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Spinning Jennies and Silicon:

The Economics of Innovating or Evaporating – Creative Destruction and Public Policies[1]

Balázs Égert[§]

Abstract

This paper reviews the contributions of the 2025 Nobel Prize in Economics laureates, Joel Mokyr, Philippe Aghion and Peter Howitt, to our understanding of innovation-driven economic growth, situating their work within the broader evolution of modern growth theory and empirical evidence. It highlights why the Industrial Revolution marked a transition to sustained, self-reinforcing technological progress and shows how Mokyr's emphasis on knowledge, culture and institutions complements Aghion and Howitt's Schumpeterian framework, which formalises innovation as a competitive process of firm entry, exit and technological replacement. The paper then uses these frameworks to interpret the widespread productivity slowdown observed in advanced OECD economies since the mid-2000s, arguing that weakened creative destruction, slower diffusion of frontier technologies, declining business dynamism and policy headwinds are key explanatory factors.

JEL codes: O30, O40, O43, L16, N10
Keywords: innovation; productivity; economic growth; creative destruction; institutions

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1. Introduction

Economic growth, one of the most central concepts in economics, reflects an economy's capacity to produce more goods and services over time, thereby improving living standards and creating opportunities for social progress. Sustained growth expands income, employment and public resources, enabling societies to invest in education, health, infrastructure and innovation. It can also support fiscal sustainability, as a growing economy generates higher tax revenues without increasing tax rates. At the same time, economic growth remains a key policy objective, not only for its material benefits but also because the manner in which it is achieved shapes broader social and environmental outcomes. Policymakers must balance the pursuit of higher output with concerns about inequality, environmental degradation and long-term resilience.

Economic growth has long stood at the core of economic research, both theoretical and empirical. Over the decades, several Nobel Prize laureates, from Solow and Romer to North, Krugman and Acemoglu, have sought to uncover the mechanisms driving long-run growth. Building on this tradition, the 2025 Economics Nobel Prize winners, Joel Mokyr, Philippe Aghion and Peter Howitt have made particularly influential contributions to our understanding of the central role of innovation in modern economic development. Their work sheds light on why innovation lies at the heart of productivity and growth, and how the interaction between institutions, technology, competition and entrepreneurship shapes both the pace and the direction of economic progress.

This article appraises the contributions of Joel Mokyr, Philippe Aghion and Peter Howitt by tracing how the analysis of innovation has evolved from the neoclassical emphasis on capital accumulation to an endogenous theory of technological progress. It first discusses their core contributions. The paper begins with Mokyr's explanation of why the Industrial Revolution triggered a more than two-century-long phase of self-sustaining, innovation-led growth, in sharp contrast to earlier, short-lived episodes of technological advance. It then turns to Aghion and Howitt's formalisation of Schumpeter's process of creative destruction, through which new firms and technologies continually displace older, less productive ones. Building on these foundations, the paper highlights key stylised facts that illustrate the empirical relevance of their ideas and shows how their frameworks remain highly informative for understanding the prolonged productivity slowdown observed in many advanced OECD economies. It also considers other complementary factors and policies shaping innovation outcomes, before concluding with a discussion of policy options to reignite innovation, productivity and long-term economic growth.

2. Economic growth in the economics literature

Modern growth theory starts with Solow (*Nobel 1987*): output rises through factor accumulation, physical capital, labour and human capital, but long-run growth ultimately comes from total factor productivity (TFP). "Productivity isn't everything, but in the long run it is almost everything" has become an often-cited sentence in modern economics (*Krugman 1994*). Lucas (*Nobel 1995*) formalised the role of human capital accumulation and externalities; Arrow (*Nobel 1972*) introduced "learning-by-doing"; and Romer (Nobel 2018) made innovation and ideas endogenous, showing how R&D, knowledge spillovers and scale effects can sustain growth.

Trade and FDI enter as engines and conduits: openness raises competitive pressure and market size. Krugman's new trade and economic geography (*Nobel 2008*) showed how scale economies, knowledge spillovers and market size could drive productivity growth and sustain increasing return. FDI and global value chains diffuse technology and managerial know-how across borders, feeding TFP.

Institutions shape all of these channels. Following Acemoglu, Johnson and Robinson (*Nobel 2024*), economic and political institutions – such as property rights and the rule of law – have a decisive impact on why some countries are rich and others poor. Nobel work by Douglass North (*Nobel 1993*) and Elinor

Ostrom (*Nobel 2009*) explains how rules, enforcement and collective governance reduce transaction costs and enable cooperation, while Simon Kuznets (*Nobel 1971*) highlighted structural transformation, e.g. the shift from agriculture to industry/services, as a hallmark of modern growth.

The consensus is clear: while factor accumulation initiates development, sustained prosperity depends on TFP growth, which in turn rests on innovation, human capital, openness and strong institutions. Innovation is a key driver of economic development and growth because it fuels productivity, competitiveness and long-term prosperity.[2] By creating new products, processes and technologies, innovation allows firms to produce more efficiently and meet evolving consumer needs. It enables economies to move up the value chain, generate high-quality jobs and adapt to structural changes, such as digitalisation and the green transition. Beyond boosting output, innovation also fosters knowledge spillovers, ideas and techniques that spread across sectors, magnifying its impact on overall growth. In essence, innovation transforms resources and talent into sustained economic progress.

Yet innovation can only flourish under certain conditions. The 2025 Economics Nobel laureates elaborated these conditions. Joel Mokyr (*Nobel 2025*) explained why the Industrial Revolution marked the beginning of more than two centuries of persistent economic growth fuelled by innovation, unlike earlier episodes where technological advances yielded only temporary gains. His work highlighted the role of an open, knowledge-based culture and supportive institutions, and the connection between theoretical advancement in science with practice-oriented engineering in transforming invention into real-life products and thus into sustained productivity growth. Philippe Aghion and Peter Howitt (*Nobel 2025*) formalised the Schumpeterian process of creative destruction to explain how innovation arises from competition among firms and drives long-run productivity growth since the late 1940s.

3. Innovation in the empirical growth literature

Empirical growth research has developed along three main strands, each mapping directly to the theoretical drivers of growth: factor accumulation, innovation, total factor productivity (TFP) and institutions. First, growth and development accounting provide the quantitative foundation. Growth accounting (*Solow 1957*) decomposes changes in output over time into the contributions of capital deepening, labour input and a residual capturing TFP growth. This approach shows that while capital accumulation explains much of short-run growth, sustained improvements in living standards require persistent gains in TFP, consistent with Solow and Romer's emphasis on technological progress and innovation. Development accounting, by contrast, explains cross-country income level differences by comparing factor inputs and productivity levels at a given point in time. Studies such as *Hall and Jones* (*1999*) show that even large cross-country differences in physical and human capital cannot fully explain income gaps, leaving TFP as the dominant source of divergence in prosperity. Together, these accounting exercises bridge theory and evidence: factor accumulation drives early growth, while long-run divergence stems from differences in innovation, efficiency and institutional quality.

Second, cross-country econometric analyses, such as the *Barro – Sala-i-Martin* (*2003*) conditional convergence framework, investigate the determinants of growth across nations. These studies confirm that, controlling for structural factors, poorer countries tend to grow faster, but the speed of convergence depends critically on education, institutional quality, trade openness and macroeconomic stability. Later refinements explicitly bring in innovation and technology diffusion (R&D, patents, adoption) and suggest that growth determinants interact rather than operate in isolation (*Comin – Hobijn 2010*).[3]

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[2] Aghion & Howitt's and Mokyr's accounts of innovation focus mainly on frontier innovations. However, most countries grow primarily by diffusing and adapting existing technologies, which supports convergence toward the technological frontier.

[3] They also highlight non-linearities and threshold effects: for example, the returns on education or openness rise sharply only beyond certain institutional or human-capital thresholds. Cross-country panels and instrumental-variable approaches

Third, micro-based productivity and innovation studies connect aggregate patterns to firm-level behaviour. Using plant- and firm-level data, research by *Hsieh – Klenow* (*2009*) and others shows that misallocation of capital and labour, driven by regulatory barriers, credit frictions or weak institutions, accounts for large cross-country productivity gaps. Other work exploits firm-level R&D, patent and trade data to demonstrate that innovation raises productivity both directly and through knowledge spillovers, and that human capital enhances the ability to absorb and adapt foreign technologies (*Crépon et al. 1998; Jaffe et al. 1993; Bloom et al, 2013; Griffith et al. 2003*). Experimental evidence from Banerjee, Duflo and Kremer (*Nobel 2019*) further highlights how micro-level constraints in credit, education and governance aggregate into slower factor accumulation and weaker innovation at the macro level.

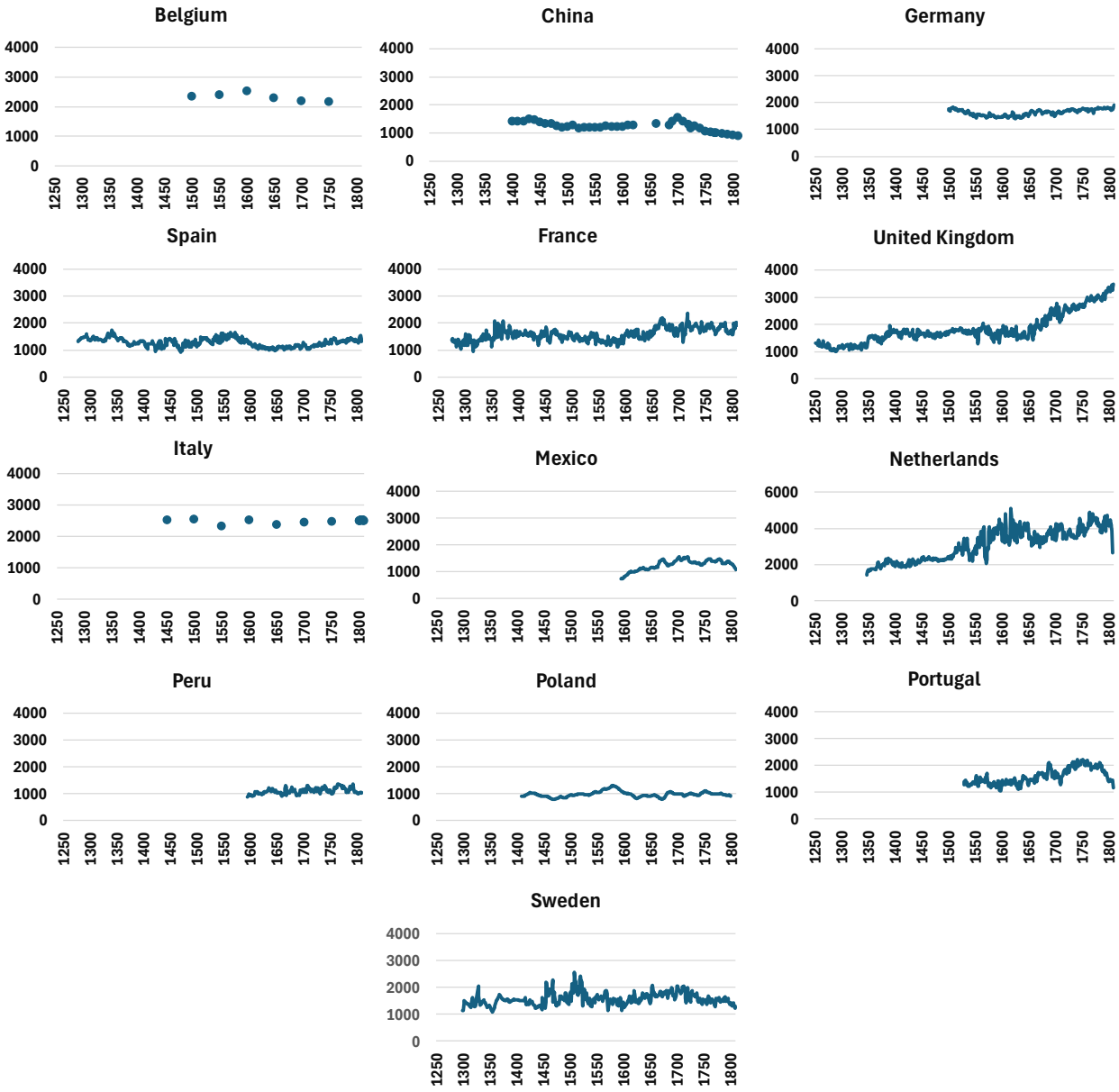
All three strands converge on the conclusion that while factor accumulation initiates growth, only innovation, efficient reallocation and strong institutions can sustain it in the long run.

4. Innovation, productivity and growth since the Industrial Revolution

For most of Europe's ancient and medieval history, technological progress was real but sporadic. Innovations such as Gutenberg's printing press, mill power and early scientific instruments including the telescope, microscope, barometer, thermometer and precision clocks, did appear, but they arrived in isolated bursts. They rarely accumulated or reinforced one another, and temporary increases in productivity were typically followed by a return to stagnation. The historical Maddison dataset shows that per capita incomes remained broadly flat for centuries. For example, per capita income in Spain was not significantly different in the 13th and 14th centuries compared with the 17th century. Similarly, economic development in 17th-century France was not substantially different from that in the mid-1300s. Other countries with long-run data available, such as Belgium, China, Germany, Italy and Poland, display similar patterns. Britain and the Netherlands, however, provide notable exceptions. The Netherlands experienced a significant rise in economic prosperity during the 16th century, reflecting the boom in international trade, while in Britain, per capita income began to rise gradually from the mid-17th century, indicating an early shift in economic power (*Figure 1*).

(e.g. Acemoglu et al. 2001) further establish the causal role of inclusive institutions, consistent with the theoretical insights of North, Ostrom, Acemoglu and Robinson on governance and incentives.

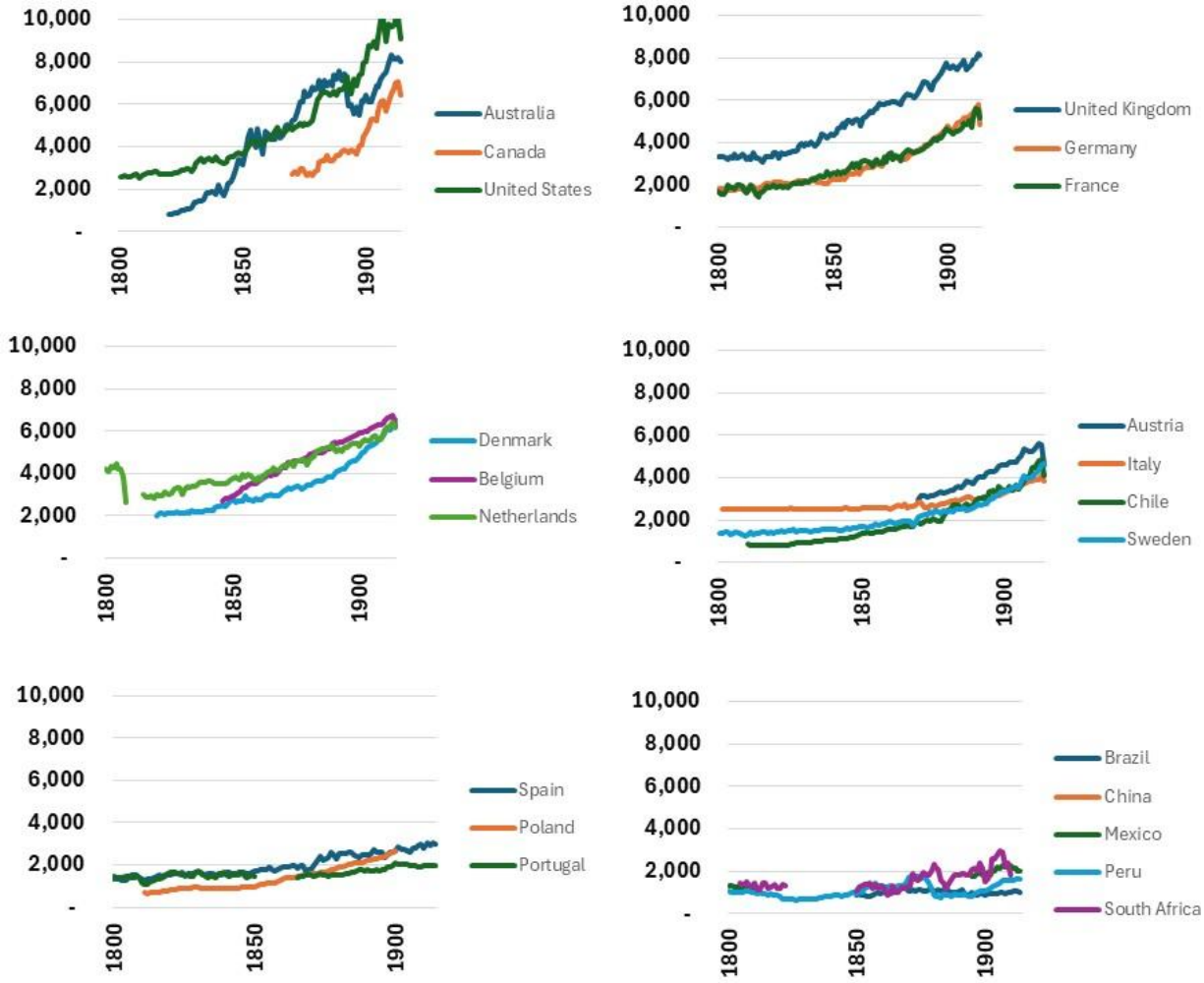
Figure 1. Evolution of per capita income from 1250 to 1800 (USD in 2011 prices)



Source: Maddison Project Database 2023 (https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2023)

However, from the late 18th century onward, this long-standing pattern broke. Within a relatively short period, Europe moved from artisanal workshops to steam engines, mechanised factories, railways and unprecedented mass prosperity. This transformation, started in Britain, initially slowly but gradually accelerating towards the second half of the 19th century and eventually spread to other parts of Europe, including Germany, France, the Netherlands and Belgium, followed by a later and smaller wave in Italy, Sweden, Spain and Poland. Still, other parts of Europe (Portugal) and the world (China and Peru) remained in the low growth regime (*Figure 2*).

Figure 2. Evolution of per capita income from 1800 to 1914 (USD in 2011 prices)



Source: Maddison Project Database 2023 (https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2023)

Joel Mokyr's work explains how this miracle happened. In fact, his work has reshaped our understanding of the origins and mechanisms of long-run economic growth by placing knowledge, institutions and cultural attitudes toward innovation at the centre of economic development (*Mokyr 1992, 2012*). His contributions offer a historically grounded explanation of how societies produce, organise and apply useful knowledge and translate ideas into sustained technological progress.

Mokyr's central argument is that the Industrial Revolution was not driven primarily by coal endowments or capital accumulation, nor was it merely a sequence of mechanical inventions or a response to relative factor prices. These conditions existed elsewhere without triggering sustained technological change. Rather, he argues, it was the consequence of a unique cultural and institutional transformation in Europe, which he calls the Industrial Enlightenment (*Mokyr 2012*).

The post-1700 period witnessed mechanisms for systematic accumulation of useful knowledge, including the establishment of institutionalised scientific societies, the codification of technical and scientific knowledge, norms of open scientific debate, improvements in communication, networking and dissemination, and a culture that valued problem-solving (*Mokyr 2012*). Artisans and scientists began to talk to one another. Inventors shared ideas in correspondence networks, coffee houses, philosophical societies and early scientific journals. Famous inventors – but also thousands of tinkerers, mechanics,

instrument builders and autodidacts – perfected practical technologies in successive waves, transforming and creating whole industries. The belief that knowledge could improve society became widespread. This shift turned innovation into a cumulative, self-reinforcing process. In this view, societies prosper when they nurture openness, experimentation and freedom of thought (*Mokyr 2012*).

Indeed, Mokyr provides a micro-foundation for how innovation actually happens. His framework links three elements: (1) a formal understanding of natural laws; (2) practical techniques applying these natural laws and focused on how things can be made and improved in practice; and (3) a market and institutional environment that rewards experimentation (*Mokyr 1992, 2012*). This resonates strongly with the institutional perspective of *North* (*1990*) and the emphasis on social norms and self-governance in *Ostrom* (*1990*), both Nobel laureates. In other words, Europe's new emerging intellectual climate was focused on empiricism, openness to experimentation and a belief in useful knowledge, and it created an environment in which new ideas were systematically generated, tested, disseminated, applied, turned into products, commercialised and merchandised.

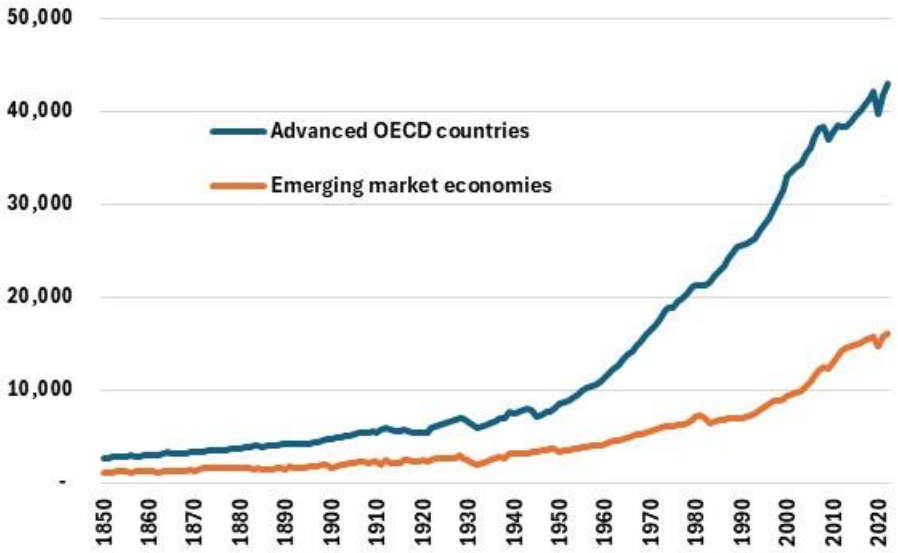
The Industrial Revolution, in Mokyr's view, emerged from a positive feedback loop between knowledge and incentives. New scientific understanding created opportunities for technological improvements, while a decentralised, competitive European political map encouraged inventors to seek patrons, apply their work commercially and migrate when constrained (*Mokyr 1992*). The lack of these interactions helps explain why earlier bursts of ingenuity did not translate into sustained growth. For example, the Hellenistic and Roman worlds produced sophisticated engineering inventions, but saw limited diffusion into broad-based productivity gains. Later episodes such as China's major advances (printing, metallurgy, navigation) or the Islamic Golden Age's scientific and mechanical achievements similarly failed to generate a self-sustaining industrial take-off.

Mokyr also emphasises the supply side of ideas. Whereas endogenous growth theory (*Romer 1990*; *Aghion – Howitt 1992*) models innovation incentives and the macroeconomic consequences of R&D and market structure, Mokyr explains what shapes the production of ideas themselves: how societies cultivate skills, curiosity and intellectual openness (*Mokyr 1992, 2012*). His work thus complements the economics Nobel tradition by offering a historical-institutional explanation for why the West innovated first, why growth persisted and how knowledge regimes evolve. Overall, Mokyr's contribution shows that sustained economic growth is fundamentally a cultural and institutional achievement, rooted in the organisation of knowledge and the social attitudes that make innovation possible (*Royal Swedish Academy of Sciences 2025*).

5. Innovation, creative destruction and the post-World War II period

If Joel Mokyr explains how the modern engine of growth was ignited, Philippe Aghion and Peter Howitt explain how it continues to run. Motivated by the post-World War II growth experience, their framework helps make sense of the explosive and unprecedented acceleration of economic growth observed in leading OECD countries. Those frontier advances then benefited many other countries indirectly, as new technologies diffused internationally and were adopted and adapted through trade, FDI and imitation. Post-war economic development far exceeded the development seen in the 19th and early 20th centuries. While per capita income levels doubled from 1800 to around 1900, they increased by a factor between 4 and 6 from 1950 to 2020 in Western countries (*Figure 3 and Figure 10 in the annex*).

Figure 3. GDP per capita, 1850–2022 (USD in 2011 prices)



Note: Advanced OECD countries is the average of Australia, Austria, Belgium, Canada, Germany, Denmark, Spain, France, the United Kingdom, the Netherlands, Poland, Portugal, Sweden and the United States. Emerging market economies is the average of Brazil, Chile, China, Mexico, Peru and South Africa.

Source: Maddison Project Database 2023 (https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2023)

Aghion and Howitt's central idea is borrowed from Joseph Schumpeter. *Schumpeter* (*1911, 1942*) described capitalism as driven by "gales of creative destruction", in which new firms and technologies displace old ones, generating both progress and instability. When a new firm invents a better product, the old one loses value. When a new method of production appears, outdated factories are scrapped. Each innovation replaces older technologies, reallocates market shares and forces firms to exit. Creative destruction is not a side effect of growth but its beating heart. However, Schumpeter's account was largely descriptive and lacked a formal model specifying how frequently innovations occur, how large their quality improvements are, and how profits and R&D incentives interact.

Aghion and Howitt's seminal 1992 paper transforms Schumpeter's idea of creative destruction into a fully micro-founded theory of innovation-driven growth based on Schumpeterian creative destruction (*Aghion – Howitt 1992*). Their paper and the subsequent body of work provided what earlier Nobel laureates had not: a rigorous framework in which long-run growth is driven by the incentives of firms to innovate, compete, enter and replace incumbents (*Aghion – Howitt 1997, 2008*). Their Schumpeterian model shows that growth results from a continual flow of innovations by entrants and incumbents, each seeking monopoly rents but constantly challenged by the next wave of innovators (*Royal Swedish Academy of Sciences 2025*).

They develop an endogenous growth model in which innovations arrive stochastically, raise productivity step by step through a quality-ladder mechanism and generate temporary monopoly profits until displaced by newer ideas (*Aghion – Howitt 1992*). Aghion – Howitt shares key foundations with the Romer tradition of endogenous growth: innovation is a profit-driven activity under imperfect competition, innovators earn market power rents and knowledge spillovers mean that private and social returns to R&D diverge. The crucial difference is the nature of technological progress. Romer-style models emphasise largely horizontal innovation and growth through expanding product varieties, whilst Aghion–Howitt emphasises vertical innovation, in which new ideas improve quality and productivity along ladders and typically replace older technologies, making creative destruction a central mechanism rather than a by-product.

In baseline Schumpeterian models, the private return on innovating scales with market size: a larger (or more integrated) market raises the rents from a successful innovation, which can increase equilibrium R&D effort and, under the baseline specification, the long-run growth rate. This scale effect parallels the market-size channel in *Romer* (*1990*).

By making firms' R&D choices depend on expected profits, competition, intellectual property protection and other policy variables, they show precisely when innovation incentives rise or fall, allowing clear analysis of how patents, taxes, subsidies and market structure affect long-run growth (*Aghion – Howitt 1997, 2008*). Their framework also distinguishes incremental from radical innovation, explains how distance to the technological frontier shapes growth strategies and models the strategic behaviour of incumbents and entrants (*Aghion et al. 2005b*; *Aghion – Howitt 2008*). Because the model is explicit, it links directly to data on patents, R&D, entry and exit, and productivity, providing testable predictions and a rigorous foundation for modern empirical research on innovation and growth (*Aghion et al. 2013*).

This framework has profound empirical and policy implications. First, their model helps answer the simple question: why do some economies grow faster than others, even with the same access to global technology? Their answer is because some economies allow new firms to enter, challenge incumbents and push the frontier forward, while others protect old firms and stagnate (*Aghion – Howitt 2008*; *Aghion et al. 2005*b).

Second, they emphasise the crucial role of frontier innovation versus catch-up growth. In late-industrialising economies, growth arises from technology adoption and structural transformation; in frontier countries, growth depends on innovation intensity, education quality, venture capital, and the flexibility of labour and product markets. Thus, frontier economies are more sensitive to innovation-policy choices (*Aghion – Howitt 2008*; *Aghion 2009*; *Aghion et al. 2009*).

Third, Aghion and Howitt's research reveals that innovation is intensely microeconomic. It happens inside firms, in labs, design offices and startups, driven by people who want to "escape competition" by inventing something better. Too little competition makes firms lazy; too much makes innovation unprofitable. The sweet spot lies in the middle. In a follow-up work, *Aghion et al.* (*2015*) show this formally and highlights the central role of competition in innovation. They find that contrary to fears that competition discourages research, the relationship is inverse-U-shaped: too little competition protects incumbents, while too much erodes the rents needed to finance innovation. The optimal point stimulates firms to innovate in order to "escape competition" (*Aghion et al. 2005a*; *Aghion – Griffith 2005*).

Fourth, Aghion and Howitt provide a unified framework linking innovation, inequality, competition, taxation, education, financial development and industrial policy (*Aghion – Howitt 1997, 2008*; *Aghion et al. 2013*). Their research shows: i) how education and human-capital policies shape innovation capacity (*Aghion 2009*; *Aghion et al. 2009*), ii) how labour-market rigidities influence reallocation and innovation (*Aghion et al. 2009*; *Aghion – Howitt 2008*); iii) how trade and foreign direct investment accelerate creative destruction (*Aghion et al. 2005b*; *Aghion – Howitt 2008*); and iv) how carbon taxation and green innovation interact (directed technological change), demonstrating that appropriate combinations of carbon taxes and research subsidies can reorient innovation towards clean technologies without sacrificing long-run growth (*Acemoglu et al. 2012*).

Finally, their recent work examines industrial policy. Unlike the discredited picking winners approaches of mid-century, from a Schumpeterian perspective, a modern, competition-friendly industrial policy does not support incumbents but potential entrants in technologically dynamic sectors (*Aghion et al. 2015*). Their framework thus provides both macroeconomic justification and microeconomic guidance for modern innovation policy. This view offers a modern vision for industrial policy, not by subsidising old giants, but by supporting potential challengers in innovative sectors. They show that the state can help but must avoid suffocating the creative destruction that drives progress.

6. Innovation and employment

Aghion and Howitt's Schumpeterian growth framework links innovation to employment through creative destruction. New technologies and entrants expand some activities while displacing others. The key labour-market consequence is often reallocation. New jobs are created in new and expanding firms, whereas jobs are destroyed in shrinking and failing firms. Innovation can raise productivity, but it can also generate transitional unemployment and distributional costs (*Aghion – Howitt 1992*).

The long-run effect of faster growth and innovation on unemployment is ambiguous, because two forces pull in opposite directions. First, when technology improves faster, existing jobs become outdated sooner, raising separations and putting upward pressure on unemployment. At the same time, when the economy is growing faster, a new job or a new idea is likely to generate higher future profits, increasing the net present value of creating them. Firms are therefore more willing to hire and create new jobs, putting downward pressure on unemployment (*Aghion – Howitt 1994*).

Mokyr's long-term employment perspective relates to technological anxiety. Fears that new technologies will permanently destroy jobs recur throughout history, but past waves of mechanisation typically produced new tasks, new industries and new demand that absorbed labour over time. This process nonetheless imposed real short-run disruptions on particular occupations and regions (*Mokyr – Vickers – Ziebarth 2015*). Overall, the employment effects of innovation may depend crucially on institutions that facilitate reallocation (competition and labour market mobility) and adaptation (training policies).

Applied to Artificial Intelligence (AI) and employment, this same framework implies that outcomes depend on whether AI primarily accelerates task substitution (raising separations and churn) or also boosts entry, new activities and vacancy creation (raising job-finding). In other words, AI can increase measured job turnover and transitional unemployment if it speeds creative destruction faster than the economy's matching, training and reallocation mechanisms can absorb workers. But it can also reduce unemployment if it raises the profitability and pace of new firm creation and new job formation. Mokyr's technological anxiety perspective complements this by stressing that repeated historical waves of automation created severe displacement for some groups but were often followed by new tasks and industries. The key question for AI is the *speed and inclusiveness of adjustment* (skills, diffusion, institutions), not a mechanical prediction of permanent mass unemployment.

7. Public policies and innovation

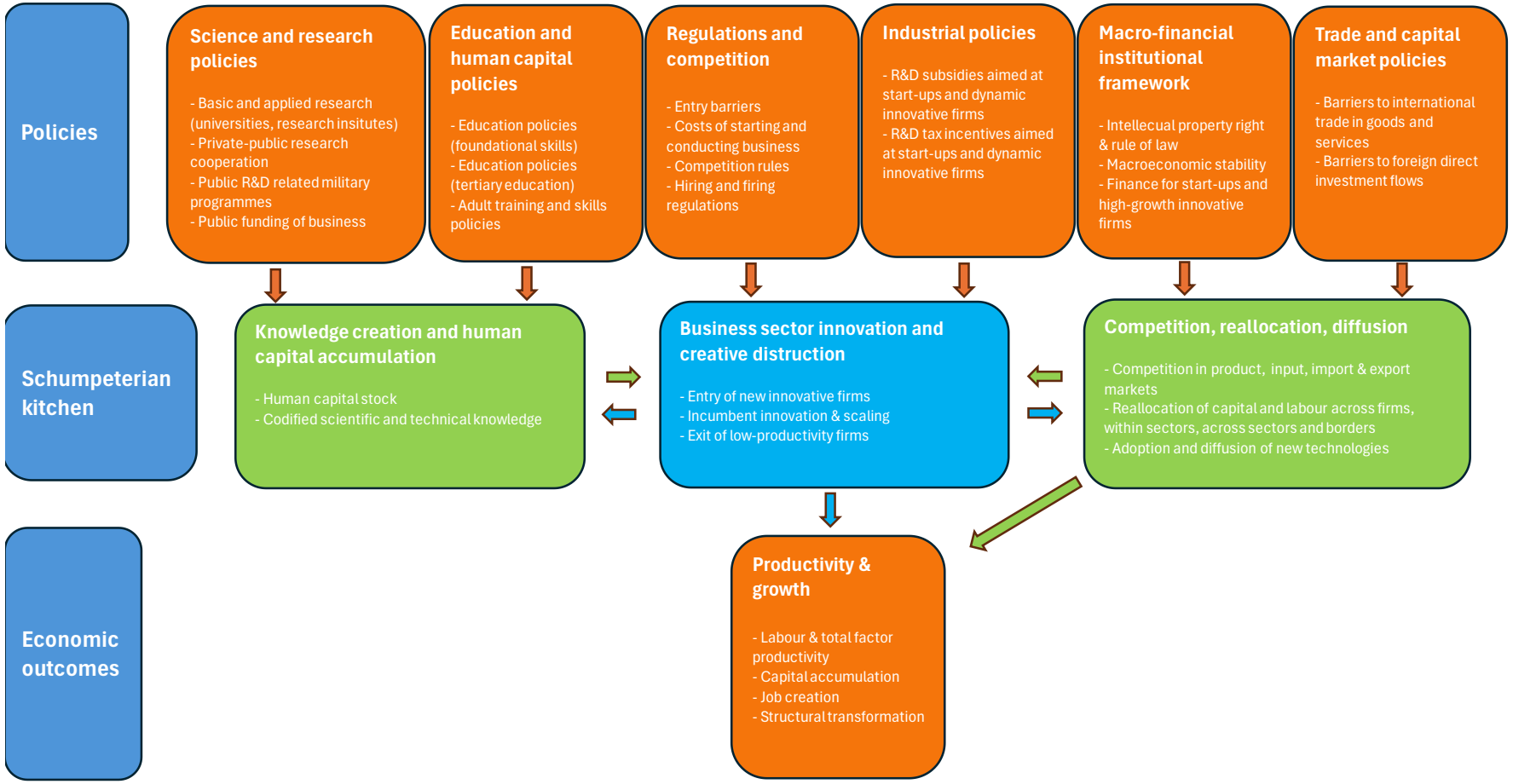
Aghion and Howitt's work helps explain why innovation, productivity and economic growth accelerated from the late 19th century and continued to surge after World War II. They place innovation incentives and diffusion at the centre of a policy-sensitive growth process. In their Schumpeterian framework, sustained productivity growth depends not only on discoveries at the frontier, but also on the rate at which firms invest in R&D, adopt new technologies and reallocate resources toward more productive uses. This immediately brings public policy into the story: education and skills shape a country's ability to innovate and absorb technologies; openness to trade and foreign direct investment (FDI) expands access to ideas and financial development, affecting whether innovative projects, often risky and intangible, can be funded at scale.

Crucially, Aghion and Howitt link long-run growth to institutions and policies that frame entry, exit and competition, because creative destruction requires that new, more productive firms can enter and expand, while obsolete technologies and low-productivity firms shrink or exit. Competition policy, product-market regulation, bankruptcy regimes and administrative barriers to entry therefore influence how strongly innovation translates into aggregate productivity gains. Similarly, labour-market and social policies matter insofar as they shape mobility, reallocation and retraining, determining whether workers can move from declining activities into expanding innovative sectors. Intellectual property rights and

innovation policies (patents, R&D tax incentives, subsidies) further affect the private returns on discovery, but also interact with diffusion and competition.

Seen this way, this section organises the main public-policy channels to show how the long-run institutional changes highlighted by Mokyr (scientific capability, incentives, and a supportive institutional environment) are complemented by Aghion–Howitt's emphasis on competition and reallocation. We now turn to a closer examination of these key factors, as sketched in *Figure 4*.

Figure 4. Policies, innovation and economic outcomes

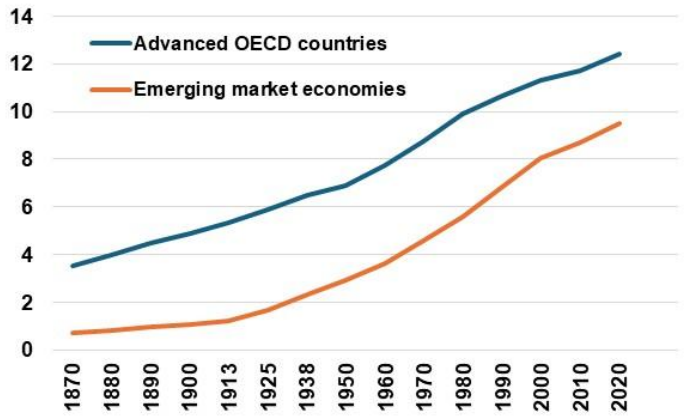


7.1. The rollout and upscaling of public education and the rise of human capital

Human capital is a central driver of innovation, underpinning the creation of new ideas, their practical application and the diffusion of technologies across firms, sectors and borders. Since the 19th century, the stock of human capital has expanded through three major waves of educational development that fundamentally transformed the innovative capacity of advanced economies. The first wave, in the late 19th century, established universal primary education to promote basic literacy and numeracy skills for industrialising societies, pioneered by Prussia, in need of literate army officers, and followed by other European countries, with France and the United Kingdom introducing compulsory schooling in the 1880s. By 1900, up to 70 per cent of children in Western Europe and the United States were enrolled in primary education, albeit with uneven quality. The second wave, from the late 1940s to the 1970s, brought the mass expansion of secondary education, as school-leaving ages were raised and lower secondary schooling became the norm. The third wave, from the 1970s onwards, saw the massification of tertiary education, transforming higher education from an elite system into a majority experience for younger cohorts in many OECD countries.

These successive expansions had profound innovation consequences: primary education enabled early industrialisation and the diffusion of mechanical technologies; secondary education supported the post-war productivity boom by providing skills for increasingly complex production; and tertiary education strengthened national innovation systems by expanding the supply of scientists and engineers, reinforcing universities as hubs of research and science-industry linkages, and fostering R&D, knowledge spillovers and the development of general-purpose technologies such as ICT, biotechnology and, more recently, artificial intelligence.

Figure 5. Mean years of schooling, 1870–2020



Note: Advanced OECD countries is the average of Australia, Austria, Belgium, Canada, Germany, Denmark, Spain, France, the United Kingdom, the Netherlands, Poland, Portugal, Sweden and the United States. Emerging market economies is the average of Brazil, Chile, China, Mexico, Peru and South Africa.
Source: Leandro Prados de la Escosura (2021) – with minor processing by Our World in Data. "Average years of schooling" [dataset]. Leandro Prados de la Escosura, "Augmented Human Development Index (AHDI) – Country data"; Leandro Prados de la Escosura, "Augmented Human Development Index (AHDI) – Regional data" [original data]. Retrieved 9 December 2025 from https://archive.ourworldindata.org/20251209-133038/grapher/years-of-schooling-prados-de-la-escosura.html (archived on 9 December 2025).

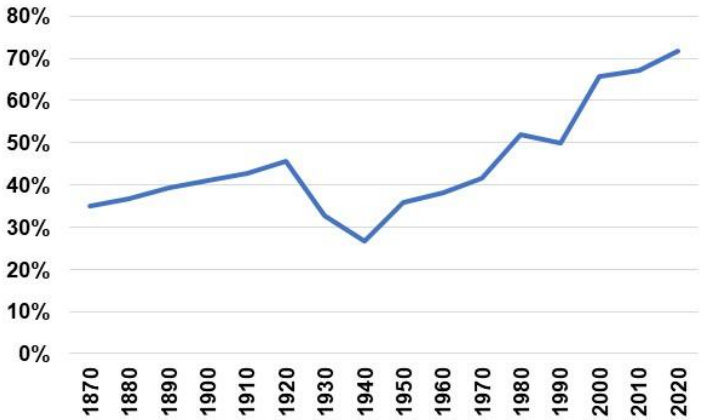
7.2. Trade integration, capital flows and technological diffusion

Since the early 19th century, international trade and capital flows among industrialised countries have expanded in successive waves, with temporary reversals but a clear long-run trend towards deeper integration. From 1870 to 1914, falling transport and communication costs (railways, steamships,

telegraph) and relatively liberal trade policies led to a sharp rise in trade among industrial economies, supporting specialisation and economies of scale in manufacturing. Trade and capital flows resumed after 1945. From the 1990s onwards, the creation of the WTO, falling ICT and transport costs, and the rise of global value chains pushed trade openness to historically unprecedented levels. Since the global financial crisis, trade integration has slowed and come under political pressure, but it remains far higher than at any time before the late 20th century (*Figure 6*).

The long-run integration of trade and capital markets strongly supported technological diffusion and returns on innovation. Open trade expanded market size, allowing firms to exploit increasing returns on scale and spread fixed R&D costs over much larger sales volumes. Trade in capital goods and intermediate inputs became a key channel for the international transmission of new technologies. Foreign direct investment further accelerated diffusion by transferring not only capital but also managerial practices, organisational know-how and proprietary technologies. International openness also reinforced specialisation in high-productivity, innovation-intensive sectors and strengthened incentives to invest in R&D. This process has accelerated technological diffusion and increased both private and social returns on innovation in the industrialised world.

Figure 6. Trade openness in the OECD average: Export and imports over GDP, 1870–2020



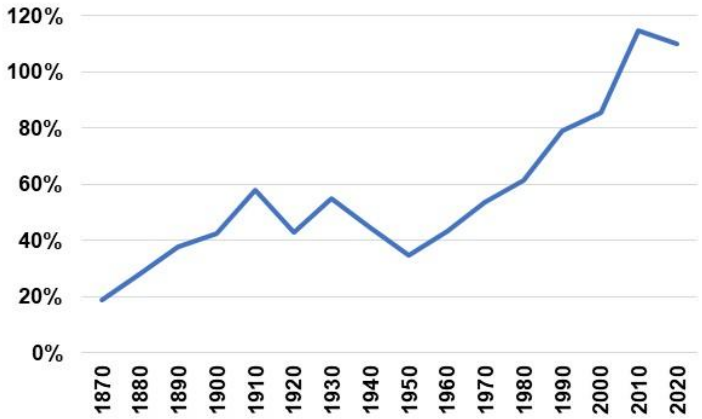
Note: Average of Australia, Belgium Canada, Switzerland, Germany, Denmark, Spain, Finland, France, the United Kingdom, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Sweden and the United States.
Source: Jordà-Schularick-Taylor Macrohistory Database (https://www.macrohistory.net/database/)

7.3. Financial system development

Financial system development is central to expanding firms' access to external funding and thereby supporting innovation. Since the early 19th century, financial systems in industrialised economies have evolved from small, local banking networks into large, diversified systems combining powerful banks, deep capital markets, and more recently, specialised venture-capital and private-equity finance. Early advances in joint-stock banking, central banking and bond markets helped finance industrialisation and large infrastructure projects, while the tightly regulated, bank-dominated post-war system provided stability but limited risk-taking. From the late 1970s onwards, financial liberalisation, global integration and technological change spurred the rapid expansion of equity and bond markets, the rise of institutional investors and the emergence of venture capital as a key mechanism for funding high-risk, technology-intensive innovation. By relaxing financing constraints, well-developed financial systems,

banks and markets alike, enable firms to undertake long-term, intangible-intensive investments and pursue high-risk, high-reward experimentation.[4]

Figure 7. Credit-to-GDP ratios in the OECD average, 1870–2020



Source: Jordà-Schularick-Taylor Macrohistory Database (JST) (https://www.macrohistory.net/database/)

7.4. Intellectual property rights

Since the early 19th century, intellectual property rights (IPR) in today's OECD countries have evolved from patchy, nationally limited protections into broadly harmonised, enforceable systems designed to secure returns on innovation as part of a wider strengthening of institutions. Early patent and copyright laws existed in Britain, France and the US in the 18th–19th centuries, but coverage was narrow, enforcement uneven and international protection weak. In the late 19th and early 20th centuries, multilateral treaties such as the Paris Convention (patents, 1883) and the Berne Convention (copyright, 1886) began to create minimum common standards and the principle of national treatment, so inventors and authors enjoyed similar protections abroad as at home. After 1945, and especially from the 1960s onwards, most OECD countries progressively modernised their patent, copyright and trademark regimes, clarifying subject matter, procedures and durations, and building more professional patent offices and specialised courts, which improved legal certainty and reduced transaction costs for innovators.

From the 1980s and 1990s, IPR protection deepened and globalised further: the creation of the WTO's TRIPS Agreement (1994) set binding minimum standards for patents, trademarks and copyright for member countries, and many OECD members also strengthened protection for pharmaceuticals, software, semiconductors and other knowledge-intensive sectors, while expanding the role of trademarks, designs and (later) data and digital rights. At the same time, competition policy, contract enforcement, corporate governance and regulatory quality improved in most OECD economies, creating a broader institutional environment in which innovators could expect contracts to be enforced, piracy to be sanctioned and disputes to be resolved in a predictable way.

However, the desirability of strong patent protection remains contested. While patents can strengthen innovation incentives by allowing inventors to appropriate returns, they also create monopoly power and can slow diffusion or raise barriers for cumulative, follow-on innovation. A prominent critique argues that many innovation episodes have occurred with weaker intellectual monopoly rights and that strong IPR

[4] At the same time, the experience of financial crises has shown that when financial development is accompanied by inadequate regulation, instability can disrupt credit provision, damage firm balance sheets and undermine innovation. This underscores that innovative activity thrives most when financial systems are both well-developed and well-regulated.

can, in some settings, do more harm than good (*Boldrin – Levine 2008*). More generally, formal endogenous growth and trade frameworks treat IPR as a policy trade-off between dynamic innovation incentives and static efficiency and diffusion (*Grossman – Helpman 1993*).

7.5. The Cold War's arms and space race

During the Cold War, the arms race and the space race turned scientific and technological superiority into a core element of geopolitical competition, leading to massive public investment in both basic and applied research, especially in the United States and the Soviet Union. US-led military and space research generated general-purpose technologies that diffused internationally and became foundational infrastructures of the modern digital economy.

Defence and space agencies funded fundamental work in physics, mathematics, electronics, materials science and computer science, while also driving highly mission-oriented applied R&D in rocketry, guidance systems, satellites, sensors, computing and secure communications. In this process, the United States emerged as the world's central innovation powerhouse and technological hub, combining large defence budgets, world-class universities, federal research agencies and dynamic private firms. This US-centred innovation system generated major civilian spillovers with global diffusion to other advanced economies. The internet grew out of the defence-funded ARPANET project; GPS was developed as a military satellite navigation system before spreading to civilian use; and rapid advances in computation and microelectronics were driven by nuclear weapons, missile guidance and space exploration, with programmes such as Apollo accelerating the development and cost reduction of integrated circuits. For the most recent period, new empirical evidence indicates that defence-related public R&D significantly increases private business R&D and leads to substantial productivity gains in downstream industries, with cross-country spillovers through international technology diffusion (*Moretti et al. 2025*).

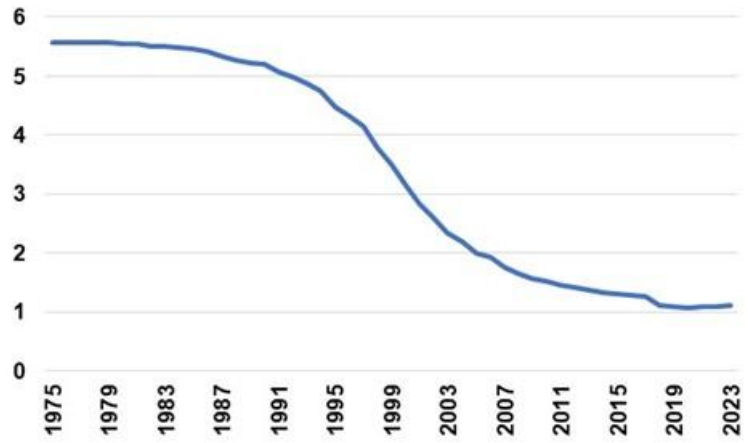
7.6. Competition policies and sectoral regulation

Relatively recent developments in competition and labour/product market policies, innovation-oriented tax instruments and digitalisation strategies have raised both the incentives and the capabilities for firms to innovate. Where these three areas are well-aligned (strong competitive pressure and reallocation, well-targeted R&D tax support, and broad-based digital adoption) OECD evidence tends to find stronger innovation, faster diffusion and higher productivity growth; where one or more are weak, productivity gains from new technologies are more muted.

First, competition, product and labour market policies have generally moved (with differences across countries and over time) towards more pro-competition, pro-entry frameworks since the 1980s: product market deregulation, the liberalisation of network industries and stronger competition enforcement have lowered barriers to entry and exit and reduced state control in many sectors, while labour market reforms have sought to combine basic protections with more flexible hiring and reallocation. The USA and other Anglo-Saxon countries were leading the way in creating more competition-friendly business environments. For instance, the US started deregulating and liberalising its network sectors, especially the telecoms in the early 1980s already, whereas Europe followed suit with a delay of decades (*Figure 8*).

These reforms tend to boost innovation and productivity by increasing the threat of entry, speeding the reallocation of labour and capital away from low-productivity incumbents, and allowing high-productivity, often younger, more innovative firms to grow faster. The recent policy debate is about how to sustain that dynamism in the face of rising market concentration and superstar firms in some digital and globalised industries.

Figure 8. Product market regulation in the OECD average, 1970–2020: Evolution of the Energy, Transport and Communications Regulation (ETCR) indicator

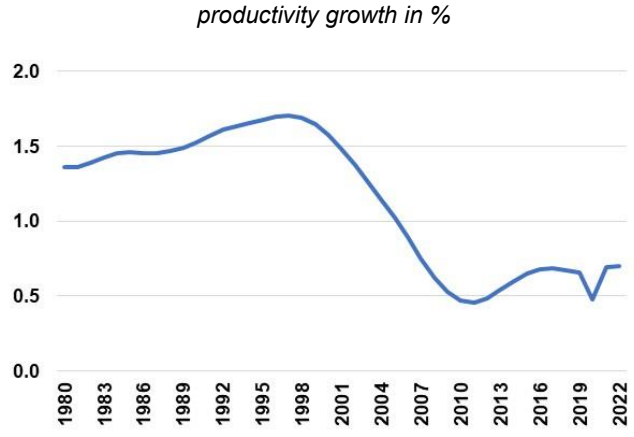


Note: Scale of 0 to 6 (0 = least regulated, 6 = most regulated)
Source: Calculations based on OECD. OECD ETCR indicators(https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwinqevukfCSAxVwU6QEHVrHCIYQFnoECB0QAQ&url=https%3A%2F%2Fwww.oecd.org%2Fcontent%2Fdam%2Foecd%2Fen%2Ftopics%2Fpolicy-sub-issues%2Fproduct-market-regulation%2FETCR%2520indicator%2520values.xlsx&usg=AOvVaw1J_tPcjCIvAne5F5S9W744&opi=89978449)

8. The post-2005 productivity slowdown

The staggering productivity gains and economic growth in the thirty years after World War II started slowing down in the 1990s and the growth engine started really stuttering in the post-2005 period. A marked, persistent decline in labour-productivity and total-factor-productivity growth has occurred across most advanced economies since the mid-2000s. The slowdown is broad-based, affecting the United States, the euro area, the United Kingdom, Japan and most other OECD economies, and is visible across many sectors rather than being confined to a few specific industries. In terms of magnitude, typical productivity growth rates in advanced economies fell from around 2–3 per cent per year in the late 1990s and early 2000s to around 1 per cent or less after the mid-2000s. *Figure 9* illustrates the marked slowdown in productivity growth from the mid-2000s onwards relative to earlier periods.

Figure 9. Productivity growth slowdown, OECD average



Note: Average TFP growth calculated for 17 OECD countries with full data coverage from 1980 to 2022.
Source: Calculations based on TFP data drawn from OECD (2023).

8.1. The Gordon vs. Mokyr debate: Innovation on the brink of a permanent decline?

The Gordon vs. Mokyr debate, which was so loud in academia a few years ago, was about whether there is a permanent slowdown in innovations. Robert Gordon represents the pessimistic view that most important technological breakthroughs have already happened (*Gordon 2012, 2016*). He points to electricity, the internal combustion engine, sanitation and mass production as unique, once-in-a-century innovations that transformed living standards and productivity. According to Gordon, recent innovations such as smartphones, social media, and even much of information technology mostly improve comfort and entertainment rather than fundamentally raising productivity. He also emphasises structural headwinds, such as aging populations, rising inequality, high debt and slowing educational progress. As a result, he predicts that advanced economies will experience permanently lower productivity growth in the long run.

Joel Mokyr strongly disagrees with this pessimistic view. He argues that innovation is not slowing down, but rather changing form. According to Mokyr, we are entering a new era of scientific and technological progress driven by artificial intelligence, biotechnology, materials science, neuroscience and other advanced fields. He emphasises that modern innovation is combinatorial, meaning that new ideas are created by recombining existing knowledge at an accelerating pace. He also stresses that major technologies often take a long time to show their full productivity impact, just as electricity and computers did in the past (*Mokyr 2017, 2018*). From this perspective, today's weak productivity growth does not mean that innovation has stalled. Instead, it may simply reflect slow diffusion. Mokyr therefore believes that long-run technological progress will continue.

More generally, Mokyr's line of thoughts illuminates contemporary growth challenges. Mokyr argues that societies stagnate when they become hostile to disruptive ideas, when vested interests gain power, or when ideology turns against openness, echoing the modern concerns of *Acemoglu – Robinson* (*2012*) about extractive institutions. His logic provides a framework for analysing the post-2005 productivity slowdown, where declining business dynamism, slower diffusion of frontier knowledge, risk aversion and regulatory rigidity may be constraining modern innovation systems (*Mokyr 2017, 2018*). Mokyr reminds us that innovation thrives in environments that reward creativity and welcome new ideas. Societies that fear change or protect incumbents risk stagnation.

8.2. Creative destruction and the productivity slowdown

Aghion's and Howitt's interpretation of innovation driven by creative destruction provides a bridge between these two opposing views (*Aghion – Howitt 1992, 2008*). Accordingly, economic growth depends not only on technology itself, but also on the incentives and institutions that shape innovation. Key factors include competition, access to finance, education, property rights and openness to new firms. Aghion emphasises the role of creative destruction, where new innovators replace old incumbents. If markets are competitive and entry barriers are low, innovation leads to strong productivity growth, supporting Mokyr's optimistic view. If incumbents block competition, investment is weak and inequality rises, innovation may fail to translate into growth, leading to outcomes closer to Gordon's pessimistic scenario. In this sense, growth is not technologically predetermined but depends on policy and institutional design.

More generally, Aghion and Howitt's Schumpeterian framework suggests why productivity growth might have slowed in advanced economies since the mid-2000s. It is not necessarily because we have run out of ideas. In their quality-ladder model, aggregate TFP growth is driven by the pace of creative destruction – the rate at which new technologies and entrants replace old ones, which depends on expected innovation rents, competition, and the ease of entry and reallocation (*Aghion – Howitt 1992,*

1994, 2008; Aghion et al. 2013). Growth can therefore slow when business dynamism weakens and diffusion slows, even if frontier science and invention remain active. This interpretation also resonates with Mokyr's emphasis on diffusion lags and institutional headwinds (*Mokyr 2017, 2018*).

The empirical literature indeed documents a decline in business dynamism, measured by firm entry and exit, job reallocation and the contribution of young firms to employment growth, in the United States and in other OECD economies. Using US Census microdata, *Decker et al.* (*2014, 2016, 2020*) and *Cooper et al.* (*2024*) show that start-up rates, job reallocation and the share of high-growth young firms have fallen sharply since 2000, contributing to weaker allocative efficiency and slower productivity growth. Parallel evidence shows that similar declines in entry rates and young-firm employment shares have occurred across many OECD countries, especially after the Global Financial Crisis (*OECD 2017*; *OECD 2019*). OECD work further shows that while productivity growth at the global technological frontier has remained relatively robust, productivity diffusion to laggard firms has slowed markedly, pointing to falling business dynamism and rising barriers to reallocation, rather than a collapse of frontier innovation as key drivers of the post-2005 productivity slowdown (*Andrews et al. 2016*; *OECD 2019*).[5]

A related literature links declining dynamism to rising market concentration and increased mark-ups (*De Loecker et al. 2020*) and tighter financial conditions for young firms that impede entry and exit (*Philippon 2019*; *OECD 2015*; *Aghion et al. 2019*); weakened competitive pressures and higher reallocation frictions now weigh on both productivity growth and innovation across much of the OECD.

Many of the forces that previously boosted innovation and productivity have slowed since the mid-2000s, turning from tailwinds into headwinds. In particular, the strong post-war expansion in education has lost momentum across many advanced economies. The slowdown in the growth of average years of schooling, combined with enduring gaps in basic skills for sizable segments of the population, has reduced the growth of effective labour input (*Goldin et al. 2024*; *Moss et al. 2020*). Slower human-capital accumulation not only directly limits productivity growth, but also constrains the adoption, diffusion and efficient use of new, skill-intensive technologies, especially those based on ICT, data and artificial intelligence. In this way, human-capital weakness acts less as an independent drag and more as a multiplier of broader diffusion failures, weak innovation returns and sluggish reallocation. As a result, a non-trivial share of the post-2005 productivity slowdown likely reflects an increasing misalignment between the rapidly rising skill requirements of new technologies and the more modest expansion of advanced and intermediate skills in the workforce (*Andrews et al. 2024*).

At the same time, the momentum of pro-competitive regulatory reforms has faded or in some cases partially reversed, potentially lowering competitive pressure and productivity growth (*Syverson 2011*). For instance, the slowdown in network-sector deregulation alone can account for up to one-sixth of the post-2005 productivity slowdown (*Andrews et al. 2025*). Finally, as globalisation has lost momentum since the mid-2000s, the forces of trade-induced competition, technology transfer and participation in global knowledge networks that once boosted productivity have visibly weakened (*Goldin et al. 2024*).[6]

Since the mid-2000s productivity slowdown in many OECD economies, governments have increasingly leaned on R&D tax incentives to stimulate business innovation and revive productivity growth. Over the past two decades, these incentives have spread and become more generous across the OECD. Many

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[5] Digitalisation policy has become a central plank of innovation and productivity strategies. Since the 1990s, and especially since the mid-2000s, OECD governments have invested in broadband infrastructure, spectrum policy and telecoms competition, and then more recently in AI, cloud, data governance and cybersecurity. These efforts have enabled frontier firms to use digital tools (cloud, big data, AI, platforms) to raise productivity, create new business models and scale innovations globally, but diffusion to laggard firms remains incomplete, contributing to widening productivity gaps within countries.

[6] Measurement issues have also been examined as a potential explanation for the productivity slowdown. Rapid digitalisation, the growth of free digital services and quality improvements in ICT goods may not be fully captured in national accounts. However, the dominant conclusion in the literature is that mismeasurement can explain only a small fraction of the observed slowdown and cannot account for its timing, cross-country pervasiveness or persistence (Syverson 2017).

countries have also adopted IP (patent) boxes, that is preferentially low tax rates on income earned from patents and other intellectual property, to boost after-tax returns from successful innovation. While R&D tax incentives might increase business R&D on average, they are not always well targeted and often disproportionately benefit large incumbents rather than high-growth entrants.

9. Conclusion: Public policies to revive the growth engine?

Aghion and Howitt's Schumpeterian theory is ultimately an optimistic one: it implies that growth can be reignited if policymakers succeed in restoring the conditions under which new ideas, firms and technologies can emerge and displace the old ones. Central to this is vigorous competition and low barriers to entry, which force incumbents to innovate and allow challengers to scale. It also requires open product and capital markets, so that ideas, technologies and managerial know-how can diffuse rapidly across borders. Flexible labour market institutions are essential to enable the swift reallocation of skills toward expanding, innovative firms, while well-functioning financial systems, including venture capital and risk finance, are needed to fund high-risk, high-potential projects. Finally, the state plays a critical enabling role: not by shielding declining incumbents, but rather by investing in basic research, human capital and innovation infrastructure, and by setting stable, pro-competitive rules that reward experimentation and tolerate failure. In this framework, sustained growth is not the product of protection or subsidy of the old, but of policies that continually renew the process of creative destruction.

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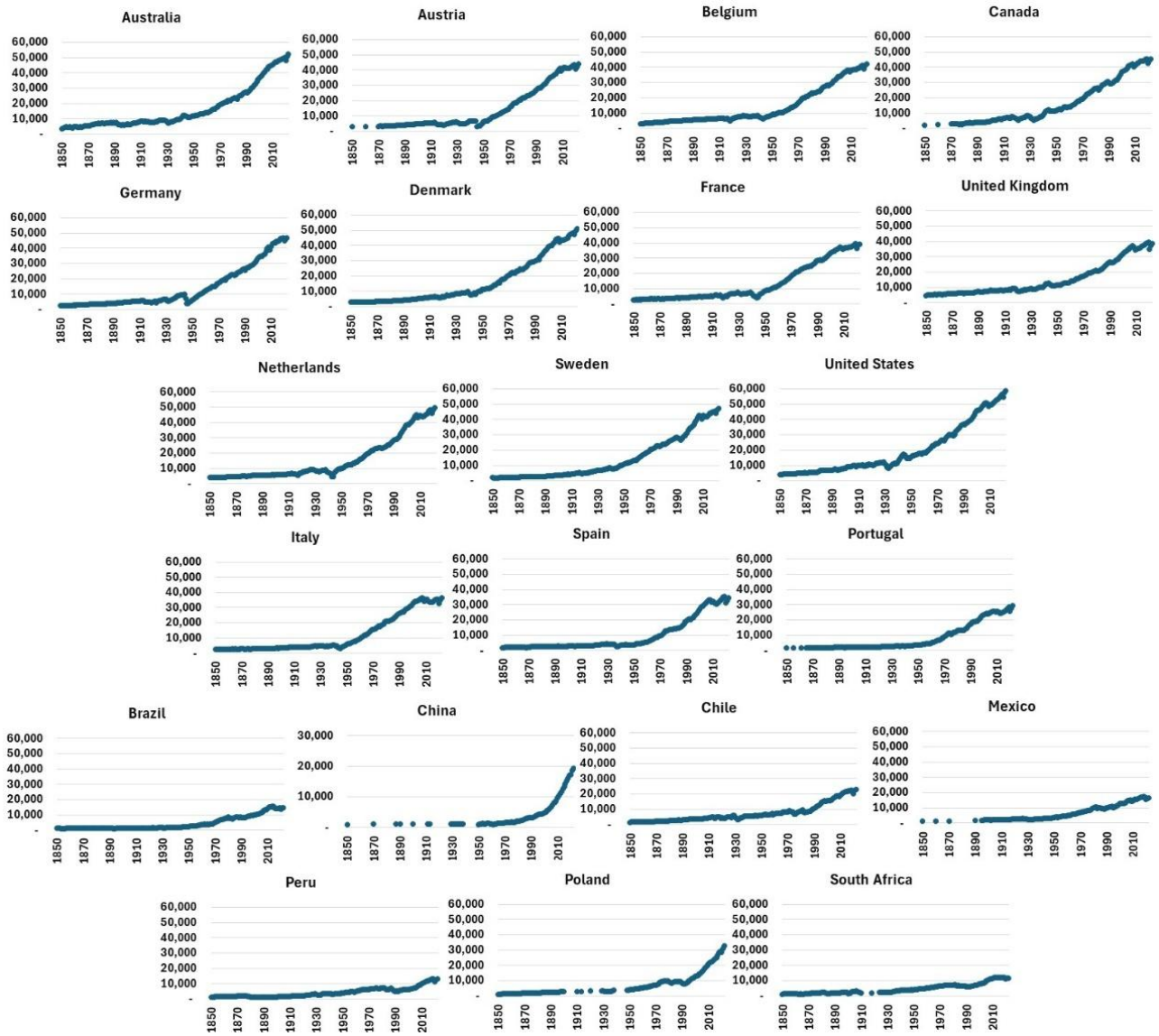
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Annex. Country-specific per capita income levels, 1850-2022

GDP per capita, 1850–2022 (USD in 2011 prices)



Source: Maddison Project Database 2023 (https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2023)