firms being reorganised as external service-sector activity (Berlingieri, 2013). Beyond outsourcing, servicification has blurred the manufacturing-services boundary from within, with manufacturing firms increasingly using, producing and selling services alongside their core goods (Lodefalk, 2014; Crozet & Milet, 2017). The headline manufacturing-to-services shift, therefore, partly understates how integrated manufacturing and KIS remain in practice.

A third driver is the geographic fragmentation of production through global value chains (GVCs). ICT advances made it easier to coordinate production across countries, allowing more standardised manufacturing activities to be relocated to lower-cost economies (Baldwin, 2016, pp. 83-85, 109-110). Baldwin and Ito (2022) describe the resulting pattern as a "smile curve of value creation", where pre- and post-fabrication stages of the value chain, such as research, design, branding, and after-sales services, now account for a larger share of value added than fabrication itself. Advanced economies have increasingly specialised in these stages, many of which are KIS, reinforcing the domestic shift toward KIS employment and value added. Cross-country differences in the scale of this shift may therefore partly reflect variation in technological capabilities, organisational structures, skill formation and internationalisation processes (Miles, 2005).

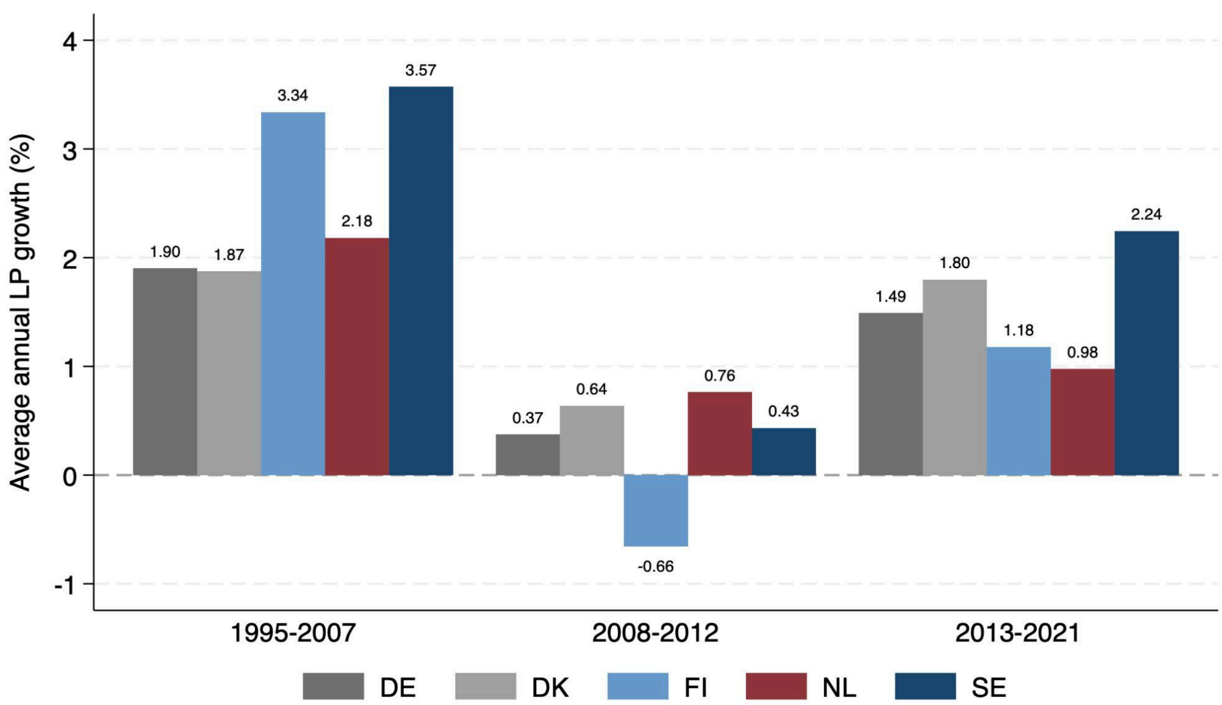
2.4 Productivity Growth and the Post-2000 Slowdown

The slowdown described in the introduction has a specific shape that matters for the analysis. After relatively strong growth in the late 1990s, particularly in economies with substantial ICT-producing and ICT-using sectors (Stiroh, 2002; Timmer et al. 2011), aggregate productivity growth in advanced economies began to fade from the early 2000s onward, and the European productivity gap relative to the United States, which had narrowed substantially in the post-war decades, got wider again (Bergeaud et al. 2016; van Ark, 2014).

The GFC made these trends worse. Output collapsed across the OECD, business investment fell, and LP growth slowed further (van Ark and Jäger, 2017). The investment response varied across asset types, with tangible investment falling harder and recovering more slowly than intangible investment (Corrado et al. 2022). The recovery that followed has been incomplete in productivity terms across much of advanced Europe, with output returning to, and eventually surpassing, pre-crisis levels, but the underlying rate of productivity growth has settled effectively below the pre-crisis trend (van Ark & Jäger, 2017). This persistence of weak productivity growth despite continued digitalisation and rising intangible investment has shifted attention toward diffusion lags, complementarities and delayed productivity transmission (Goldin et al. 2024).

The panel follows the same pattern, as Figure 5 shows. Sweden's average annual market-economy LP growth fell from 3.6% in 1995-2007 to 0.4% in 2008-2012, before recovering partially to 2.2% in 2013-2021. The other countries show the same sequence of strong pre-crisis growth, crisis collapse and incomplete recovery, although with smaller magnitudes. This forms the empirical baseline for the mechanism analyses that follow, with knowledge-intensive activity and intangible investment continuing to expand, while productivity growth has weakened across the same economies and period.

Figure 5. Market-sector LP growth by sub-period



Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations.

3. Theoretical Framework

The theoretical reasons to expect the knowledge-intensive and intangible-intensive transition to generate productivity growth can be found in different strands of the productivity literature. This thesis adopts a framework that brings together the three channels introduced in Section 1.1. Each generates a prediction about what should be observable in the data if the transition is doing the productive work the broader narrative expects of it, and these predictions form the baseline against which the empirical results are evaluated. But to understand how the transition can translate into productivity, the concept of productivity itself must first be understood.

3.1 Labour Productivity

Long-run economic development has historically been understood as closely tied to improvements in productive efficiency. As Krugman (1997, p.11) famously said, “productivity isn’t everything, but in the long run almost everything”. In the neoclassical growth tradition associated with Robert Solow (1956, 1957), long-run economic growth ultimately depends on how efficiently labour and capital are translated into output over time, forming the basis of sustained increases in income and living standards. While this productive capacity can be measured in several ways, LP remains the central measure, capturing the average economic value produced per hour worked (OECD, 2001; Syverson, 2011). In this thesis, LP is measured as real GVA per hour worked, where GVA is the value created by production after accounting for intermediate inputs and is distributed as factor income to both labour and capital (OECD, 2001). LP is therefore the dependent variable in the empirical work that follows, and the question of whether the knowledge-intensive transition has translated into productivity growth is, operationally, a question about LP growth.

3.2 Within-Sector Productivity Growth and Intangible Capital

LP growth across an economy depends, in significant part, on sectors becoming more productive over time. But how a sector becomes more productive can vary considerably. Two sectors can exhibit similar LP growth while relying on different underlying drivers, such as more capital per worker, a more skilled workforce, or other efficiency gains that cannot be attributed to any specific input. Therefore, understanding what produces within-sector LP growth requires separating it into its underlying sources.

The standard framework for distinguishing between these contributions is the growth accounting tradition developed from Solow (1957) and later extended through the detailed input measurement framework of Jorgenson and Griliches (1967) and the industry-level productivity accounting approaches of Jorgenson, Ho and Stiroh (2008). The underlying logic is that if you know how much of each input a sector used and what share of output each input was compensated for, you can attribute observed productivity growth arithmetically to each source. In simplified form, LP growth can be expressed as follows (Bontadini et al. 2023a; Crafts & Woltjer, 2021):

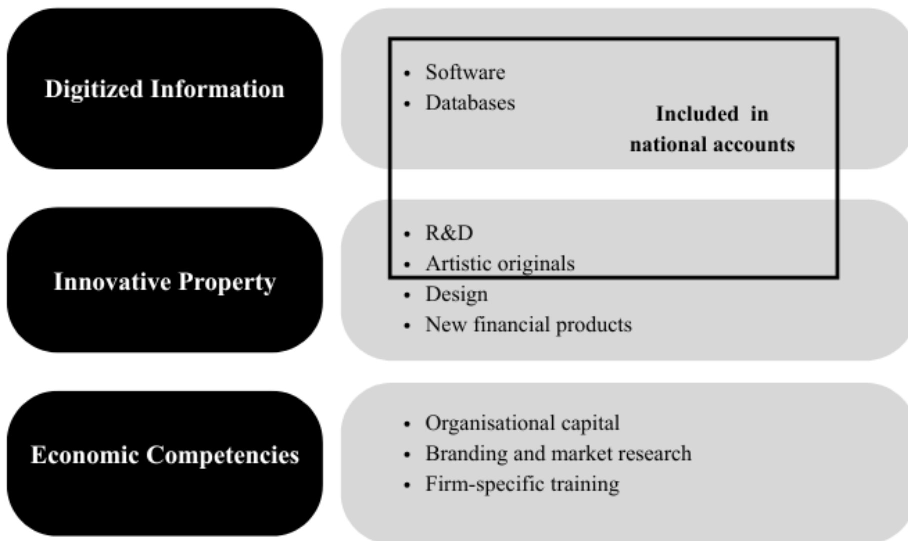
$$\Delta \ln LP = sK \cdot \Delta \ln K + sLC \cdot \Delta \ln LC + \Delta \ln TFP$$

where LP growth reflects contributions from capital deepening ($sK \cdot \Delta \ln K$), labour composition ($sLC \cdot \Delta \ln LC$), and total factor productivity ($\Delta \ln TFP$). The s terms are the income shares of capital and labour, which weight each input by how much it is compensated. Capital deepening reflects increases in productive capital services per hour worked, while labour composition reflects improvements in workforce quality through changes in education, skills, or experience. TFP is the residual component of the growth-accounting decomposition, capturing the portion of LP growth that remains after accounting for the measured contributions of capital services and labour composition.

In practice, however, TFP is not a clean measure of technology or efficiency alone. Because it is calculated residually, it also reflects factors not directly captured by measured inputs, including organisational improvements, spillovers, utilisation effects, measurement error, and omitted inputs (Syverson, 2011; Van Beveren, 2012). The interpretation of TFP, therefore, depends on how comprehensively the measured-input side captures the productive resources actually used. In knowledge-intensive economies, where an increasing share of productive investment takes forms that traditional accounting does not recognise as capital, this dependence becomes a significant theoretical issue rather than a residual technicality.

The theoretical response to this question came from Corrado, Hulten, and Sichel (CHS) (2005, 2009), who proposed expanding the capital boundary itself on theoretical grounds rather than as a measurement fix. Their core argument, grounded in intertemporal capital theory, is that any expenditure that reduces current consumption in order to raise future output should qualify as investment, regardless of whether it takes a physical or knowledge-based form. Software, R&D, organisational practices, branding, design, and firm-specific training all meet this criterion. The CHS framework groups these assets into three broad categories as outlined in Figure 6.

Figure 6. Intangible capital: broad categories and types of investment



Notes: Box indicates intangible assets currently included within standard national accounts boundaries. Adapted from Corrado et al. (2022) and Bontadini et al. (2023a).

National accounting (NA) systems have since partially incorporated this expanded capital logic, as software and R&D are now treated as capital formation in most advanced economies (Bontadini et al. 2023a). This is a significant step, but it only captures a part of the CHS framework. Organisational capital, firm-specific training, branding, design and related "economic competency" assets remain largely outside the official boundary, despite representing the largest category of intangible investment in the CHS framework (Corrado et al. 2005; 2009). Their estimates suggest that excluding these assets materially understates both output and productivity growth, with the inclusion of broader intangible capital increasing measured U.S. LP growth by roughly 10-20% relative to conventional accounting measures (Corrado et al. 2009). This means that a substantial share of the productive investment most relevant to knowledge-intensive economies is still absent from standard productivity accounts, and, where it is present, its contribution appears instead in the TFP residual rather than in measured capital deepening. The CHS framework, therefore, makes a theoretical case for treating the capital boundary itself as a variable in productivity analysis, since the measured productivity record of a knowledge-intensive economy will depend in part on how comprehensively intangibles are capitalised.

Taken together, this provides the theoretical basis for examining within-sector productivity growth in knowledge-intensive economies through the components that constitute LP growth, with an extended capital boundary that gives a more complete picture of the knowledge economy.

3.3 Structural Reallocation and Knowledge-Intensive Services

As the previous section explained, productivity growth depends on how efficiently production is organised within sectors. But this is only one part of the picture, as what activities an economy actually carries out, and how labour is distributed across sectors with different productive characteristics, matters in its own right. The same workforce, deployed across a different mix of sectors, produces a different aggregate output. This is the between-effect, and the idea that the composition of activities shapes aggregate productivity is foundational to the structural-change tradition in growth economics associated with Kuznets (1973), Kaldor (1966), and Baumol (1967), and was later formalised through work on structural reallocation and multi-sector productivity dynamics (Herrendorf et al. 2014; McMillan & Rodrik, 2011).

The proposition rests on a simple observation about heterogeneity. Sectors differ systematically in output per hour worked, in their capacity for capital deepening, in their exposure to international competition, and in the intangible and knowledge-based inputs they rely on. These differences reflect the underlying nature of what sectors produce and how production is organised within them. Aggregate productivity is therefore partly shaped by how labour is distributed across activities with different productive characteristics, and the direction of this distribution over time becomes an empirical question with theoretical content.

In its classical form, this tradition predicted that the shift from manufacturing toward services would slow aggregate productivity growth, since services were assumed to have lower scope for productivity gains than goods production, a phenomenon known as Baumol's cost disease

(Baumol, 1967). The expansion of KIS has led to revisions of this prediction. Unlike many traditional service activities, certain KIS sectors exhibit relatively strong productivity performance alongside high ICT- and skill-intensity, which raises the possibility that reallocation toward KIS in advanced economies is a productivity-enhancing rather than a productivity-dampening structural shift (Inklaar et al. 2008; Jorgenson & Timmer, 2011; Triplett & Bosworth, 2003).

In the contemporary advanced-economy setting, structural change increasingly takes the form of expansion into KIS rather than the older shift from agriculture to manufacturing or from manufacturing to general services. In a knowledge-intensive economy, the structural-change tradition therefore generates a specific prediction. If KIS sectors have higher productivity levels than the sectors they have grown alongside or replaced, and if labour has been moving into them in significant numbers, then this reallocation should be visible in aggregate productivity growth as a positive between-sector contribution. Whether the prediction holds depends on how the productivity levels of expanding and contracting sectors compare, and on the magnitude of labour reallocation between them. This is the theoretical basis for examining structural reallocation to KIS as a component of aggregate LP growth.

3.4 Intangible Investment and the Timing of Productivity Growth

The within-sector channel developed in Section 3.2 treats intangible capital as a contribution to LP growth at the accounting level. A separate theoretical claim follows from the same CHS framework. If intangibles function as productive capital, then the relationship between intangible investment intensity and LP growth should be systematically observable across sectors and economies, rather than merely an aggregate contribution within a single decomposition. Sectors that invest more heavily in intangible assets should, conditional on other determinants, exhibit stronger LP growth than sectors that invest less. This is a stronger claim than the decomposition exercise can deliver, because it asks whether the relationship holds as a regularity in the data rather than as a contribution to a particular aggregate.

However, the form that this relationship takes has a specific feature that distinguishes it from the equivalent relationship for tangible capital. Tangible capital generates productivity gains through a relatively immediate mechanism. A new machine installed in a factory is productive once it is operating, and its contribution to output can be measured year by year. Intangible capital is different. Software adoption typically requires process redesign and complementary organisational change. R&D investment generates productivity gains only when the resulting knowledge is integrated into production. Investments in branding, design, and training raise productivity through changes in how production is organised, not by being directly substituted into the production process. These complementarities mean that intangible investment often has to be matched by other adjustments in organisational practices and production processes before measurable productivity gains become visible in the data (Bresnahan et al. 2002; Brynjolfsson & Hitt, 2003; Corrado et al. 2022).

Brynjolfsson et al. (2021) formalise this as a J-curve dynamic. During the adjustment phase, firms absorb the costs of intangible investment without yet reaping the corresponding gains, and measured productivity may appear weak or even temporarily decline. Once complementary investments are in place, the productivity payoff becomes clearer, and the cumulative relationship between intangible investment and productivity turns positive. The theoretical implication is that the productivity contribution of intangibles is not only present but conditional on the time horizon over which it is examined. A simple contemporaneous relationship between intangible investment intensity and productivity growth may be weak or absent, while a lagged relationship over one or more years should be stronger and more clearly positive.

Together, this framework generates a specific theoretical prediction. If intangibles function as productive capital, intangible investment intensity should be positively associated with subsequent LP growth, conditional on other determinants of within-sector productivity. Given the adjustment dynamics described above, this relationship should be most visible at one- to several-year horizons rather than contemporaneously. This is the theoretical basis for examining the systematic relationship between intangible investment intensity and LP growth across sectors and economies.

4. Empirical Evidence

4.1 Intangible Capital and Within-Sector Productivity Growth

There is a considerable body of empirical literature on intangibles and within-sector LP growth, in which studies covering different countries, time periods, and asset definitions generally agree on a positive association (Adarov & Stehrer, 2019; Bontadini et al. 2024; Chen et al. 2016; Corrado et al. 2017; Hintzmann et al. 2021; Niebel et al. 2017; Roth, 2024). What the literature is less unified on is most of what is past that, including the size of the effect, which intangibles do the work, whether the within-sector contribution shows up in aggregate productivity, and how much of the picture changes once measurement and diffusion are considered.

Sectoral estimates report intangibles contributing on average 0.1 to 0.6 percentage points to annual LP growth across one-digit NACE sectors in EU10 economies (Niebel et al. 2017), with the highest contributions in manufacturing and finance. Aggregate studies frame this differently, with Corrado et al. (2016) reporting that widening the asset boundary shifts the EU tangible-intangible split within capital deepening from 80/20 to 60/40 over 2000-2013, and Roth (2024) estimating roughly 40% of LP growth for an EU-10 sample over 1995-2018. Bontadini et al. (2024) find that using the full CHS framework raises 2019 LP by 7.6% in the EU27 and 9.6% in the Nordic group, with the broader boundary lowering average measured TFP growth by 0.27 percentage points per year, closely tracking the original Corrado et al. (2009) estimate. The aggregate-versus-sectoral gap is disputed, with some attributing it to spillovers and complementarities operating beyond sector boundaries (Corrado et al. 2017; Niebel et al. 2017), while others find the opposite or weak coefficients altogether (Adarov & Stehrer, 2019; Roth, 2024).

Regarding which intangibles matter most, some recent sectoral studies place greater weight on the broader CHS boundary, and on economic competencies in particular (Hintzmann et al. 2021; Roth, 2024). Roth and Mitra (2025) show that goods-producing sectors rely more heavily on R&D and non-ICT tangibles, while services depend more on non-R&D intangibles such as software, training and organisational capital, with Roth et al. (2023) reaching the same conclusion using German firm-level data. Corrado et al. (2017) and Chen et al. (2016) further argue that these broader intangible assets appear especially productive in ICT-intensive sectors.

Swedish and Nordic evidence points in the same direction. Edquist (2011a) finds that intangible capital accounted for almost 35% of Swedish business-sector LP growth over 1995-2004, and Edquist (2011b) shows intangible investment intensity to be higher in manufacturing than in services, reaching around 25% of manufacturing value added against 11% in services. Edquist and Henrekson (2017a) reinforce this with ICT capital and R&D contributions to Swedish business sector growth. More recent applications of the Bontadini-style decomposition for Sweden (Lappi et al. 2024; Mattsson, 2021) show the growing importance of intangible relative to tangible capital in Swedish business-sector LP growth, with the intangible contribution overtaking the tangible one around the post-crisis period in Sweden and across most compared advanced economies. Bloch et al. (2023) find that the productivity effects of intangible assets in Denmark and Finland actually strengthened somewhat after the financial crisis, despite weaker intangible investment growth, particularly in Finland.

A more fundamental disagreement is over whether any of these within-sector gains translate into aggregate productivity growth. Goodridge et al. (2013) estimate intangibles account for around five percentage points of the UK's 16% post-crisis productivity shortfall, through understated value added and lagged TFP spillovers from earlier intangible investment. Goodridge and Haskel (2023) extend this to 2019 and find the slowdown concentrated in the most intangible, knowledge- and digitally intensive industries, yet attribute 78% of it to slower TFP growth and only 10% to slower intangible capital deepening. This places them alongside Fernald (2024) and Nikolov et al. (2026) in a strand reading the puzzle as fundamentally a TFP story, where capitalising intangibles sharpens the accounting without resolving the underlying slowdown. Van Ark et al. (2024) sit somewhere in between, finding that intangible capital deepening still contributes positively but not strongly enough to offset the post-crisis collapse in tangible investment and productivity. Andrews et al. (2015; 2016), Corrado et al. (2021) and Le Mouel and Schiersch (2024) add a final nuance, in that productivity dispersion has been bigger in intangible-intensive industries, with frontier firms pulling further ahead of laggards. This suggests that strong intangible accumulation and productivity gains within leading firms or sectors can coexist with weak aggregate productivity growth, when diffusion across firms remains uneven.

4.2 Structural Change, KIS and Reallocation

Empirical work on structural change generally finds modest between-sector contributions relative to within-sector growth, with labour reallocation sometimes generating small positive effects and sometimes slightly negative ones as employment shifts toward services (Bauer et al. 2020; Duernecker & Sánchez-Martínez, 2023; Kuusk et al. 2017; Maroto-Sánchez & Cuadrado-Roura, 2009; Peneder, 2003). Duernecker and Sánchez-Martínez (2023) provide one of the most direct estimates for the thesis country group, finding that structural change reduced average annual aggregate LP growth in the EU14 by approximately 0.4 percentage points over 1970-2017, with the Sweden-specific effect smaller at around -0.2 percentage points and a similar Swedish magnitude in the JRC report by Bauer et al. (2020). Both studies emphasise that negative effects come from stagnant service subsectors rather than from services as a whole, echoing Peneder's (2003) observation that aggregate service effects conceal differences within the sector itself.

A strand of literature focuses on exactly these differences within services. Triplett and Bosworth (2003) and Jorgenson and Timmer (2011) document heterogeneity in productivity levels and growth across different service activities, particularly during the ICT period, implying that treating services as a single category distorts the underlying reallocation picture (Duernecker et al. 2024; Sen, 2024). Bacovic et al. (2022) link this heterogeneity explicitly to KIS in a European panel for 1995-2019. They find KIS labour productivity roughly 15% above other services but around 25% below industry, with KIS productivity growing at 1.1% annually against 2.9% in industry. Over the same period, the KIS employment share rose from 9.4% to 16.1%. The implication is that KIS expansion is not mechanically productivity-enhancing, since it raises aggregate productivity when labour moves into KIS from lower-productivity services, but can weaken the between-effect when labour instead moves out of higher-productivity industry.

For Sweden, Bauer et al. (2020) offer the best sector-level evidence, where the impact of structural change on Swedish LP growth has been "overall rather subdued” (p.212). The slow-growth expanding branches are accommodation and food services, and non-market services, rather than KIS, with ICT, financial activities, and other knowledge-intensive sectors growing at relatively strong productivity rates. This is consistent with broader Swedish work emphasising the post-1990s shift toward knowledge-intensive activity (Edquist, 2011a; Heyman et al. 2019) and indicates that the productivity-suppressing branches in the Swedish case are not the sectors most central to the KIS reallocation mechanism outlined in Section 3.3.

Higher KIS productivity does not automatically translate into positive aggregate between-effects, however. Studies argue that the productivity contribution of KIS depends on how effectively these activities connect to the wider economy through spillovers and inter-sectoral linkages, rather than on service expansion itself (Peneder et al. 2003; Windrum & Tomlinson, 1999). Sorbe et al. (2018) find that reallocation efficiency is weaker in services than in manufacturing and not significantly stronger in KIS than in less knowledge-intensive services, citing regulatory frictions such as occupational licensing. They also document continued geographic concentration of KIS, with some activities still relying on face-to-face interaction for effective knowledge transmission, a pattern visible in Sweden, where around 45% of high-tech manufacturing and KIS employment is concentrated in the Stockholm region (André and Pak, 2021). This can imply that even where KIS reallocation is productivity-enhancing, the aggregate contribution can be modest if the linkages that would amplify it are constrained. In cross-country terms, Inklaar et al. (2008) find that differences in aggregate productivity growth after the mid-1990s were primarily driven by differences in market services performance, with market-services contributions substantial in Finland and the Netherlands and close to zero in Germany, though their sample excludes Sweden.

The literature presents a more refined view of structural change in advanced economies than the traditional Baumol framework suggests. Aggregate between-sector effects seem modest relative to within-sector productivity growth, while the composition of service-sector expansion appears to matter considerably. Reallocation toward KIS may therefore differ from reallocation toward services more broadly, while recent work suggests that sector-level decompositions might also understate the extent of structural reallocation occurring within firms themselves (Ding et al. 2022). No published study, as far as the literature reviewed here indicates, isolates a KIS-specific between-sector term for Sweden or the standard advanced-European comparison group using a McMillan-Rodrik for the Eurostat KIS taxonomy.

4.3 Timing, Complementarities and the Productivity J-Curve

Consistent with the within-sector decomposition evidence reviewed in Section 4.1, the systematic regression evidence covered in this section also generally finds a positive relationship between intangible investment and LP growth across sectors and over time, with certain caveats. Niebel et al. (2017) estimate sectoral intangible output elasticities in the 0.10 to 0.18 range and find consistently positive relationships across specifications. Cross-country and EU panel studies find similar positive and statistically significant productivity effects, while also highlighting variation across sectors and intangible asset types (Roth & Thum, 2013; Roth & Mitra, 2025; Piekkola, 2018). Cette et al. (2024) and Castelli et al. (2024) build upon this to show that absorptive capacity, organisational quality, workforce composition and institutional conditions shape how effectively intangible investment translates into productivity gains, while Corrado et al. (2017) and Bontadini et al. (2023b) find that the relationship is strongest in highly digitalised industries where ICT, organisational capital and other intangibles act as complements.

The relationship, however, does not appear to be contemporaneous. Empirical support for the J-curve appears in several studies, beginning with Brynjolfsson et al. (2021), who show, using US data, that adjusting TFP for computer-related intangibles raises measured TFP by 15.9% by end-2017 relative to official measures. Bounfour et al. (2024) find similar but smaller J-curve patterns for France, Germany, the UK and Japan. Lagged sectoral and firm-level evidence points in the same direction. Liu et al. (2026) find intangible capital growth negatively associated with value-added growth contemporaneously across 42 economies but positively associated at longer horizons, while Bijnens et al. (2025) and Anghel et al. (2024) show that intensive intangible investment and digital adoption temporarily suppress measured firm productivity before gains emerge later. Edquist and Henrekson (2017b) find a related Swedish industry pattern, where R&D is positively associated with contemporaneous TFP growth, but ICT becomes significant only at lags of seven to eight years, highlighting that lag lengths differ by asset type and by the extent of complementary adjustment required. Empirical specifications focused on a single horizon may therefore yield different results depending on the intangible mix and the period studied.

Systematic sectoral estimation of the intangibles-LP relationship across multiple lag horizons within a single specification, for European economies using the current EU KLEMS & INTANProd 2025 data extended through 2021, has not been carried out. The closest predecessor is Roth and Mitra (2025), which estimates sectoral intangibles-LP relationships for 14 EU member states plus the UK over 1995-2019, but with contemporaneous and single-lag specifications rather than a multi-horizon lag structure. The broader timing evidence comes from firm-level designs, single-country studies, and aggregate cross-country analyses. This is the empirical gap that the regression in Chapter 6 addresses.

5. Data

5.1 EU KLEMS & INTANProd 2025

The empirical analysis uses the EU KLEMS and INTANProd 2025 database, produced by the Luiss Lab of European Economics at Luiss University in Rome and funded by the European Commission (Bontadini et al. 2023a). EU KLEMS is the standard harmonised industry-level productivity database for the EU, built to enable cross-country, industry-level analysis of productivity growth and its sources. It covers EU member states, the United Kingdom, the United States, and Japan. The 2025 release is the most recent version available at the time of writing, extending coverage from 1995 to 2021 and providing updated harmonised estimates of both national accounts (NA) intangibles and non-NA intangibles across all sample countries, following the framework established in Bontadini et al. (2023a). This is what makes the dataset well-suited to the present analysis, as it allows productivity to be examined under the expanded capital boundary developed in Section 3.2 rather than the narrower NA boundary.

The database is organised into modules, four of which are used in this thesis. The Growth Accounts Extended module provides pre-computed annual sector-level decompositions of LP growth into the contributions of its underlying inputs under the CHS-expanded boundary. The Growth Accounts Basic module provides the equivalent decomposition under the conventional NA boundary, used for the boundary comparison analysis. The Intangible Analytical module provides sector-level data on investment flows and capital stocks of intangible assets, covering both NA and non-NA types. The NA Statistical module contains real value added and hours worked by sector.

5.2 Country Selection

The comparative design of including Sweden in a panel with Denmark, Finland, the Netherlands, and Germany serves two purposes. First, it tests whether the sector-level patterns identified in Sweden are distinctive or general among structurally similar economies, something a Sweden-only study cannot establish. Second, it expands the regression sample from a Sweden-only sectoral panel to 133 sector-country units, as discussed further in Section 5.3.1

The selection is motivated by structural and institutional criteria. Sweden, Denmark, Finland, and the Netherlands are all classified as Innovation Leaders by the European Commission's European Innovation Scoreboard, the highest performance tier, which includes countries performing above 125% of the EU average on composite innovation indicators (European Commission, 2025). All four countries have large KIS sectors and high intangible investment intensity relative to the EU average, as shown in Table 1. These structural similarities make them appropriate peers for examining whether sector-level patterns observed in Sweden also appear across economies sharing its broad structural profile, but also mean that the findings should be read as evidence for a targeted group of similar advanced European economies rather than as a generalisation about advanced Europe as a whole.

Germany is included as a structural contrast within the panel. Germany is the EU's largest manufacturing economy, accounting for approximately one quarter of the EU’s industrial production value in 2024 (Eurostat, 2025). As shown in Table 1, it is classified as a Strong Innovator rather than an Innovation Leader, while its KIS employment share of 44.1% is below Sweden’s 57.4%, and its average intangible investment intensity of 10.9% of adjusted GVA over 1995-2021 also remains below the Nordic-Dutch group. Germany is chosen over other potential contrasts, such as Austria or Belgium, because of its scale and its lower KIS employment share and intangible intensity, which makes the structural contrast clearer.

The sample is intentionally confined to these five countries. The analysis is centred on Sweden as the most knowledge-intensive economy in the European Union, and the country set is designed to reflect that focus, being structurally similar enough to enable meaningful comparisons while remaining sufficiently targeted to keep Sweden as the analytical anchor. Countries such as France and Italy are not included as they are less directly comparable in structural terms. Data availability within EU KLEMS also imposes practical constraints on the set of potential candidates, as, for several EU member states, sector-level data is insufficient for growth accounting and regression analysis. In other cases, exclusion reflects more fundamental measurement issues, such as Ireland's well-documented NA distortions arising from multinational intellectual property relocations, which complicate sector-level value-added and productivity measures (Kostarakos et al. 2022).

Table 1. Country Characteristics

Country	EIS 2025 Classification	2025 KIS Employment Share (%)	Intangible Intensity (% GVA)	Role
Sweden	Innovation Leader	57.4	17.2	Primary case
Denmark	Innovation Leader	50.5	14.6	Peer
Finland	Innovation Leader	46.9	15.6	Peer
Netherlands	Innovation Leader	53.6	14.0	Peer
Germany	Strong Innovator	44.1	10.9	Contrast

Notes: Intangible intensity is the 1995-2021 average share of total intangible investment in adjusted GVA.
Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations; KIS employment shares from Eurostat (2026b); EIS classifications from European Commission (2025).

5.3 Sector Scope

The analysis operates at the sector level throughout, so the choice of which sectors to include, how to group them, and which to exclude directly shapes what the empirical analysis can show. This subsection documents those choices and the resulting four-group classification.

5.3.1 Sector Inclusions and Exclusions

The starting point is the full set of sectors available in the EU KLEMS 2025 release for the five countries. The raw data reports both detailed individual sector codes and higher-level aggregates that combine several underlying activities. To avoid double-counting the same economic activity, only one level of aggregation is kept where these overlaps exist. For manufacturing, the aggregate codes of C, C20-21, and C26-27 are dropped in favour of the underlying sectoral components. In the same way, the aggregate transport code H is replaced by the individual subsectors H49, H50, H51, H52 and H53, while the combined R-S category is separated into R and S. Conversely, some pre-aggregated sectors are kept where EU KLEMS does not provide consistent disaggregation, including J58-J60, J62-J63, M, N, and C31-C33. The market economy aggregate MARKT is kept throughout as a descriptive benchmark in the growth accounting and shift-share analysis, but excluded from regression estimation.

Several categories are thereafter excluded to keep the analysis focused on comparable market-economy activities. Non-market sectors such as public administration, education, health, and household activities (O-Q, T-U) are excluded because their output is not market-priced, making productivity comparisons with market sectors methodologically problematic. Real estate activities (L, L68A) are excluded as their measured output is heavily influenced by imputed rents rather than directly comparable production activity. Petroleum refining (C19) is also excluded, due to its extreme annual productivity swings driven by oil price movements rather than underlying production dynamics.

After applying identical sector exclusions, country filters, and classifications across all three modules, the cleaned panel contains 146 sector-country units observed between 1995 and 2021. Fewer sector-country pairs enter the regression estimation because some have missing productivity growth or intangible investment data. In particular, pharmaceutical manufacturing (C21) has no usable productivity growth observations for Sweden, while agriculture (A), financial services (K), and other personal services (S) in Finland contain missing intangible investment values. The main regression accordingly uses 133 sector-country units. A small number of sectors are also not fully usable in the shift-share analysis due to missing employment share observations, primarily affecting pharmaceutical manufacturing (C21) and parts of the transport sector (H49-H53). These cases reflect source-data availability rather than additional sample restrictions.

5.3.2 Sector Classification

With the sample defined, sectors are grouped into four analytical types following the Eurostat high-technology manufacturing and KIS taxonomy based on NACE Rev.2 (Eurostat, n.d.a; Eurostat, n.d.b; Eurostat, 2024a). Service sectors are classified according to knowledge intensity, with knowledge-intensive activities defined by Eurostat as those in which tertiary-educated workers account for more than one-third of employment (Eurostat, 2024b). Manufacturing sectors are classified separately by R&D intensity (R&D expenditure as a share of value added) into high-, medium-high-, medium-low-, and low-technology groups, which are then consolidated into the broader categories of high-tech manufacturing and other manufacturing used in this thesis (Eurostat, 2024a). Using an externally defined standard ensures the grouping reflects a published statistical methodology rather than categories constructed specifically for this thesis. Within KIS, Eurostat further distinguishes high-tech KIS, financial KIS, market KIS and other KIS, with the sub-categories reflecting different combinations of R&D intensity, ICT use and the type of knowledge service provided. These sub-categories are reported in Table 2, but the empirical analysis is conducted at the broader KIS level.

KIS is the primary group of analytical interest and includes ICT and information services, telecommunications, finance, professional and administrative services, media activities, arts and recreation, as well as air and water transport activities classified by Eurostat as knowledge-intensive. Averaged across the five countries over 1995-2021, intangible investment intensity is 15.7% of adjusted GVA in KIS, against 31.8% in high-tech manufacturing, 15.5% in other manufacturing and 8.3% in other market sectors. High-tech manufacturing, therefore, sits at the upper end of intensity in per-unit terms, but represents a much smaller share of activity than KIS in both employment and value-added terms. This combination of intensity and scale underpins the KIS focus established earlier. The full set of NACE Rev.2 codes and Eurostat sub-category mappings for KIS is reported in Table 2

High-tech manufacturing is kept as a separate analytical category rather than being merged into broader manufacturing. Following the Eurostat taxonomy, this group comprises pharmaceutical manufacturing (C21) and computer, electronic, and optical products (C26). These sectors are classified as high-technology by Eurostat based on R&D expenditure as a share of value added, making them among the most innovation-intensive parts of manufacturing. Keeping them separate avoids treating high-technology manufacturing as representative of manufacturing as a whole and allows the analysis to distinguish between productivity patterns in technology-intensive manufacturing and those in the wider manufacturing base.

Some of the aggregate sector codes that were kept over the individual ones, as outlined in the previous section, span more than one Eurostat classification category. For example, J58-J60 combines publishing activities (Eurostat: other KIS) with audiovisual and broadcasting services (Eurostat: high-tech KIS), while M combines scientific R&D with broader professional and technical services. Since these underlying activities are not separately available in the source data, the aggregate sectors are kept. However, because these sectors remain broadly knowledge-intensive, the overall analytical grouping is not materially affected.

The remaining two groups, other manufacturing and other market sectors, serve as the basis for comparison in the analysis. While the thesis is centred on KIS and high-tech activities, it is necessary to include the broader market economy to evaluate whether labour reallocation toward knowledge-intensive sectors contributed to aggregate productivity growth in the shift-share analysis.

Table 2. Sector Classification

Group	Sector	NACE Rev.2	Eurostat basis
KIS	Publishing, audiovisual & broadcasting	J58-J60	Other KIS (J58) / High-tech KIS (J59-J60)
	Telecommunications	J61	High-tech KIS
	IT & information services	J62-J63	High-tech KIS
	Financial & insurance services	K (64-66)	Financial KIS
	Professional, scientific & technical services	M (69-75)	Market KIS / High-tech KIS (approx.)
	Administrative & support services	N (78-82)	Market KIS (approx.)
	Arts, entertainment & recreation	R	Other KIS
	Water transport	H50	Market KIS

	Air transport	H51	Market KIS
High-tech manufacturing	Pharmaceuticals	C21	High-tech manufacturing
	Computers, electronics & optical products	C26	High-tech manufacturing
Other manufacturing	Food, beverages & tobacco	C10-C12	Low-tech manufacturing
	Textiles, apparel & leather	C13-C15	Low-tech manufacturing
	Wood, paper & printing	C16-C18	Low-tech manufacturing
	Chemicals and chemical products	C20	Medium-high-tech manufacturing
	Rubber, plastics & non-metallic minerals	C22-C23	Medium-low-tech manufacturing
	Basic & fabricated metals	C24-C25	Medium-low-tech manufacturing
	Electrical equipment	C27	Medium-high-tech manufacturing
	Machinery & equipment	C28	Medium-high-tech manufacturing
	Transport equipment	C29-C30	Medium-high-tech manufacturing
	Furniture, other manufacturing & repair	C31-C33	Low- / medium-low-technology manufacturing (approx.)
Other market	Agriculture, forestry & fishing	A	-
	Mining & quarrying	B	-
	Construction	F	-
	Wholesale & retail trade	G	Less KIS
	Land transport	H49	Less KIS
	Warehousing & transport support	H52	Less KIS
	Postal & courier services	H53	Less KIS
	Accommodation and food services	I	Less KIS
	Other personal services	S	Less KIS

Aggregate benchmark	Market economy total	MARKT	Aggregate benchmark only

Source: Eurostat, n.d.a; Eurostat, n.d.b; Eurostat, 2024a

The sector types also differ in observed productivity levels within the sample. Appendix Table A1 reports average PPP-adjusted LP levels by sector type across countries and sub-periods. High-tech manufacturing is the most productive group in most country-period observations, while KIS productivity levels consistently exceed those in the broader market-service economy and are generally around or above other manufacturing, depending on the country. This productivity heterogeneity is the empirical basis on which the shift-share analysis operates.

5.4 Variables

The three empirical components require different variables. The decomposition uses pre-computed factor contributions, the shift-share uses LP levels and employment shares, and the regression uses annual LP growth and intangible investment intensity. Table 3 reports descriptive statistics for the pooled panel. The main variables are available for most sector-country-year observations, although the number of observations varies slightly due to missing values in certain sectors and components. The wide minimum and maximum values for LP growth and TFP contributions reflect sector-level volatility, especially in crisis-exposed sectors such as air transport and mining. The empirical analysis, therefore, relies on period averages and fixed-effect specifications rather than isolated annual extremes.

5.4.1 Decomposition Variables

Five variables are taken directly from the Growth Accounts Extended module, each measuring the annual contribution of one source to LP growth in percentage points. Intangible capital deepening (con_intang), TFP (con_tfp), tangible ICT capital (con_ict), tangible non-ICT capital (con_nict), and labour composition (con_lc). Together, these variables sum to total LP growth for each sector-year. The intangible contribution is further split into NA intangibles (con_intang_NA) and non-NA intangibles (con_intang_nonNA), allowing the expanded capital boundary developed in Section 3.2 to be examined separately from the narrower NA measure.

The TFP contribution is computed by EU KLEMS as the Solow residual under a translog production function, with factor inputs weighted by their average shares of nominal value added across adjacent years (Bontadini et al. 2023a).

5.4.2 Shift-Share Variables

The shift-share analysis uses LP levels rather than growth rates, meaning productivity levels must be comparable across countries. Since LP in EU KLEMS is measured in national currencies, cross-country productivity levels are not directly comparable without accounting for differences in price levels and purchasing power. Three variables are constructed from the NA Statistical module. Absolute LP (lp_abs) is real GVA per hour worked in national currency. PPP-adjusted LP (lp_ppp) is the productivity measure used in both terms of the shift-share decomposition. It converts lp_abs into purchasing power standard (PPS) units using country-year GDP purchasing power parity conversion factors from Eurostat's prc_ppp_ind dataset (Eurostat, 2026c). Employment shares (emp_share) measure each sector's hours worked as a share of total market-economy hours within the same country-year.

5.4.3 Regression Variables

The regression uses two variables. LP growth (lp_growth) is the annual log change in real GVA per hour worked, expressed in percentage points and taken directly from the Growth Accounts Extended module. Intangible investment intensity (intang_intensity) is total intangible investment as a share of adjusted GVA, where the adjustment reflects the capitalisation of intangible investment under the framework discussed in Section 3.2.

Table 3. Descriptive statistics of empirical variables, 1995-2021

Variable	N	Mean	SD	Min	Max
lp_growth	3,794	1.899	8.208	-104.296	97.741
intang_intensity	3,861	0.147	0.097	-2.091	0.897
con_intang	3,796	0.470	1.377	-14.731	20.945
con_intang_NA	3,666	0.253	1.073	-14.605	17.555

con_intang_nonNA	3,796	0.226	0.651	-3.909	10.101
con_tfp	3,638	0.874	8.223	-115.570	95.371
con_ict	3,640	-0.007	0.316	-4.058	5.605
con_nict	3,666	0.259	1.381	-9.795	20.328
con_lc	3,796	0.337	1.864	-16.167	51.905
lp_abs	3,942	0.251	0.433	-0.079	6.904
lp_ppp	3,942	0.051	0.054	-0.023	0.665
emp_share	3,996	0.067	0.179	0.001	1.000

Note: lp_growth and con_* variables are in percentage points; intang_intensity, lp_abs, lp_ppp and emp_share are decimal shares. Extreme values are concentrated mainly in air transport during crisis years and in mining and quarrying sectors.
Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations.

5.5 Data Limitations

A few data limitations should be noted before turning to the methodology. First, the growth accounting decompositions are taken directly from EU KLEMS rather than computed independently, meaning that the decomposition approach is inherited rather than replicated. The methodology is documented in Bontadini et al. (2023a), and the decomposition identities are internally consistent in the cleaned data. However, because the assumptions are built into the production process, the underlying assumptions about capital pricing, factor shares, and asset-specific user costs cannot be independently verified within this thesis.

Second, the measurement of intangible investment is also indirect, especially for non-NA assets, which are estimated using proxies, surveys and standardised capitalisation assumptions. Data availability and the level of detail vary across countries and over time, and parts of the capital and labour inputs used in the growth accounting are constructed using interpolation, aggregation or external sources (Bontadini et al, 2023a). Therefore, similar measured values across sectors or countries do not necessarily reflect identical underlying economic activity. Since the TFP contribution is calculated residually, these measurement issues may also affect how the decomposition is interpreted, with some productivity-relevant intangible activity appearing in the residual rather than in the intangible-capital contribution.

These limitations are standard in the data, and the studies reviewed in Chapter 4 work within the same constraints. The analysis follows that literature in treating the harmonised data as the empirical basis, and the constraints should mainly be kept in mind when interpreting cross-country differences and the split between measured intangible contributions and residual TFP.

6. Methodology

This chapter operationalises the three empirical components introduced in Section 1.2. Each is described in turn, covering the analytical form, the application of the variables, the sample treatment, and the choices made in implementation.

6.1 Growth Accounting Decomposition

The growth accounting framework introduced in Section 3.1 is operationalised here at the sector level. While the general identity distinguishes capital deepening, labour composition, and TFP, this operational form adopts an extended intangible capital boundary, separating intangible capital from tangible capital and further splitting tangible capital into ICT and non-ICT, yielding five contributions in total. The accounting identity is:

$$\Delta \ln LP(i,t) = ConIntang(i,t) + ConTFP(i,t) + ConTangICT(i,t) + ConTangNICT(i,t) + ConLC(i,t)$$

where the LP growth of sector i at time t is the sum of contributions from intangible capital, TFP, tangible ICT capital, tangible non-ICT capital, and labour composition. The intangible contribution is the primary object of interest, with the remaining components serving as the within-sector benchmark against which its magnitude is interpreted. The intangible contribution is also reported separately for its NA and non-NA components, drawing on the boundary distinction established in Section 3.2.

The decomposition is presented as sub-period averages by sector type and country across the three sub-periods of 1995-2007, 2008-2012, and 2013-2021. The split treats the GFC as a structural break in productivity dynamics, with 1995 to 2007 capturing the pre-crisis growth phase, 2008 to 2012 covering the crisis and its immediate aftermath, and 2013 to 2021 covering the recovery. Treating the GFC as a structural break is standard in the intangibles and productivity literature, including in recent work with similar empirical setups. Roth and Mitra (2025) use a two-period before-and-after split, while Nikolov et al. (2026) isolate the crisis window itself on the substantive grounds that capacity utilisation collapsed during 2008 to 2012, producing cyclical TFP swings that would contaminate longer averages. Averaging within sub-periods reduces year-to-year volatility and brings out the underlying structural pattern. The decomposition is accounting-based and reports the relative size of within-sector contributions rather than causal effects between inputs and outcomes.

In addition to the decomposition under the extended boundary, a direct comparison is reported between LP growth measured under the conventional NA boundary and LP growth measured under the CHS-expanded boundary, as explained in Section 3.2. The comparison follows Corrado et al. (2009) and gives a direct measure of how much the boundary choice affects measured productivity growth across the panel.

6.2 Shift-Share Analysis

The structural reallocation mechanism developed in Section 3.3 is operationalised through a shift-share decomposition of aggregate LP change. The decomposition separates the two channels identified in the theory, being change generated within sectors and change generated by the movement of labour between sectors of differing productivity.

Following McMillan and Rodrik (2011), aggregate LP change is written as

$$\Delta LP = \Sigma_i \left(\theta_{i,base} \times (LP_{i,end} - LP_{i,base})\right) + \Sigma_i \left(LP_{i,end} \times \Delta\theta_i\right)$$

The first term captures how much productivity grew within each sector, scaled by the sector's size at the start of the period, so that improvements in larger sectors count more toward the aggregate. The second term captures structural change through labour reallocation between sectors with differing productivity levels. When labour moves toward higher-productivity sectors, the term is positive and structural change contributes to aggregate productivity growth. When labour moves toward lower-productivity sectors, the term becomes negative and acts as a drag on aggregate growth. Both terms use the PPP-adjusted productivity measure (lp_ppp) defined in Section 5.4.2.

The shift-share decomposition should be interpreted descriptively rather than causally. Sectoral productivity and sectoral expansion are jointly determined in services in particular, since profitable or productive sectors attract firm entry, investment and workers over time. Observing the labour movement in KIS alongside high KIS productivity, therefore, does not establish that the movement caused the productivity outcome. The reverse direction is also possible, with productive opportunities drawing labour into the sector. The between-effect shows whether labour moved toward sectors with higher productivity levels, but interpretation should remain at the descriptive level. The growth accounting decomposition in Section 6.1 faces a related issue, since intangible investment, labour composition, and tangible capital are also jointly determined with sector productivity, yet the accounting identity is, by construction, descriptive rather than causal.

The decomposition is computed over the same three sub-periods as the growth accounting analysis, but uses endpoint years rather than period averages, comparing 1995-2007, 2007-2013, and 2013-2021. This is because growth accounting is based on changes within a period, while shift-share compares the structure of the economy between two points in time. For this reason, the GFC sub-period begins in 2007 here rather than 2008. The within and between effects are normalised by base-year aggregate LP and annualised by the number of years in each sub-period, so they are reported as annual contributions to aggregate LP growth in percentage points.

6.3 Panel Regression

The relationship between intangible investment intensity and LP growth developed in Section 3.4 is operationalised here as a fixed-effects panel regression at the sector-country level. The contemporaneous and lagged versions of the specification together identify the timing structure of the relationship anticipated by the J-curve dynamic.

The specification is:

$$\Delta LP(i,c,t) = \alpha + \beta \cdot IntangIntensity(i,c,t) + \mu(i,c) + \tau(t) + \varepsilon(i,c,t)$$

where ΔLP is annual LP growth, IntangIntensity is intangible investment intensity as defined in Section 5.4.3, and μ(i,c) and τ(t) are sector-country and year fixed effects. The sector-country fixed effects absorb everything stable about a given sector in a given country, such as its average productivity level, industrial structure and institutional context. The year fixed effects absorb shocks common to all sectors and countries in a given year. The coefficient β is therefore identified from how the LP growth of a given sector changes as its intangible intensity changes over time, net of common shocks. Standard errors are clustered at the sector-country level, yielding 133 clusters, which is well above the range where cluster-robust inference is typically considered unreliable due to few-cluster concerns (Cameron & Miller, 2015). This specification follows standard practices in the sector-country panel literature on intangibles and productivity (Niebel et al. 2017; Nikolov et al. 2026; Roth & Mitra, 2025). No additional time-varying controls are included. The fixed-effects structure already absorbs time-invariant heterogeneity and common time shocks, and adding further controls would risk absorbing variation that the mechanism in Section 3.4 implies should operate through intangible investment.

The timing dimension is evaluated by comparing the relationship across different lag structures. The baseline specification is estimated contemporaneously and at one-, two- and three-year lags of intangible intensity. The one-year lag is the primary specification, with the two- and three-year lags tracking how the relationship evolves over longer time. Lags are estimated separately rather than jointly, since intangible intensity is highly autocorrelated within sector-countries (inter-lag correlation $r \approx 0.97$), and joint inclusion produces severe multicollinearity. A relationship that appears at lag but not contemporaneously is the empirical signature of the J-curve pattern set out in Section 3.4, where complementary organisational adjustment delays the productivity payoff.

Several robustness checks are reported. The COVID years 2020 and 2021 are excluded in one specification, with the COVID dummy alternative absorbed by the year fixed effects. Germany is excluded in a separate specification, given the measurement concerns described in Section 5.5, and a Germany-only specification is reported alongside to examine whether the relationship holds in the structural contrast case. As a supplementary check, the data are collapsed to sub-period averages and re-estimated with sub-period and country fixed effects to test whether the association holds over medium-run horizons.

Results are interpreted as associations rather than causal effects. The fixed effects and lag structure reduce but do not eliminate concerns about reverse causality and omitted variables. Sectors that anticipate future productivity gains may invest more heavily in intangibles in advance, meaning the estimated relationship may partly reflect expectations of future performance rather than the productivity effect of intangible investment itself. A related concern applies more broadly to sectoral investment dynamics, since more productive or more profitable sectors are also more likely to attract investment, particularly in intangible assets where expected returns are high. The estimated relationship should therefore be interpreted as a conditional association between intangible intensity and subsequent LP growth at the sector-country level, rather than a causal effect.

7. Empirical Results

This chapter presents the findings for the three empirical components corresponding to the theoretical mechanisms established in Chapter 3. Tables report the full panel, with the prose focused on KIS, where the mechanisms identified in Chapter 3 are expected to be most clearly visible at the scale of activity that matters for aggregate productivity dynamics. Results are read as descriptive decompositions and statistical associations rather than causal estimates, and interpretation against the broader literature is deferred to the discussion.

7.1 Within-Sector Mechanism

Table 4 reports the growth accounting decomposition by sector type and country, while Appendix Table A2 reports the Swedish sub-sectoral breakdown. Across the market economy as a whole, intangible capital operates as a productive input with a positive contribution to LP growth in 56 of the 60 country-sector-period observations. The four exceptions are concentrated in high-tech manufacturing, with Sweden accounting for two of them. In KIS, the intangible contribution is positive in all 15 country-period observations, ranging from 0.21 to 1.02 percentage points per year. These magnitudes generally sit above those in other manufacturing

(0.23 to 0.80) and other market sectors (0.04 to 0.44), while remaining more stable than the highly volatile high-tech manufacturing results. KIS therefore combines the most consistently positive within-sector intangible contribution with relatively large magnitudes across the panel.

Within Swedish KIS, the intangible contribution remains comparatively stable across the three sub-periods at 0.73, 0.97, and 0.64 percentage points, respectively, even as the surrounding growth composition changes significantly. Pre-crisis, labour composition is the largest contributor at 1.22 percentage points, with TFP at 1.11 and intangibles at 0.73. During the crisis years, intangibles and TFP are comparable at 0.97 and 1.04, while labour composition and tangible capital fall to near zero. By 2013-2021, TFP is the largest contributor at 1.70, followed by non-ICT tangible capital at 0.75 and intangibles at 0.64. Overall, Swedish KIS LP growth fell from 3.56 percentage points per year pre-crisis to 1.73 during the crisis years and recovered to 3.17 by 2013-2021. Expressed as a share of Swedish KIS LP growth, the intangible contribution accounts for roughly 20% pre-crisis and 20% post-crisis, rising to 56% during the crisis years, mostly because the other contributors collapsed.

The sub-sectoral breakdown inside Swedish KIS shows that the intangible contribution is concentrated in a small number of KIS activities rather than evenly distributed across the group. IT and information services (J62-J63) record the strongest intangible contributions in the entire decomposition, peaking at 6.01 percentage points during the crisis years and remaining at 2.07 post-crisis. Professional, scientific and technical services (M) contribute 1.20, 0.90 and 0.97 across the three sub-periods, and finance and insurance (K) contributes 1.64, 0.87 and 0.64. Telecommunications (J61) grows rapidly throughout the sample, but the growth is driven primarily by TFP rather than intangibles. High-tech manufacturing presents the opposite pattern, with Swedish C26 swinging from an intangible contribution of 3.26 percentage points pre-crisis to -7.29 during the crisis and -2.56 in the recovery, and post-crisis negatives in Finland (-0.21) and the Netherlands (-1.49) following the same direction at smaller magnitudes.

Table 4. Growth Accounting Decomposition by Sector Type and Country

Panel 1 of 2: Sweden, Denmark, Finland

		Sweden						Denmark						Finland					
Sector type	**Period**	**LP**	**Intang.**	**TFP**	**ICT**	**Non-ICT**	**Lab. comp.**	**LP**	**Intang.**	**TFP**	**ICT**	**Non-ICT**	**Lab. comp.**	**LP**	**Intang.**	**TFP**	**ICT**	**Non-ICT**	**Lab. comp.**
KIS	1995-2007	3.56	0.73	1.11	-0.06	0.56	1.22	4.46	0.64	2.81	-0.02	0.58	0.45	3.01	0.50	2.20	-0.04	-0.09	0.15
	2008-2012	1.73	0.97	1.04	-0.21	-0.14	0.07	3.03	0.52	2.09	-0.15	0.05	0.52	0.69	0.21	0.28	0.16	0.04	0.27
	2013-2021	3.17	0.64	1.70	-0.03	0.75	0.15	1.87	0.44	0.95	0.03	0.33	0.12	1.41	0.78	0.28	0.12	0.14	0.08
High-tech manuf.	1995-2007	19.02	3.26	14.63	-0.11	0.24	1.01	6.46	1.95	3.81	0.15	0.51	0.05	9.51	2.79	6.66	-0.08	0.00	0.14
	2008-2012	-2.92	-7.29	4.38	-0.09	0.02	0.06	5.48	1.99	4.05	-0.13	-0.15	-0.27	-0.56	2.93	-3.97	0.10	0.15	0.23
	2013-2021	2.49	-2.56	5.04	-0.08	-0.22	0.32	4.00	1.64	2.09	0.02	0.17	0.09	3.48	-0.21	3.49	0.03	0.11	0.05
Other manufacturing	1995-2007	3.36	0.29	2.45	-0.15	0.64	0.13	1.74	0.54	0.26	0.02	0.46	0.46	3.12	0.33	2.74	-0.12	-0.11	0.29
	2008-2012	-0.12	0.80	-1.51	-0.04	0.47	0.16	2.60	0.39	1.72	0.07	0.47	-0.06	-0.63	0.73	-2.17	0.05	0.23	0.53
	2013-2021	2.55	0.78	1.06	0.02	0.34	0.35	2.44	0.23	2.25	0.03	-0.21	0.15	1.28	0.33	0.68	0.03	0.13	0.10
Other market	1995-2007	1.97	0.20	0.48	0.05	0.83	0.42	0.52	0.25	-0.51	0.01	0.50	0.26	1.08	0.16	0.54	-0.09	0.15	0.31
	2008-2012	-1.49	0.38	-2.94	-0.14	0.96	0.24	-2.21	0.28	-2.85	-0.10	-0.26	0.72	1.35	0.33	0.11	0.02	0.76	0.14
	2013-2021	0.93	0.44	0.24	0.00	0.12	0.14	-1.38	0.23	-2.04	-0.01	0.32	0.11	-0.20	0.43	-1.05	0.00	0.34	0.08

Notes: Sub-period averages of annual contributions to LP growth in percentage points.

Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations.

Panel 2 of 2: Netherlands, Germany

		Netherlands						Germany					
Sector type	**Period**	**LP**	**Intang.**	**TFP**	**ICT**	**Non-ICT**	**Lab. comp.**	**LP**	**Intang.**	**TFP**	**ICT**	**Non-ICT**	**Lab. comp.**
KIS	1995-2007	3.49	0.45	1.09	0.07	0.53	0.58	1.17	0.42	0.21	0.06	0.37	0.10
	2008-2012	1.15	0.85	-0.95	0.06	0.46	0.43	1.79	0.50	0.27	0.02	0.56	0.44
	2013-2021	0.25	1.02	-0.19	0.08	0.22	0.15	1.81	0.68	0.74	0.07	0.24	0.07
High-tech manuf.	1995-2007	8.22	1.71	6.14	-0.09	-0.32	0.78	8.34	0.54	7.21	0.02	0.43	0.14
	2008-2012	5.49	2.14	3.12	-0.01	0.01	0.23	3.01	0.25	2.36	-0.03	0.06	0.37
	2013-2021	4.40	-1.49	6.17	0.01	-0.52	0.22	2.07	0.05	1.90	-0.01	-0.08	0.21
Other manufacturing	1995-2007	3.41	0.46	1.80	0.01	-0.12	1.26	2.50	0.27	1.80	-0.01	0.23	0.20
	2008-2012	0.59	0.78	-0.59	-0.01	0.03	0.38	0.25	0.24	-0.56	-0.03	0.05	0.55
	2013-2021	1.45	0.39	0.74	0.00	-0.07	0.39	1.48	0.40	0.69	0.00	0.09	0.31
Other market	1995-2007	1.14	0.21	-0.70	0.03	0.56	0.76	0.93	0.04	0.68	-0.01	-0.03	0.25
	2008-2012	-0.64	0.22	-1.61	-0.01	0.44	0.39	0.79	0.08	-0.06	-0.02	0.23	0.57
	2013-2021	-1.55	0.24	-2.30	0.00	0.32	0.24	1.08	0.21	0.38	0.00	0.37	0.11

Notes: Sub-period averages of annual contributions to LP growth in percentage points.

Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations.

7.1.1 The Capital Boundary and Measured LP Growth

Appendix Table A3 splits the intangible contribution into NA and non-NA components. In Swedish KIS, the intangible contribution comes mostly through NA assets throughout the sample, with non-NA contributions of 0.19 to 0.23 percentage points across the three sub-periods. Finland and the Netherlands exhibit different patterns, with their post-crisis non-NA contributions of 0.54 and 0.74 exceeding their NA contributions of 0.24 and 0.36, respectively.

Table 5 compares LP growth under the conventional NA boundary with the CHS-expanded boundary used in the decomposition above. For 2013-2021, the expanded boundary raises measured LP growth in every country in the panel, by 7.7 to 19.5%. In absolute terms, the effect is relatively similar across countries at 0.1 to 0.2 percentage points per year. The percentage figures vary because they scale against each country's overall LP growth, with Sweden having the highest absolute LP growth in the panel and consequently the smallest percentage uplift at 7.8%, while Finland has the lowest LP growth and the largest at 19.5%.

The pre-crisis boundary effect is small and runs in opposite directions across the panel, becoming slightly negative in Finland, the Netherlands and Sweden, and slightly positive in Germany and Denmark. The Swedish results differ more substantially during the crisis years, where LP growth under the conventional boundary was essentially zero at 0.09% per year, compared to 0.43% under the expanded boundary, with non-NA intangibles accounting for roughly 72% of measured growth.

Table 5. LP Growth Under Conventional and CHS-Expanded Capital Boundaries

Country	Period	Conventional	Expanded	Difference (pp)	% higher
Germany	1995-2007	1.88	1.90	+0.02	+1.2
	2008-2012	0.27	0.37	+0.10	+37.3
	2013-2021	1.37	1.49	+0.12	+8.7
Denmark	1995-2007	1.76	1.87	+0.12	+6.8
	2008-2012	0.75	0.64	-0.11	-15.2
	2013-2021	1.64	1.80	+0.15	+9.3

Finland	1995-2007	3.50	3.34	-0.17	-4.8
	2008-2012	-0.89	-0.66	+0.23	(negative base)
	2013-2021	0.99	1.18	+0.19	+19.5
Netherlands	1995-2007	2.26	2.18	-0.08	-3.5
	2008-2012	0.49	0.76	+0.27	+54.6
	2013-2021	0.89	0.98	+0.09	+9.7
Sweden	1995-2007	3.77	3.57	-0.20	-5.2
	2008-2012	0.09	0.43	+0.34	(small base)
	2013-2021	2.08	2.24	+0.16	+7.8

Notes: Conventional and Expanded show annual LP growth in percentage points under the NA and CHS-expanded capital boundaries. Percentage figures for sub-periods with LP growth close to or below zero are flagged, as the percentage measure becomes unstable.
Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations.

7.2 The Reallocation Mechanism

The KIS reallocation effect is positive across almost the entire panel. Table 6 reports the shift-share decomposition by sector type, with the KIS between-effect positive in fourteen of fifteen country-period observations, the exception being the Netherlands in 2013-2021 at -0.04 percentage points per year. The manufacturing pattern is the mirror image, with between-effects in other manufacturing negative in every country-period observation, indicating labour moving steadily out of manufacturing over the full sample.

Pre-crisis, the KIS between-effect is economically meaningful across the panel and broadly comparable in size across countries, with Sweden at 0.68 percentage points per year, Denmark at 0.60, Finland at 0.44, the Netherlands at 0.62 and Germany at 0.88. The within-KIS effect over the same period varies more, ranging from essentially zero in Germany to 0.83 in Sweden and 0.81 in the Netherlands.

The aggregate picture is more modest, as reported in Appendix Table A4. Sweden's economy-wide between-effect for 1995-2007 is only 0.04 percentage points per year against a within-effect of 3.65. The aggregate between-effect is small because the positive KIS reallocation contribution of 0.68 is offset by negative manufacturing between-effects, particularly other manufacturing at -0.38. The same compositional pattern appears across all five economies pre-crisis.

After 2007, Sweden's within-KIS and between-KIS channels diverged. The within-KIS effect fell from 0.83 percentage points pre-crisis to 0.22 during the crisis and recovered only partially to 0.34 by 2013-2021. The between-KIS effect held up better, declining from 0.68 to 0.17 and recovering to 0.44. By the end of the sample, reallocation into KIS contributed more to Swedish KIS productivity than did within-KIS growth. Germany shows the opposite configuration, with its within-KIS effect rising from essentially zero pre-crisis to 0.45 while its between-KIS effect fell from 0.88 to 0.16. At the aggregate level, the two economies record near-identical post-crisis recoveries of 1.20 percentage points per year, but through opposite KIS channels.

Table 6. Shift-share Decomposition of Aggregate LP Growth

		Sweden		Denmark		Finland		Netherlands		Germany	
Sector type	**Period**	**Within**	**Between**	**Within**	**Between**	**Within**	**Between**	**Within**	**Between**	**Within**	**Between**
KIS	1995-2007	0.83	0.68	0.48	0.60	0.45	0.44	0.81	0.62	-0.01	0.88
	2007-2013	0.22	0.17	0.37	0.57	-0.28	0.43	0.37	0.03	0.10	0.10
	2013-2021	0.34	0.44	0.69	0.08	0.42	0.35	0.13	-0.04	0.45	0.16
High-tech manuf.	1995-2007	0.36	-0.21	0.19	0.04	0.63	+0.15	0.14	-0.05	0.20	-0.02
	2007-2013	-0.05	-0.01	0.29	0.22	-0.29	-0.29	0.08	-0.03	0.08	0.00
	2013-2021	0.04	-0.05	0.36	0.11	0.21	-0.12	0.06	+0.03	0.07	0.06
Other manufacturing	1995-2007	1.18	-0.38	0.42	-0.58	1.16	-0.42	0.71	-0.54	1.15	-0.28
	2007-2013	-0.30	-0.62	0.51	-0.49	-0.51	-0.39	-0.06	-0.08	-0.12	-0.06
	2013-2021	0.39	-0.13	0.45	-0.17	0.34	-0.11	0.19	-0.08	0.42	-0.04
Other market	1995-2007	1.28	-0.05	0.46	0.04	0.74	+0.11	0.89	-0.30	0.87	-0.42
	2007-2013	-0.68	0.27	-0.08	-0.05	-0.29	-0.03	-0.06	-0.02	-0.05	-0.13
	2013-2021	0.23	-0.06	0.65	-0.06	0.35	-0.22	0.19	-0.16	0.23	-0.15

Notes: Annual percentage point contributions to aggregate LP growth
Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations.

7.3 The Intensity-Lag Mechanism

Table 7 reports the panel regression of annual LP growth on intangible investment intensity at the sector-country level. The contemporaneous coefficient is 0.81, with a standard error of 9.27, and is statistically indistinguishable from zero. The one-year lagged coefficient is 28.69 with a standard error of 6.54 and is significant at the 0.001 level. There is no measurable same-year relationship between intangible intensity and LP growth at the sector level, but there is a strong systematic relationship at a one-year lag.

Since intangible intensity is measured as a share of adjusted GVA, the coefficient implies that a 1 percentage-point increase in intangible intensity is associated with roughly a 0.29 percentage-point higher LP growth in the following year. Against a sample mean LP growth of 1.9 percentage points, that magnitude is substantial.

The relationship is concentrated at the one-year horizon, as the coefficient falls to 11.04 with a standard error of 5.80 at two years, and drops further to 2.58 at three years, becoming statistically indistinguishable from zero beyond the first lag.

The L1 finding remains robust across the alternative specifications. Excluding the COVID years leaves the coefficient at 24.25 and highly significant, while excluding Germany yields an almost identical coefficient of 28.71. The Germany-only specification remains positive at 44.24, although with lower precision due to the smaller cluster count of 25. Collapsing the data to sub-period averages produces a coefficient of 10.93, smaller in magnitude but consistent in direction and significant. Taken together, the results suggest that the relationship is not driven by the pandemic years, by Germany specifically, or by short-run annual volatility.

Table 7. Panel Regression: Intangible Investment Intensity and LP Growth

	(1)	(2)	(3)	(4)
Panel A. Lag structure				
	L0 (baseline)	L1 (main)	L2	L3
Intangible intensity (L0)	0.814 (9.271)			
Intangible intensity (L1)		28.685*** (6.537)		
Intangible intensity (L2)			11.042 (5.797)	
Intangible intensity (L3)				2.583 (6.132)
Sector-country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	3,456	3,456	3,323	3,190
Clusters	133	133	133	133
R^2 (within)	0.080	0.102	0.084	0.081
Panel B. Robustness checks (L1 specification)				
	(5)	(6)	(7)	(8)
	Excl. COVID	Excl. Germany	Germany only	Period avg.
Intangible intensity (L1)	24.247** (7.944)	28.711*** (6.681)	44.241* (20.311)	10.930** (3.658)
Sector-country FE	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	No
Sub-period + country FE	No	No	No	Yes
N	3,192	2,806	650	399
Clusters	133	108	25	-
R^2 (within)	0.093	0.099	0.163	0.138

Notes: Dependent variable is annual LP growth (log change in real GVA per hour worked, percentage points). Intangible intensity is in decimal share units. L0 is contemporaneous, L1-L3 are one- to three-year lags. Standard errors clustered at the sector-country level in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.
Source: EU KLEMS & INTANProd 2025 (Bontadini et al. 2023a), author's calculations.

7.4 Integrated Interpretation of the Results

The three theoretical mechanisms that were set out as potential reasons to expect the knowledge-intensive and intangible-intensive transition to generate productivity growth are all identifiable in the results. They largely operate in the direction the framework predicts, and at first glance, each one looks like a fairly clean knowledge-economy result. Intangibles function as productive capital inside KIS, KIS reallocation contributes positively to aggregate productivity, and the systematic relationship between intangible investment intensity and LP growth registers at a one-year lag. Because each method tests something the others cannot, the three findings together carry more weight than any one of them in isolation, with the framework's machinery visible at three different points of the same process.

Read more carefully, however, there are caveats that result in weaker support for a reading in which the three mechanisms can operate at magnitudes large enough to act as the drivers behind large and sustained productivity gains. The intangible contribution is positive across KIS, but at a magnitude that makes it a co-contributor alongside TFP, labour composition, and tangible capital. The KIS reallocation channel is positive across the panel, but its aggregate contribution is small because labour flowing into KIS is matched by labour flowing out of manufacturing sectors that hold strong relative productivity positions. The lagged relationship is robust but dissipates within two to three years, identifying an association rather than a causal effect. The mechanisms are present, but they are not, on their own, the kind of force that generates a transformative aggregate outcome.

8. Discussion

The joint reading in Chapter 7 leaves the knowledge-economy interpretation in an ambiguous position. The mechanisms are visible enough that weak aggregate productivity growth cannot be read as evidence that intangibles and KIS are irrelevant, but they are not strong enough to sustain the expectation that structural depth itself translates into proportionate productivity growth. The discussion, therefore, turns to the conditions that shape the productivity payoff once the transition is already in place. The discussion is structured around five conditioning factors. They concern where inside the economy the within-sector intangible contribution is concentrated, how it combines with other inputs, what labour movement into KIS displaces elsewhere in the economy, how the capital boundary is drawn, and over what horizon productivity effects become visible. These factors are not separate explanations of the slowdown, nor claims about what would be sufficient to resolve it. They describe channels through which otherwise productivity-supporting mechanisms may be amplified, weakened or only partly registered in measured LP growth.

Regarding where the within-sector intangible contribution is concentrated, the Swedish results suggest a reversal of the pattern identified in the Swedish literature reviewed in Chapter 4. Earlier work placed much of the Swedish intangible and ICT productivity story in manufacturing and the ICT-producing business-sector structure (Edquist, 2011a, 2011b; Edquist & Henrekson, 2017a, 2017b). In the current data, the clearest and most stable within-sector intangible contribution appears inside KIS, particularly IT and professional services, with Swedish KIS magnitudes of 0.64 to 0.97 percentage points sitting at the upper end of the cross-EU sector range identified in earlier work (Niebel et al. 2017), while Swedish computers and electronics records sustained negative intangible contributions after the crisis. The comparison should be interpreted cautiously, given differences in sector classifications and the absence of Swedish pharmaceutical manufacturing observations, but the directional contrast is still important. The earlier Swedish reading, therefore, needs updating, with the current results pointing toward a more KIS-centred configuration of the intangible economy.

The second conditioning factor is how the within-sector intangible contribution combines with other inputs. Inside Swedish KIS, the within-channel recovery runs on a different input mix than it did pre-crisis. Labour composition declines, while TFP becomes more central to the recovery. The intangible contribution remains stable, but the surrounding inputs through which it translates into productivity have changed, with that stability most visible during the crisis years, when intangibles rose from around 20% to over half of Swedish KIS LP growth as other contributors collapsed. One plausible interpretation is that the earlier phase of Swedish KIS productivity growth relied more heavily on workforce upgrading alongside intangible accumulation, while the post-crisis recovery depended relatively more on the efficiency and organisational effects captured through the TFP residual. Read alongside the L1 finding from the regression, this is consistent with the broader complementarities literature, where the productivity effects of intangibles are shaped by the organisational and workforce conditions through which they are implemented (Castelli et al. 2024; Cette et al. 2024). The thesis cannot test those complementarities directly, but the pattern is more consistent with that interpretation than with a reading in which intangible accumulation mechanically produces LP growth.

The third conditioning factor is what labour movement into KIS displaces elsewhere in the economy. The KIS between-effect is positive in all but one panel observation, which fits a Baumol-revisionist view in which KIS do not behave as stagnant residual services. The Swedish case nevertheless shows why this revision should remain qualified. KIS expansion can support productivity growth, but its aggregate effect depends on what labour moves out of and into. In Sweden, part of the KIS gain is offset by labour leaving relatively productive manufacturing activities, which places the finding between older service-sector pessimism and stronger knowledge-economy optimism. Germany illustrates the same point from the other side. As the structural contrast, with a smaller KIS sector and lower intangible intensity, Germany moves in the opposite direction to Sweden across the post-crisis period, with its within-KIS channel strengthening and its reallocation channel falling. The two economies, therefore, represent different points of the knowledge-economy transition. In Sweden, the KIS contribution is increasingly shaped by reallocation into an already large KIS sector, while in Germany, it comes more through within-sector productivity gains in a smaller one.

The fourth conditioning factor is how the capital boundary is drawn. Under the conventional NA boundary, Swedish LP growth flatlined through 2008-2012, while under the CHS-expanded boundary, it did not. The economy continued to accumulate non-NA intangible assets through the crisis years, and whether that activity counts as productive is a substantive analytical choice rather than a technical one. Broadening the boundary does not, however, alter the post-crisis composition of Swedish KIS LP growth, in which TFP, rather than intangibles, carries most of the recovery. This is consistent with the strand of the literature arguing that capitalising intangibles improves the accounting without resolving the slowdown itself (Fernald, 2024; Goodridge & Haskel, 2023; Nikolov et al. 2026). The cross-country dimension adds a further layer, with Finland and the Netherlands drawing the majority of their post-crisis KIS intangible contribution from non-NA assets, while Sweden draws most of its contribution from inside the conventional boundary. Conventional productivity statistics, therefore, risk understating productivity-relevant intangible activity more strongly in some economies than in others.

The fifth conditioning factor is the horizon over which productivity effects become visible. The L1 result is consistent with the J-curve accounts, but the timing horizon found here is shorter than the asset-specific horizons identified in earlier studies, where ICT operates with seven-to-eight-year lags in Swedish data, while R&D appears to be more contemporaneous (Edquist & Henrekson, 2017b). One possible explanation is that the broader intangible mix captured here, together with the larger role of KIS in the contemporary Swedish economy, produces a more immediate aggregate timing structure than the earlier ICT-centred evidence registered. The thesis cannot distinguish this from the possibility that the timing structure of intangible investment itself has changed over time, but the contrast suggests that the relationship between intangible investment and productivity is sensitive to the sectoral and historical context in which it is observed.

Taken together, these factors point toward a refinement rather than a rejection of the knowledge-economy narrative. The results are not consistent with a pessimistic reading in which intangibles and KIS are unable to support productivity growth, but they also qualify the expectations attached to intangible-intensive and knowledge-intensive growth.

9. Implications

The main implication of the findings is that the knowledge-economy transition should not be evaluated only by its inputs. Measures such as intangible investment intensity, KIS employment, innovation rankings and digital adoption describe the depth of structural change toward knowledge-intensive activity, but they do not by themselves demonstrate sustained productivity growth. The findings therefore support the knowledge-economy interpretation only in a qualified sense, since these features appear productivity-supporting without being equivalent to aggregate productivity leadership. The Swedish case makes this distinction especially visible because Sweden already approximates the kind of intangible-intensive economy often presented in European competitiveness strategies.

This matters for policy, but not in the sense that the thesis can identify which instruments should be used, since it does not directly test policy interventions, institutional reforms, or firm-level diffusion mechanisms. The implication is more refined, suggesting that policy debates centred on "more digitalisation", "more innovation" or "more intangible investment" risk staying at the level of inputs unless they also ask how those investments become productivity-relevant across sectors. In this sense, the thesis supports a shift in emphasis from the presence of knowledge-economy assets toward their productivity consequences.

The same point matters for how future sources of knowledge-economy productivity are interpreted. Artificial intelligence, data-intensive services, organisational automation, and the continued reorganisation of GVCs all reinforce the expectation that advanced economies can generate growth by moving toward knowledge- and intangibles-intensive activities. This thesis does not analyse AI directly, and its data end before the main diffusion of generative AI, but the findings still caution against reading adoption, investment or structural positioning as evidence of productivity effects in advance. If new technologies and higher-value functions follow the logic of earlier digital and intangible transitions, their productivity effects are likely to depend on complementary investments in software, data systems, skills, management practices and organisational redesign, and on whether these gains extend beyond particular firms or sectors. The timing result in this thesis is consistent with this broader logic, since the relationship between intangible intensity and LP growth appears with delay rather than contemporaneously. The same caution applies to GVC upgrading, where movement into higher-value functions may still fail to translate into broad productivity gains. Future research may therefore be particularly important in assessing whether these patterns hold beyond the specific group of advanced European economies examined here, how they differ across more detailed sectoral and intangible asset classifications, and whether the current post-2021 phase of knowledge-intensive growth follows similar timing and reallocation dynamics to earlier intangible-intensive transitions.

The broader contribution of the thesis is therefore not to reject the knowledge-economy interpretation, but to show why the expansion of intangible-intensive and knowledge-intensive activity alone is insufficient as evidence of strong aggregate productivity performance.

10. Conclusion

This thesis began with a productivity puzzle. The structural shift toward knowledge-intensive activity and intangible investment continued through the 2000s and beyond, but aggregate productivity growth across advanced European economies weakened rather than accelerated. Sweden made this tension especially visible, since it entered the analysis as one of Europe's most knowledge-intensive economies while still experiencing the same broad post-2000 slowdown. The thesis asked to what extent intangible investment and knowledge-intensive activity are reflected in measurable LP dynamics in Sweden and comparable European economies over 1995-2021. All three mechanisms are identifiable in the data and largely operate in the direction the framework predicts, though unevenly and not at magnitudes sufficient to generate a correspondingly strong aggregate productivity outcome.

The thesis, therefore, ends with a narrower but clearer answer to the productivity puzzle. Sweden is not a case where the knowledge-economy transition fails to appear in the data. It is a case where that transition appears clearly, but where its measurable effects remain conditional in magnitude, sectoral location and timing. For the competitiveness strategies and productivity commissions referenced at the outset, this reframes rather than dismisses the knowledge-economy emphasis, placing the analytical burden on the conditions through which intangible and knowledge-intensive activity becomes productivity-relevant rather than on the depth of the transition itself. The central finding is therefore not that intangible investment and KIS expansion are unproductive, but that the depth of the knowledge-economy transition does not mechanically translate into the aggregate productivity outcomes attached to it.

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Appendix

Table A1. LP Levels by Sector Type and Country

Sector type	Period	Sweden	Denmark	Finland	Netherlands	Germany
KIS	1995-2007	39.2	42.7	39.9	46.0	49.4
	2007-2013	47.2	48.8	40.1	50.6	45.6
	2013-2021	50.8	53.9	38.7	50.2	48.0
High-tech manuf.	1995-2007	19.3	57.3	51.8	43.8	34.3
	2007-2013	55.3	94.3	100.9	78.7	72.2
	2013-2021	57.4	152.2	108.1	126.9	85.1
Other manuf.	1995-2007	36.4	33.5	35.0	44.7	40.1
	2007-2013	44.8	41.8	43.1	56.2	49.2
	2013-2021	47.6	51.2	44.1	58.5	53.6
Other market	1995-2007	30.9	34.1	25.0	33.3	27.2
	2007-2013	33.4	35.3	28.5	36.1	31.2
	2013-2021	32.3	37.3	27.6	37.4	33.2

Notes: PPP-adjusted real value added per hour worked, rescaled ×1000 for readability. Swedish high-tech manufacturing reflects C26 only, since C21 is unavailable for Sweden in EU KLEMS.
Source: EU KLEMS & INTANProd 2025, author's calculations.

Table A2. Growth Accounting Decomposition - Sweden, Key Sectors

Sector	Period	LP	Intang.	TFP	ICT	Non-ICT	Labour comp.
Telecoms (J61)	1995-2007	9.24	1.05	8.72	-1.46	0.71	0.23
	2008-2012	5.61	0.18	5.07	-0.89	1.23	0.02
	2013-2021	6.16	0.57	4.17	-0.39	1.77	0.04

IT services (J62-J63)	1995-2007	2.25	1.16	0.18	-0.35	0.13	1.12
	2008-2012	4.07	6.01	-2.37	0.09	0.21	0.12
	2013-2021	4.88	2.07	2.12	0.18	0.41	0.09
Finance & insurance (K)	1995-2007	3.11	1.64	0.92	0.19	-0.26	0.61
	2008-2012	1.66	0.87	0.00	0.18	0.19	0.41
	2013-2021	2.39	0.64	1.72	-0.06	-0.14	0.23
Prof. & scientific (M)	1995-2007	2.10	1.20	-0.37	0.07	0.14	1.07
	2008-2012	0.33	0.90	-0.62	0.01	0.07	-0.04
	2013-2021	1.99	0.97	0.74	0.02	0.06	0.20
Admin. & support (N)	1995-2007	2.45	0.04	0.86	-0.28	0.58	1.25
	2008-2012	0.02	0.39	-0.89	-0.11	0.42	0.22
	2013-2021	-0.47	-0.11	-0.80	-0.02	0.28	0.18
Water transport (H50)	1995-2007	4.20	-0.49	4.45	0.19	0.59	-0.55
	2008-2012	2.45	-0.15	4.54	-0.14	-1.50	-0.29
	2013-2021	4.65	0.31	3.21	0.11	0.73	0.29
Air transport (H51)	1995-2007	5.57	0.83	-4.24	1.09	2.54	5.36
	2008-2012	-0.75	-0.48	3.07	-0.74	-2.42	-0.19
	2013-2021	5.75	0.61	1.66	0.04	3.32	0.26
Arts & recreation (R)	1995-2007	1.22	0.45	-0.68	0.09	0.38	0.98
	2008-2012	0.26	0.25	-0.61	-0.20	0.45	0.37
	2013-2021	-0.93	0.33	-1.74	-0.02	0.52	-0.02
Computers & electronics (C26)	1995-2007	19.02	3.26	14.63	-0.11	0.24	1.01

	2008-2012	-2.92	-7.29	4.38	-0.09	0.02	0.06
	2013-2021	2.49	-2.56	5.04	-0.08	-0.22	0.32
Electrical equipment (C27)	1995-2007	3.50	0.84	2.09	0.00	0.49	0.08
	2008-2012	-1.97	0.11	-3.04	0.14	0.49	0.33
	2013-2021	3.87	0.95	1.10	0.27	1.17	0.38
Machinery & equipment (C28)	1995-2007	4.24	0.60	2.69	-0.30	0.48	0.78
	2008-2012	-0.05	1.85	-2.74	-0.01	0.69	0.14
	2013-2021	1.95	1.13	0.61	-0.02	-0.06	0.30
Transport equipment (C29-C30)	1995-2007	5.44	-0.70	4.91	0.15	0.51	0.56
	2008-2012	2.79	2.18	0.20	-0.10	0.36	0.15
	2013-2021	5.15	2.14	2.51	-0.02	0.24	0.28
Market economy (MARKT)	1995-2007	3.57	0.63	1.94	-0.04	0.52	0.52
	2008-2012	0.43	0.47	-0.52	-0.09	0.40	0.17
	2013-2021	2.24	0.78	0.89	0.01	0.31	0.26

Notes: Annual contributions to LP growth in percentage points, averaged across each sub-period. Coverage includes all KIS sectors and the manufacturing sectors most central to the Swedish industrial base (computers and electronics, electrical equipment, machinery, transport equipment), with MARKT included as the market-economy benchmark.
Source: EU KLEMS and INTANProd 2025, author’s calculations.

Table A3. Intangible Capital Contributions: NA vs Non-NA Accounts

		Sweden			Denmark			Finland			Netherlands			Germany		
Sector type	**Period**	**Total**	**Non-NA**	**NA**	**Total**	**Non-NA**	**NA**	**Total**	**Non-NA**	**NA**	**Total**	**Non-NA**	**NA**	**Total**	**Non-NA**	**NA**
KIS	1995-2007	0.73	0.19	0.54	0.64	0.29	0.34	0.50	0.19	0.32	0.45	0.19	0.34	0.42	0.17	0.25
	2008-2012	0.97	0.23	0.74	0.52	0.09	0.43	0.21	0.15	0.05	0.85	0.70	0.19	0.50	0.17	0.33
	2013-2021	0.64	0.23	0.43	0.44	0.24	0.20	0.78	0.54	0.24	1.02	0.74	0.36	0.68	0.32	0.36
High-tech manuf.	1995-2007	3.26	0.50	2.76	1.95	0.33	1.63	2.79	0.61	2.18	1.71	0.99	0.72	0.54	0.28	0.26
	2008-2012	-7.29	-0.19	-7.10	1.99	-0.08	2.07	2.93	1.11	1.82	2.14	0.50	1.64	0.25	0.04	0.21
	2013-2021	-2.56	-0.87	-1.69	1.64	0.25	1.39	-0.21	-0.07	-0.13	-1.49	-0.50	-0.98	0.05	0.11	-0.07
Other manufacturing	1995-2007	0.29	0.10	0.19	0.54	0.18	0.37	0.33	0.09	0.24	0.46	0.16	0.30	0.27	0.22	0.05
	2008-2012	0.80	0.23	0.57	0.39	0.02	0.37	0.73	0.29	0.44	0.78	0.57	0.21	0.24	0.12	0.11
	2013-2021	0.78	0.36	0.42	0.23	0.28	-0.05	0.33	0.19	0.14	0.39	0.34	0.05	0.40	0.22	0.18
Other market	1995-2007	0.20	0.03	0.18	0.25	0.12	0.14	0.16	0.07	0.09	0.21	0.13	0.12	0.04	0.01	0.03
	2008-2012	0.38	0.32	0.06	0.28	0.22	0.06	0.33	0.17	0.15	0.22	0.17	0.06	0.08	0.05	0.03
	2013-2021	0.44	0.36	0.08	0.23	0.18	0.05	0.43	0.34	0.10	0.24	0.27	-0.05	0.21	0.17	0.05

Notes: Annual percentage point contributions to aggregate LP growth. Total = Within + Between.
Source: EU KLEMS & INTANProd 2025, author's calculations.

Table A4. Aggregate Shift-share Decomposition - Country Totals

Country	Period	*Within*	*Between*	*Total*
Sweden	1995-2007	+3.65	+0.04	+3.69
Denmark		+1.55	+0.10	+1.65
Finland		+2.98	+0.28	+3.26
Netherlands		+2.55	-0.27	+2.28
Germany		+2.21	+0.16	+2.37
Sweden	2007-2013	-0.81	-0.19	-1.00
Denmark		+1.09	+0.25	+1.34
Finland		-1.37	-0.28	-1.65
Netherlands		+0.33	-0.10	+0.23
Germany		+0.01	-0.09	-0.08
Sweden	2013-2021	+1.00	+0.20	+1.20
Denmark		+2.15	-0.04	+2.11
Finland		+1.32	-0.10	+1.22
Netherlands		+0.57	-0.25	+0.32
Germany		+1.17	+0.03	+1.20

Source: EU KLEMS & INTANProd 2025, author's calculations.

AI Statement

During the preparation and writing of this thesis, certain AI-based tools were used as support tools to assist with specific tasks that did not replace my own intellectual work. All conceptual development, theoretical framing, empirical analysis, interpretation of results, and final writing decisions are my own.

Tools used: Claude (Anthropic), ChatGPT (OpenAI), and Grammarly Pro.

Degree of use:

Claude and ChatGPT were used for editorial feedback and consistency checking across the thesis, including reviewing structure and clarity, identifying terminological inconsistencies, reviewing the reference list against in-text citations, and drafting and refining table notes. Both were also used as discussion partners for how to frame and present results. During the data work, both tools assisted with generating and debugging Stata code for sector classification, variable construction, and empirical components. The underlying analytical decisions, including which sectors to include, how to construct variables, and how to specify the regression, are my own.

Grammarly Pro was used for grammatical and typographical checks throughout the thesis.

All output from these tools was reviewed before incorporation. The final thesis remains my own intellectual work, and I take full responsibility for its content.