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CHINA IS NO LONGER AN EMERGING COUNTRY

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Abstract

This thesis analyzes whether China can still be considered an emerging economy in light of its economic slowdown and profound structural changes. After four decades of exceptional growth driven by capital accumulation, industrialization, and exports, the country is entering a new phase, marked by demographic decline, rising debt, and productivity stagnation. The analysis combines a macroeconomic overview with the empirical application of the Solow growth model, estimating China's long-term growth potential and evaluating the effect of structural reforms. Special attention is given to the Dual Circulation Strategy, aimed at boosting domestic demand and technological self-reliance. The findings show that China is increasingly converging toward the characteristics of advanced economies, with declining marginal returns on capital and growth stabilizing around 3.5–4.5%. While still officially classified as an emerging market, its structural profile is progressively maturing. Overall, this thesis contributes to the debate on China's global economic status by offering a data-driven and theoretically grounded assessment of its growth trajectory and policy challenges.

Abstract in Italiano

Questa tesi analizza se la Cina possa ancora essere considerata un'economia emergente, alla luce del rallentamento economico e dei profondi cambiamenti strutturali in atto. Dopo quarant'anni di crescita eccezionale trainata da capitale, industria ed export, il Paese sta entrando in una nuova fase, segnata da declino demografico, debito crescente e stagnazione della produttività. L'analisi combina una ricostruzione macroeconomica con l'applicazione empirica del modello di Solow, stimando il potenziale di crescita di lungo periodo e valutando l'effetto delle riforme strutturali. Particolare attenzione è rivolta alla Dual Circulation Strategy, volta a rafforzare la domanda interna e l'autonomia tecnologica. I risultati mostrano che la Cina si sta avvicinando a caratteristiche proprie delle economie avanzate, con rendimenti decrescenti del capitale e una crescita tendenziale attorno al 3,5–4,5%. Sebbene ancora classificata come economia emergente, il suo profilo strutturale è sempre più maturo. La tesi intende contribuire al dibattito sul ruolo della Cina nel sistema economico globale, fornendo un'analisi fondata su dati e modelli consolidati.

Contents

Introduction

China's economic rise has been one of the most significant global phenomena of recent decades. Starting from the economic reforms of 1978, following the Great Cultural Revolution launched in 1966 by Mao Zedong, the country recorded high and sustained growth rates, transitioning from a low-income economy to an upper-middle-income one. This transformation was driven by massive capital accumulation, an expanding labor force, and gradual technological advancements.

However, as the economy matures, China is undergoing a phase of structural transition, during which growth is slowing and the economic model is evolving. This raises crucial questions about its economic classification and its future global role. While some continue to regard China as an emerging market, others argue that its structural features are increasingly similar to those of advanced economies. This debate is further complicated by internal challenges, such as demographic changes and a highly leveraged real estate sector, as well as external pressures, including geopolitical tensions and supply chain disruptions.

To address these challenges, the Chinese government has introduced the Dual Circulation Strategy, a policy framework aimed at reducing dependence on external markets and promoting domestic demand.

In this context of uncertainty and complexity, my research aims to assess whether China can still be considered an emerging economy by analyzing its macroeconomic indicators, evaluating its medium-term growth potential through the Solow growth model, and testing the impact of government policies on future growth projections.

China's current classification is the subject of heated debate, reflecting a real dichotomy. The criteria used to distinguish between developing, emerging, or advanced economies vary depending on the institutions and investment firms involved.

However, a universally accepted principle is that an economy is considered emerging when it is characterized by rapid growth, an ongoing process of industrialization, and significant potential for economic expansion.
The concept of emerging market was introduced in 1981 by economist Antoine van Agtmael, then an executive at the International Finance Corporation (IFC), an institution affiliated with the World Bank. The term was created to distinguish those countries that, while not yet advanced economies, exhibited high growth and industrialization potential, making them attractive to international investors. This new category of economies led in 1988 to the creation of the MSCI Emerging Markets Index by Morgan Stanley, an index that has undergone several revisions over the years and currently includes 26 countries, including China [MSCI, 2025].
However, the definition of an emerging market is not univocal and varies depending on the institutions that adopt it. The International Monetary Fund (IMF), for example, classifies economies based on three main criteria [Fund, 2023a]:

1. **Per capita income**, that is, the average income level of the population;
2. **Export diversification**, which measures how much an economy relies on a limited number of production sectors;
3. **Financial integration**, meaning the degree of access to global financial markets.

In addition to these parameters, other institutions such as MSCI, FTSE Russell, and S&P adopt criteria that take into account the liquidity and maturity of financial markets, the degree of openness to foreign investment, and financial regulation. For this reason, a country may be classified as emerging by one institution and as developed by another, depending on the indicators used.
As shown in Table 1, China is still officially classified as an emerging market by the main financial institutions: the IMF, MSCI, FTSE Russell, and S&P all share this view. However, its economy exhibits many characteristics typical of advanced economies, raising doubts about the validity of this classification in the current context.

Table 1: China's Classification According to Major Institutions

Institution/Index	China's Classification	Source
International Monetary Fund	Emerging Market	[Fund, 2023a]
MSCI	Emerging Market	[MSCI, 2025]
FTSE Russell	Emerging Market	[Russell, 2025]
Standard & Poor's	Emerging Market	[Indices, 2025]
World Bank	Upper-Middle-Income Country	[Bank, 2025]

A useful example is that of South Korea, which for years was classified as an emerging economy before being recognized as a developed one, despite maintaining high growth rates.

The classification of a country has significant implications, especially for international capital flows. Inclusion in emerging market indices attracts passive funds and investors seeking higher returns compared to those offered by advanced economies. A reclassification as a developed economy, on the other hand, could reduce the inflow of speculative capital, making access to financing more stable but less dynamic.

China's economic growth fits into this context with contrasting dynamics. On the one hand, the country retains some characteristics typical of emerging markets, such as a still lower per capita income compared to advanced economies and a heavily regulated financial system. On the other hand, China has already achieved a high level of industrialization, a dominant role in global trade, and an increasingly sophisticated financial market.

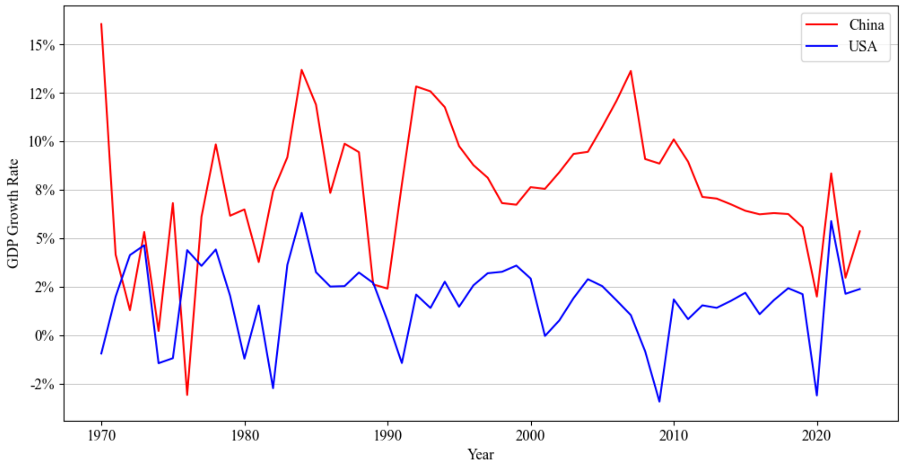
This complexity gives rise to a central research question: can China still be considered an emerging market?

This research aims to argue that, in the medium term, China will definitively lose the characteristics of an emerging economy—not necessarily due to a formal reclassification by financial institutions, but because, in line with the concept of emerging market coined by Antoine van Agtmael, its growth rate will no longer reflect that of an emerging economy. The Solow growth model, applied to this context, will allow us to test this hypothesis and assess whether China is stabilizing around a new long-term growth rate, more similar to that of advanced economies.

In an increasingly polarized geopolitical scenario, where two major powers—the

United States and China—are emerging as the main global actors while other countries, notably Europe, appear to be assuming a more marginal role, understanding the direction of the Chinese economy becomes strategically crucial. China's role in the international economic system is no longer limited to its previous position as the world's factory, but is instead evolving into a central hub for technological innovation, global infrastructure, and international finance.

Figure 1: China vs United States: GDP Growth Rate Comparison



Source: Author's elaboration based on data from World Bank (2024), indicator NY.GDP.PCAP.KD.ZG.

Figure 1 clearly illustrates the evolution of GDP growth rates in China and the United States from the 1970s to the present, highlighting two very different trajectories. While the United States has maintained relatively stable growth, fluctuating around 2–3% per year with occasional recessions, China has recorded double-digit growth rates for much of the past decades, driven by an economic model based on high levels of investment, rapid industrialization, and export expansion.

However, starting in the 2010s, China's trajectory began to show signs of deceleration. This phenomenon can be attributed to several factors: the attainment of a higher level of economic development, a shift in the production structure with greater emphasis on domestic consumption over exports, rising trade tensions with the United States, and increasing debt levels in both the private and public sectors. The real estate crisis and financial control policies have further contributed to restraining the growth rate.

In recent years, China has stabilized at a growth rate of around 5%, a figure still higher than that of advanced economies, but significantly lower than the levels observed in the past. This supports the notion that China is undergoing a phase of economic transition, moving away from the typical profile of an emerging economy. A comparison with the United States also reveals that the growth differential between the two economies is narrowing, which carries important geopolitical and strategic implications. While in the early 2000s China grew at a pace nearly four times that of the United States, today the gap has significantly diminished, suggesting that China's growth model is gradually converging toward that of more mature economies.

This convergence in growth trajectories between China and the United States has significant implications not only in economic terms, but also in strategic ones. If China stabilizes at lower growth levels, its ability to compete with the United States and consolidate its influence in global markets could be diminished.

According to the most recent estimates by institutions such as the International Monetary Fund (IMF), China's GDP growth is expected to stabilize around 4–5% annually in the coming year, gradually declining to 3.5% by 2028—a figure significantly lower than the double-digit growth rates that characterized previous decades [Fund, 2024b].

Studying China's economic trajectory not only allows for the anticipation of its domestic developments, but also offers insight into the global repercussions that its consolidation as an economic power will have in the coming decades.

A key example of China's growing economic influence is the Belt and Road Initiative [Belt and Portal, 2024], an ambitious global investment program launched in 2013 by President Xi Jinping, which has transformed the country into a central player in emerging markets and beyond.

The expansion of the Belt and Road Initiative not only reinforces China's role in emerging markets, but also suggests a growth model more oriented toward global integration rather than mere internal industrialization. This aspect will be analyzed in detail in the following chapters to assess its impact on China's transition toward advanced economy status.

This program, along with other ambitious Chinese initiatives, will serve as a practical lens through which to interpret the current and future structure of China's economy. The objective of this research is to analyze in detail the structure of the Chinese economy, understanding its underlying dynamics and identifying potential imbalances that could explain the current growth slowdown. In particular, this analysis aims to assess whether China is approaching a new economic equilibrium—more similar to that of advanced economies—and to identify the key factors driving this transition.

The Beijing government has not remained unprepared in the face of this slowdown and has proactively introduced the aforementioned Dual Circulation Strategy: a plan designed to rebalance the country's development model by reducing dependence on exports and strengthening domestic demand.

This research therefore aims to answer the following key questions:

1. Can China still be considered an emerging economy, or does the slowdown in growth suggest a transition toward a new economic status?
2. What are the structural factors driving the slowdown, and how do they affect the country's future growth prospects?
3. To what extent can the Dual Circulation Strategy contribute to ensuring sustainable long-term growth?

Through this thesis, I will analyze in detail the measures adopted by the Chinese leadership to implement this strategy and evaluate their effectiveness by constructing alternative scenarios. Using economic simulations and quantitative analytical tools, I will assess the impact of the Dual Circulation Strategy on China's growth trajectory, providing a critical evaluation of its potential success in ensuring a stable transition toward long-term sustainable growth.

The ultimate goal of this research is therefore to contribute to the academic and financial debate on China's economic status by providing an analysis based on well-established growth models and advanced quantitative methodologies.

Through the application of the Solow model and the assessment of Chinese economic policies, this research aims to determine whether China is indeed completing its

economic transition. Its future trajectory will have significant implications for global economic balances and the strategies of major world powers.
To address these questions, the analysis adopts a quantitative approach that allows for an objective evaluation of China's growth process, distinguishing between cyclical and structural factors. The adopted methodology is articulated in three main phases:

1. Descriptive macroeconomic analysis, to contextualize China's economic evolution over recent decades and identify the main trends and growth drivers;

2. Application of the Solow growth model, to estimate whether China has reached its steady-state and to assess the contribution of capital, labor, and technological progress to its GDP;

3. Econometric analysis and deterministic scenario simulations, to test the validity of the Solow model's assumptions and evaluate the robustness of future growth projections for China, with particular attention to government policies under the Dual Circulation Strategy.

The adoption of a quantitative approach is based on the need to provide an empirical and structured assessment of China's growth, using data from authoritative sources and advanced economic modeling tools. Moreover, the integration of econometric techniques and deterministic simulations allows for the comparison of alternative scenarios, offering a broader perspective on China's future economic developments. This approach makes it possible to analyze not only the historical path of Chinese growth but also long-term prospects, providing a solid foundation for understanding its future positioning in global markets.
To carry out this analysis, I have relied on a wide range of data from reliable sources, allowing for the examination of China's economic growth from macroeconomic, trade, and financial perspectives. The Penn World Table (PWT) is the primary source for estimating the fundamental parameters of the Solow model, including the capital depreciation rate and the investment-to-GDP ratio, while Total Factor Productivity (TFP) has been calculated residually by subtracting the contribution of input factors from overall growth. This method allows for a more accurate assessment of productivity's role in China's growth trajectory.

To gain a broader view of China's macroeconomic performance, I have incorporated data from the World Bank and FRED (Federal Reserve Economic Data), which provide detailed information on GDP, investment, consumption, inflation, and demographic dynamics. A crucial aspect of this research is the analysis of China's international trade structure, as the Solow model will be adapted to incorporate an open economy framework. For this purpose, I use data from the World Trade Organization (WTO), which allow for an examination of China's export dependence and its positioning in global markets.

At the same time, the financial dimension plays a fundamental role in China's growth. Therefore, I employ FRED data to analyze variables such as interest rates, capital flows, and the monetary policies adopted by the People's Bank of China (PBoC). These data help to understand the degree of financial maturity in China and to assess its impact on long-term growth.

The analysis also extends to economic forecasts, combining estimates provided by the IMF with independently developed forecasting models. Although some forecast data are available up to 2028, many future estimates will be generated through advanced econometric models and deterministic simulations based on counterfactual scenarios. At present, I am following the guidelines provided by several academic papers, including:

- "The Neoclassical Growth of China" (Fernández-Villaverde et al., 2023), which analyzes China's convergence process through a Ramsey-Cass-Koopmans model, suggesting a significant future growth slowdown.

- "Accounting for Growth in China" (Bosworth & Collins, 2008), which applies an empirical extension of the Solow model to estimate the contribution of capital, labor, and productivity to China's growth.

- "A Contribution to the Empirics of Economic Growth" (Mankiw, Romer & Weil, 1992), which justifies the inclusion of human capital in the growth model and provides a solid empirical framework for cross-country analysis.

The integration of these studies provides a solid theoretical foundation for my analysis, allowing for a comparison of different methodologies and a validation of my hypotheses regarding Chinese growth. The objective is to test the robustness of existing projections and to develop alternative scenarios, taking into account structural variables such as demographic trends, productivity, and the impact of economic reforms.

This approach—based on empirical data, advanced quantitative tools, and references to established academic literature—makes it possible to offer a comprehensive and rigorous analysis, providing a clear view of China's growth trajectory and its implications in the global context.

Despite the adoption of a structured analytical framework, grounded in well-established theoretical models and a wide array of empirical data, this research inevitably presents some limitations. First, the Solow model, although flexible and widely used in the literature, is built on simplifying assumptions that may be too restrictive in the Chinese context. The assumption of exogenous technological progress, the homogeneity of labor, and the Cobb-Douglas production function may fail to capture the institutional, sectoral, and demographic specificities of an advanced transitional economy like China. Furthermore, although the data used are drawn from reputable sources such as the Penn World Table, the International Monetary Fund, and the World Bank, there remain margins of uncertainty regarding the quality and consistency of Chinese statistics, particularly concerning physical capital, total factor productivity, and some forecast variables.

Additional limitations arise from the use of deterministic simulations in the analysis of future scenarios. Although calibrated on historical parameters and supported by sensitivity analyses, these simulations are unable to capture the full range of systemic risks and discontinuities that could affect China's growth trajectory. Potential exogenous shocks—such as geopolitical crises, disruptive technological innovations, or changes in economic governance—may radically alter the projections, without being reflected in the models used. The construction of counterfactual scenarios based on plausible assumptions represents an attempt to overcome such limitations, but inevitably remains subject to a certain degree of arbitrariness and subjectivity in parameter selection.

Finally, the aggregated nature of the analysis—focused on long-term average macroeconomic variables—entails a partial neglect of microfounded, regional, and distributional dynamics that could further enrich the understanding of China's economic transition. In this sense, the results obtained should be interpreted as a structured foundation for reflection, rather than as a precise forecast of the country's future growth path.

In light of these considerations, a structured analytical framework is required—one that combines theoretical rigor with empirical depth.

This work is structured into three main chapters, each addressing a complementary aspect of China's growth trajectory and its position in the global economy. The objective is to combine a solid empirical reconstruction with a theoretical and quantitative analysis capable of assessing long-term dynamics and the strategic implications of the Chinese development model.

- **Chapter 1** reconstructs the evolution of the Chinese economy from the post-Maoist reforms to the present;
- **Chapter 2** applies the Solow model to estimate China's long-term growth potential;
- **Chapter 3** is devoted to forecasting and counterfactual analysis.

Each chapter is conceived as a complementary building block: from the empirical reconstruction in Chapter 1, to the theoretical modeling in Chapter 2, and finally to the simulation of future developments in Chapter 3. Together, they form a coherent and structured narrative of China's path toward advanced economic status.

In conclusion, this research aims to provide a thorough assessment of China's growth trajectory and its actual economic status by integrating theoretical analysis, empirical evidence, and counterfactual simulations. The goal is to contribute to the debate on one of the most relevant topics in contemporary global economics: China's transition from an emerging market to an advanced economic power. The following chapters will develop this path gradually and consistently, starting with the macroeconomic reconstruction, continuing with the theoretical and quantitative formalization, and concluding with the analysis of future prospects.

Chapter 1

Macroeconomic Overview of China

This chapter provides a comprehensive macroeconomic overview of China's development process, serving as the empirical foundation for the growth model introduced in Chapter 2. It retraces the evolution of the Chinese economy from the Maoist period to the present, highlighting structural transformations, key growth drivers, and emerging constraints.

Section 1.1 explores the long-run dynamics of China's growth model, identifying key historical turning points and phases of transition, from early industrialization to the post-2008 slowdown. Section 1.2 examines the main macroeconomic variables relevant to the Solow framework—including demography, saving behavior, investment, capital efficiency, monetary dynamics, and total factor productivity (TFP)—providing descriptive evidence and policy context. Section 1.3 focuses on the Dual Circulation Strategy, the Chinese government's current policy response to structural challenges, and its potential implications for long-term growth.

By linking historical evolution, empirical trends, and strategic policy shifts, this chapter sets the stage for the theoretical and quantitative modeling of China's growth trajectory in the remainder of the thesis.

1.1 Macroeconomic Evolution of China

1.1.1 The evolution of the Chinese growth model (pre e post-1978)

The economic evolution of China represents one of the most extraordinary transformations in modern history. However, in order to fully grasp its scope, it is necessary to begin with the period prior to the 1978 reforms, when the country was still heavily influenced by Maoist ideology.

Following the founding of the People's Republic of China in 1949, the economy was organized according to a Soviet-style socialist model: centralized production, state ownership of the means of production, and total control by the Communist Party. The economic structure was predominantly agricultural, with over 80% of the population employed in the primary sector [Bank, 1981]. Campaigns of forced industrialization, such as the Great Leap Forward (1958–1961) and the Cultural Revolution (1966–1976), led to severe imbalances and one of the most devastating humanitarian disasters of the twentieth century: the 1960–61 famine caused approximately 30 million deaths [Dikötter, 2010]. The economic system was inefficient, isolated from international markets, and unable to meet the basic needs of the population.

In 1978, China's GDP per capita ranked among the lowest in the world, just 156 USD [Bank, 2023c], and the urgency of economic transformation was increasingly evident.

The turning point came with the Third Plenum of the 11th Central Committee of the Chinese Communist Party, during which Deng Xiaoping launched a new phase of reforms oriented toward economic pragmatism. Without relinquishing political control, the Party gradually decided to integrate elements of market economy, guided by the slogan "socialism with Chinese characteristics."

Among the first structural reforms, particularly significant was the introduction of the Household Responsibility System in agriculture (1979), which replaced collective agricultural communes with individual family contracts, leading to a sharp increase in productivity. Between 1978 and 1984, agricultural output rose by approximately 50% [Lin, 1992].

At the same time, China promoted the establishment of Special Economic Zones (1980), initially located in Shenzhen, Zhuhai, Shantou, and Xiamen. These areas benefited from preferential fiscal policies and were designed to attract foreign capital, resulting in a rapid increase in FDI inflows—from negligible levels in 1978 to over USD 3.5 billion by 1990 [UNCTAD, 2023].

A third pillar of reform was the gradual liberalization of market mechanisms, through the implementation of a dual pricing system (planned and market-based), the encouragement of private investment, and the launch of local collective enterprises known as TVEs (Township and Village Enterprises).

As a result of these reforms, China experienced a long phase of capital- and labor-intensive growth, driven by investment, exports, and rapid urbanization. Between 1978 and 2008, real GDP grew at an average annual rate of 9.9%, enabling over 800 million people to escape poverty [Bank, 2022c].

However, China's growth path has not been homogeneous. While the initial reforms triggered an unprecedented expansion, over time new challenges have emerged: structural imbalances, excessive dependence on investment, real estate sector crises, and international tensions. To fully understand this trajectory, it is useful to divide the post-1978 period into three major phases, each with its own features, dynamics, and criticalities. These phases will be analyzed in the following section.

1.1.2 Stages of growth and economic transition

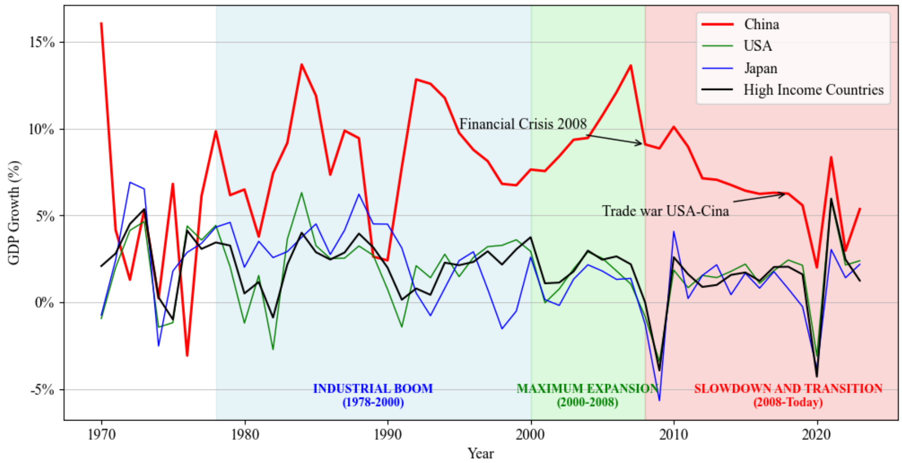
To fully grasp the trajectory of China's economic transformation after 1978, it is useful to distinguish three main phases, each marked by distinct dynamics, policy orientations, and external contexts. These stages reflect the gradual evolution from a centrally planned economy to a more market-oriented system, followed by a period of consolidation and adjustment.

As illustrated in Figure 1.1, China's GDP growth path can be divided into three main periods:

Phase 1: Industrial Boom (1978–2000)

This phase, marked by the economic reforms initiated by Deng Xiaoping as previ-

Figure 1.1: From economic miracle to new equilibrium: China's growth path



Source: Author's elaboration based on data from World Bank (2024), indicator NY.GDP.PCAP.KD.ZG.

ously discussed, saw China achieving annual growth rates exceeding 9.5% thanks to industrialization, investment, and a strong export-oriented strategy. Rapid urbanization and the influx of foreign direct investment (FDI) fueled the manufacturing sector, turning China into the "world's factory" [TG24, 2010].

Phase 2: Peak Expansion (2000–2008)

In this second phase, China's growth reached its peak with the country's accession to the WTO in 2001, which dramatically expanded international trade and pushed GDP growth above 10% annually. However, the 2008 global financial crisis exposed the first vulnerabilities of China's growth model, initiating a period of transition.

Phase 3: Slowdown and Transition (2008–present)

After the global crisis, China entered a transition toward a more sustainable growth model, with GDP stabilizing around 5% annually. This slowdown is driven by several factors:

First, China is facing a demographic decline, with the working-age population having peaked in 2015 at 911 million, and projected to fall to 830 million by 2030. By 2050, nearly 39% of the total population will be of retirement age [Forum, 2016]. Second, the country has experienced a decline in investment efficiency, as rising debt and the real estate crisis have led to lower capital productivity. Third, the economy has become increasingly dependent on debt, especially in the real estate sector, where excessive borrowing has contributed to the financial distress of major developers such as Evergrande and Country Garden. Finally, geopolitical tensions, notably the trade war with the United States and export restrictions on strategic technologies like semiconductors and AI, have negatively affected key sectors of the Chinese economy.

According to the International Monetary Fund (IMF), China's GDP growth may fall to 3.5% by 2028 [Fund, 2024a], gradually converging with the levels of advanced economies. These trends suggest that China is transitioning toward advanced economy status, raising questions about its future classification.

The structural problems revealed in China's economy following the 2008 global financial crisis share significant similarities with Japan's "lost decade" of the 1990s.

In the 1980s, Japan experienced an unprecedented economic boom, driven by strong growth in the real estate and financial sectors, low interest rates, and expansionary monetary policies. However, this expansion resulted in the formation of a speculative bubble in the real estate and stock markets.

The bursting of Japan's speculative bubble in the early 1990s triggered a prolonged recession. The collapse in real estate prices severely weakened the banking system, while highly indebted firms drastically reduced investment and consumption. As a result, Japan's GDP stagnated throughout the decade, with average annual growth falling below 1%. The crisis was further exacerbated by deflation, which increased the real burden of debt and discouraged both spending and investment.

The Bank of Japan attempted to stimulate growth through ultra-low interest rates and fiscal stimulus programs, but low productivity and an unfavorable demographic profile hindered a sustained recovery.

Although China differs in some key respects from Japan in the 1990s, including:

- a larger domestic market and lower dependence on exports compared to Japan at the time,
- a government that retains direct control over the economy and banking system, with more flexible fiscal and monetary tools,

– foreign exchange reserves exceeding USD 3 trillion [Bank, 2023b], ensuring greater capacity for intervention,

the dynamics of debt accumulation and dependence on the real estate sector indicate that China could face a prolonged period of stagnant growth unless it manages to rebalance its economic model toward more sustainable domestic consumption, alongside structural reforms to avert a deeper crisis.
Unlike Japan, however, the Chinese government still retains significant room for intervention and control mechanisms that could mitigate the most severe consequences of the downturn.
Due to these factors, China's annual GDP growth has fallen below 7%, stabilizing around 5% in recent years. This deceleration has led the government to reconsider its development strategy and pursue new reform packages and long-term policy shifts.

1.1.3 Recent Trends and Future Prospects

Recent years have seen China facing a series of structural challenges that will significantly shape the trajectory of its future growth. The most recent data show a slowdown in the Chinese economy that goes well beyond the post-COVID cycle: this is a systemic phenomenon, linked to long-term trends that are reshaping the country's macroeconomic context.

Real estate crisis and risks to financial stability
One of the most concerning signs is the crisis in the real estate sector, which for over two decades had been a pillar of China's economic expansion. Currently, real estate, including construction and related sectors such as banking, materials, and appliances, is estimated to account for around 25–29% of the country's GDP[Rogoff and Yang, 2021].
However, since 2020, the introduction of the "three red lines" policy to limit excessive corporate debt has led to the collapse of real estate giants like Evergrande and Country Garden, revealing a property bubble fueled by easy credit and speculation. By the end of 2023, home prices in major cities had been declining for seventeen consecutive months[Bloomberg, 2023], and property sales had dropped by more than

20% year-on-year.

The implications of this crisis are profound: weakened local government revenues, a loss of household wealth (with up to 70% of savings allocated to real estate), and a rise in corporate debt, which surpassed 160% of GDP in mid-2023[for International Settlements, 2023].

Debt and the sustainability of the growth model

Total debt (public + private) exceeded 300% of GDP in 2023[of International Finance, 2023], a level comparable to that of advanced economies, but with a much more fragile structure. Growth driven by infrastructure and real estate investment has shown signs of saturation, with diminishing marginal efficiency of capital. The concept of "diminishing returns to investment" is particularly relevant in a context where new projects often fail to generate adequate economic returns.

In response, Chinese authorities are attempting a rebalancing toward domestic consumption and productivity, also through incentives for innovation and digital development.

Demographic challenge and labor force transformation

Demographics represent another crucial challenge. After peaking in 2022 at 1.41 billion inhabitants, China's population began to decline, registering a drop for the second consecutive year in 2024[Division, 2023]. As noted in Section 1.1.3: the working-age population is expected to fall from 911 million (2015) to around 830 million by 2030, while the share of people over 65 will reach 39% by 2050[Bank, 2022b]. This trend is placing significant pressure on the pension and healthcare systems, but more importantly on the availability and quality of the labor force. In response, the government is promoting higher specialization by investing in technical and university education, particularly in STEM (Science, Technology, Engineering, Mathematics) fields. The goal is to compensate for the numerical contraction with a qualitative leap in labor productivity.

Geopolitical tensions and a new global trade configuration

Tensions with the United States, particularly the trade war launched in 2018 and restrictions on technology exports, are accelerating the process of de-risking and restructuring global value chains.

Between 2018 and 2023, Chinese exports to the United States fell by 20%, while alternative markets such as ASEAN (Association of Southeast Asian Nations) and Latin America gained importance[OECD, 2024]. At the same time, China is seeking to strengthen its technological self-sufficiency, especially in critical sectors such as microchips, batteries, AI, and telecommunications.

Outlook: from transition to rebalancing

The coming years will be decisive in determining whether China can successfully transform its economic model, shifting from one based on investment and manufacturing to a more balanced paradigm focused on consumption, innovation, and services. In this context, the Dual Circulation Strategy plays a key role, aiming to reinforce domestic demand while maintaining integration in global markets. This strategy will be analyzed in detail in Section 1.3.

In summary, China is facing a structural transition: the focus is no longer on growing "at all costs," but rather on achieving more balanced, sustainable, and innovative growth. The complexity of the challenges is substantial, but the scale of the policy response and the adaptability of the system will play a decisive role in shaping China's future economic trajectory.

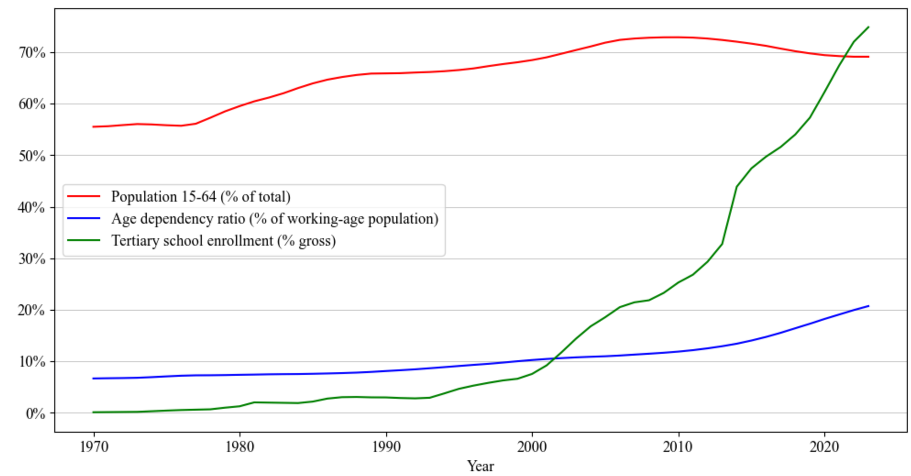
1.2 Key Economic Variables and Their Trends

1.2.1 Demography and impact on growth

The evolution of human capital and demographic structure is one of the most important factors for assessing China's future growth potential. In theoretical terms, labor is a central variable in the Solow model, both in quantitative terms (available workforce) and qualitative terms (human capital). However, China is currently facing a profound demographic transition that will profoundly influence its development trajectory.

In recent decades, the country has benefited from a favorable demographic composition, which contributed significantly to its rapid economic growth. Yet, new trends are emerging. As the next figure shows, the structure of the population is undergoing major shifts in terms of working-age share, aging, and education.

Figure 1.2: Demographic transition and human capital enhancement in China



Source: Author's elaboration based on data from World Bank (2024), indicators SP.POP.1564.TO.ZS, SP.POP.DPND.OL, and SE.TER.ENRR.

As shown in Figure 1.2, the share of the working-age population (15–64 years) grew steadily from the 1970s to 2010, reaching a peak of over 73% of the total. This trend provided a favorable "demographic dividend" for decades, supporting economic growth through abundant low-cost labor and accelerated urbanization. However, starting in 2015, the working-age population began to decline in relative terms, falling below 70% in 2023, with a downward trend projected to continue in the coming decades[Bank, 2024g].

At the same time, population aging is increasing pressure on the economic system. The age dependency ratio (over 64 / working-age population) rose from about 9% in 2000 to over 20% in 2023, and it is expected to exceed 40% by 2050[Bank, 2024a]. This implies a growing number of elderly people dependent on a shrinking labor base, with consequences for productivity, public spending, and welfare sustainability.

In response to these trends, the Chinese government has undertaken a strategy to strengthen human capital, focusing on expanding higher education and technical specialization of the workforce. The tertiary enrollment rate rose from about 10% in 2000 to over 70% in 2023, reflecting a massive expansion in access to university education[Bank, 2024i]. This trend clearly represents an attempt to offset the shrinking labor force with quality improvements, in the hope of sustaining labor productivity growth.

In this context, a particularly significant figure is that, according to the China Statistical Yearbook on Education, about 46% of Chinese graduates in 2021 came from STEM (Science, Technology, Engineering, Mathematics) programs: one of the highest shares in the world[of Education of the People's Republic of China, 2022]. This composition reflects a strategic intention to orient the education system toward disciplines crucial for technological development, advanced manufacturing, and scientific self-sufficiency.

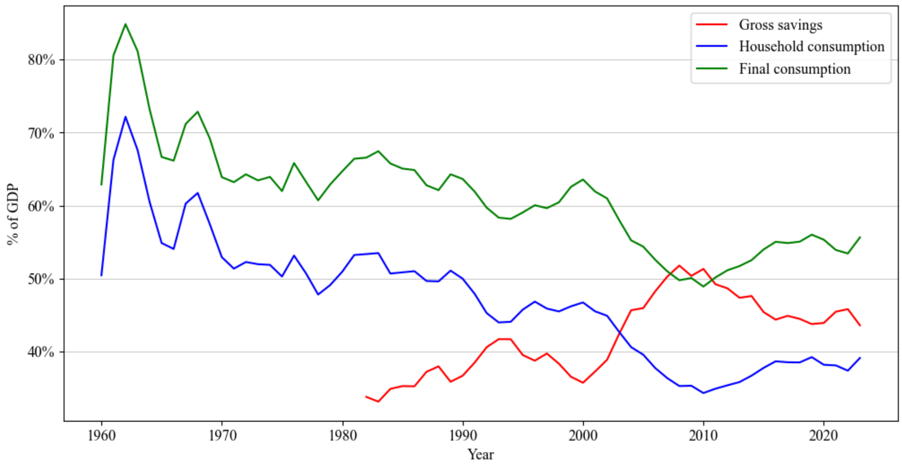
From a long-term growth perspective, the interaction between demographic decline and educational progress will be crucial: while the contraction of the working-age population is an evident constraint, the accumulation of advanced human capital may partially mitigate the negative effects on productive potential. This balance will be especially relevant in the context of the transition to a new development model, which will be further explored in the following sections.

1.2.2 Savings, consumption and capital formation

The balance between savings and consumption is one of the most relevant variables for understanding the Chinese growth model and its future developments. Within the Solow model framework, the savings rate represents the engine of physical capital accumulation and, consequently, long-term output growth. However, an excess of savings at the expense of domestic demand can generate significant macroeconomic imbalances, especially in a transition phase like the current one.

A long-standing feature of the Chinese economy is the coexistence of extremely high savings rates and chronically weak consumption. These dynamics are clearly illustrated in the following figure, which compares the share of gross savings, private consumption, and final consumption in GDP over the past two decades.

Figure 1.3: Imbalances between savings and consumption: the Chinese domestic demand paradox



Source: Author's elaboration based on data from World Bank (2024), indicators NY.GNS.ICTR.ZS, NE.CON.PRVT.ZS, and NE.CON.TOTL.ZS.

As shown in Figure 1.3, China has displayed one of the highest savings propensities in the world for decades, with a peak exceeding 50% of GDP in 2008, coinciding with the massive stimulus plan following the global financial crisis. Even after the normalization of fiscal policies, gross savings have remained consistently above 43–45% of GDP in recent years[Bank, 2024d]. This level has supported extraordinarily high investment rates, facilitating the country's infrastructure, industrial, and real estate expansion.

However, the flip side of the coin is represented by chronically weak private consumption. The share of household consumption in GDP fell below 40% in the early 2010s, reaching lows below 36%. Despite a modest post-COVID rebound, the level remains extremely low compared to advanced economies, where household consumption typically accounts for over 55–60% of GDP[Bank, 2024e].

The gap between savings and private consumption is partially offset by public consumption, but even final consumption expenditure (households + government) does not consistently exceed 55–58% of GDP, confirming a structural reliance on external demand and domestic investment[Bank, 2024b].

The causes of this configuration are manifold:

- a still-limited welfare system, pushing households to save for healthcare, education, and pensions;
- an unstable and evolving labor market, encouraging precautionary behavior;
- and, partly, cultural and intergenerational saving habits.

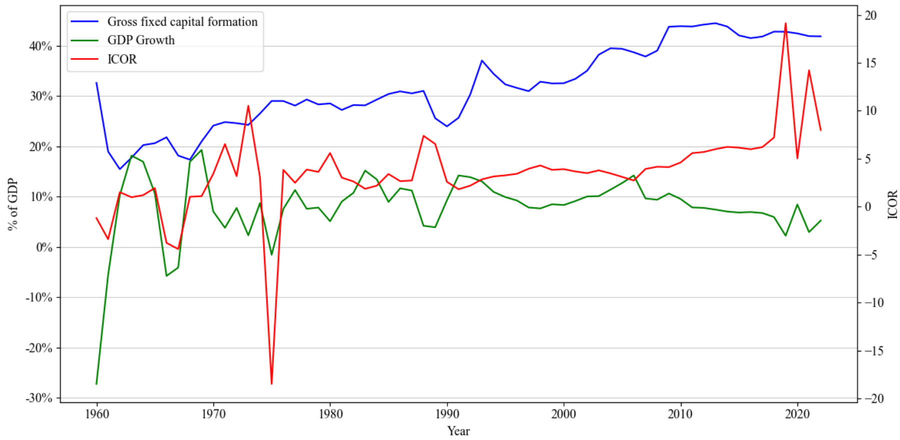
In the current context, this imbalance has become a strategic challenge. The authorities' goal is to rebalance growth by reducing dependence on investment and exports, while fostering the expansion of domestic demand, in line with the pillars of the Dual Circulation Strategy. From this perspective, increasing the propensity to consume through welfare reform, rising disposable income, and reduced uncertainty is a top priority for the sustainability of the Chinese growth model.

1.2.3 Investment and capital productivity

In the Chinese growth model, fixed investment has served for decades as the main engine of economic expansion. The abundant availability of domestic savings, state intervention in credit allocation, and rapid urbanization favored an unprecedented capital accumulation dynamic. However, in recent years, a growing decline in the marginal efficiency of investment has emerged, raising concerns about the sustainability of this approach.

This decline is particularly evident when comparing the evolution of fixed investment with that of GDP growth. The next figure shows the persistent intensity of capital formation and the simultaneous weakening of growth rates, highlighting the decline in capital productivity over time.

Figure 1.4: Capital productivity and investment dynamics in Chinese growth



Source: Author's elaboration based on data from World Bank (2024), indicators NE.GDI.FTOT.ZS and NY.GDP.MKTP.KD.ZG.

As shown in Figure 1.4, the share of Gross Fixed Capital Formation (GFCF) in GDP has consistently remained above 40% since the 2000s, reaching peaks close to 45% in the decade following the global financial crisis. Such a high value is exceptional in international comparison: in OECD countries, the average is below 25%[Bank, 2024c].

Despite this investment intensity, the real GDP growth rate has followed a steadily declining path. After exceeding 10% annually for much of the 1990–2010 period, growth has dropped below 6% in recent years and is projected to approach 3.5% by 2028[Fund, 2023b]. This trend suggests a decreasing effectiveness of capital accumulation in driving growth.

A useful indicator to measure this relationship is the ICOR (Incremental Capital-Output Ratio), calculated as the ratio between fixed investment and real GDP growth. Economically, a higher ICOR implies that more investment is needed to achieve the same unit of growth. As highlighted in Figure 1.4, China's ICOR has increased in recent years, indicating declining capital productivity. The peaks observed in correspondence with external shocks (such as COVID-19) reinforce the notion of rising structural inefficiencies 3.3.4.

Among the main causes of this trend are:

– Overinvestment in mature sectors, often driven by planning logic rather than economic efficiency;

- Industrial overcapacity, with underutilized plants in many heavy and traditional industries;
- The presence of "zombie firms," kept alive by public banks and accommodative credit policies;
- Distortions in capital allocation, caused by a financial system still dominated by state-owned banks.

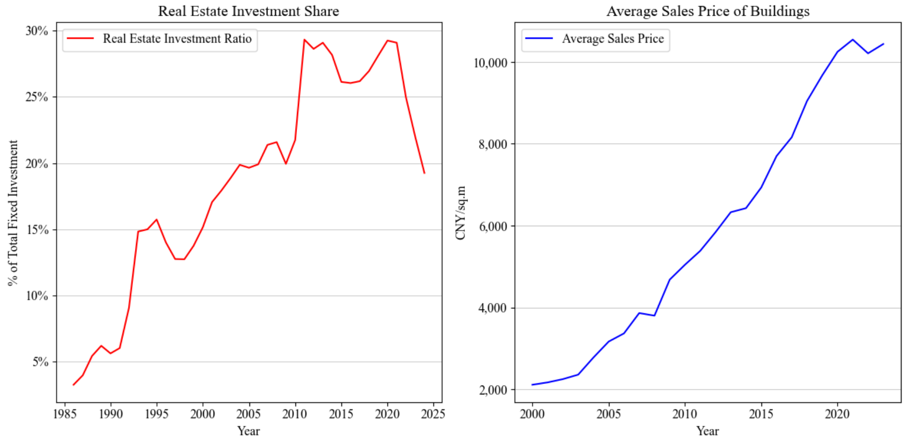
In this context, the debate is shifting from a model based on the quantity of investment to one focused on the quality of accumulation. The Chinese government has declared its intention to improve capital productivity through financial system reforms, selective openness to private capital, and support for innovative and high-tech sectors. Here too, the link with the Dual Circulation Strategy is clear: to reduce dependence on extensive investment and external demand, it will be essential to pursue a more efficient and targeted use of capital.

1.2.4 Real estate, debt and the distorted allocation of capital

In the transition from an investment-driven growth model to one focused on capital quality and efficiency, the role of the real estate sector stands out as a critical component of China's economy. It is in the real estate market, in fact, that some of the country's main structural weaknesses are concentrated: excessive capital allocation, growing debt, and financial vulnerability of firms.
The first aspect to consider is the increasing exposure of the Chinese investment structure to the real estate sector. This is clearly visible in the evolution of the share of real estate investment over total fixed asset investment, and in the parallel increase in property prices.

A long-term view of the share of real estate investment over total fixed asset investment, as shown to the left of Figure 1.5, clearly highlights the growing weight of this

Figure 1.5: The increasing exposure of Chinese growth to real estate



Source: Author's elaboration based on data from National Bureau of Statistics of China (2023), indicators: Real Estate Development, Total Investment in Fixed Assets in the Whole Country, and Average Selling Price of Commercialized Buildings.

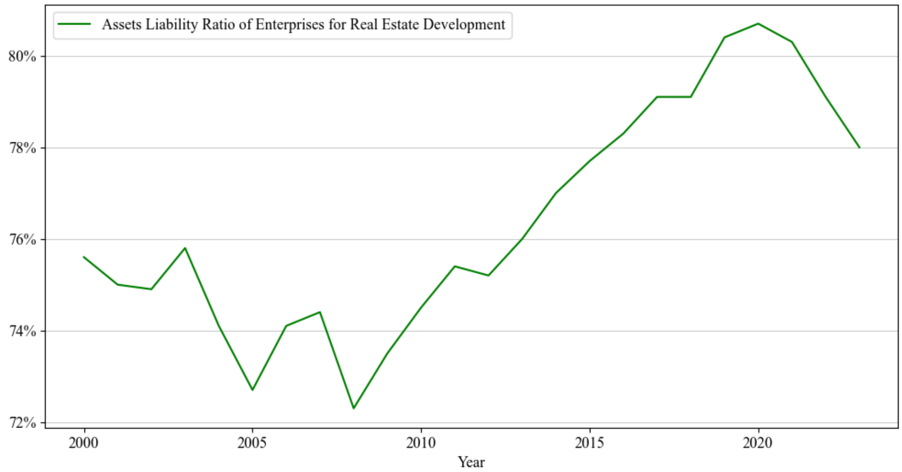
sector 3.3.4. Since the 1990s, this share rose from under 10% to nearly 30% in the years following the 2008 global financial crisis, reaching record levels in 2013 and 2020[of Statistics of China, 2023c], signaling the centrality of real estate in driving growth. However, starting from 2021, the trend has reversed, due to a less favorable macroeconomic context and a shift in Beijing's economic strategy.

This boom was also fueled by the rapid increase in the selling prices of commercialized buildings, shown in Figure 1.5 to the right, which rose from around 2,100 CNY to over 10,500 CNY per m^2 between 2000 and 2022[of Statistics of China, 2023b]. Price dynamics reflect not only rising urban housing demand but also speculative expectations and easy credit availability, which incentivized real estate purchases as investment. This behavior reinforced a self-sustaining cycle of construction, sales, and reinvestment, now showing signs of fragility.

Closely linked to this expansion is the sector's growing indebtedness. The following figure illustrates how real estate developers have accumulated high levels of debt over the last decade.

The construction boom was also driven by extensive use of debt. Figure 1.6 shows that the debt ratio of real estate developers exceeded 80% in 2020[of Statistics of China, 2023a], highlighting the sector's growing financial vul-

Figure 1.6: Structural indebtedness and financial vulnerability of the sector



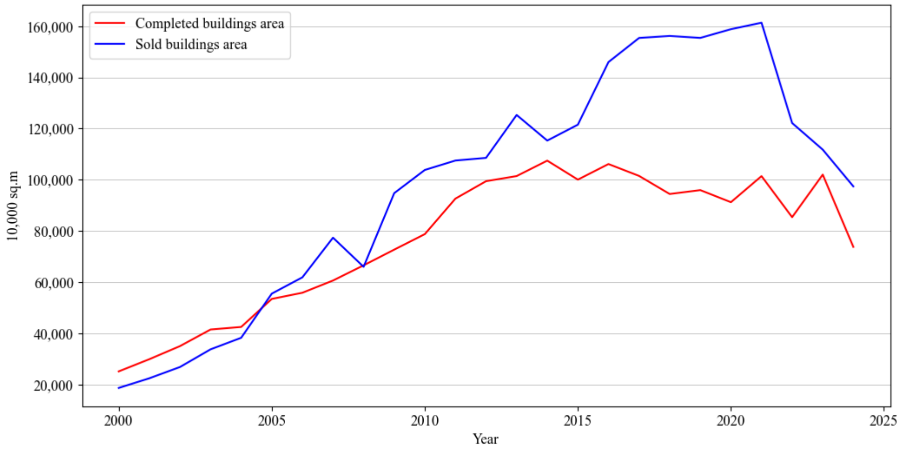
Source: Author's elaboration based on data from National Bureau of Statistics of China (2023), indicator: Assets Liability Ratio of Enterprises for Real Estate Development (%).

nerability. The emblematic case of Evergrande revealed the systemic magnitude of this fragility: high financial leverage, combined with opaque management and unrealistic growth expectations, led to a spiral of defaults that spread to other firms in the sector[Rogoff and Yang, 2020]. Government policies, including the introduction of the "three red lines," sought to curb the issue by promoting a gradual deleveraging process.

A further symptom of distortion is the imbalance between housing supply and actual demand. The next figure compares the floor space of completed and sold properties. One of the most concerning issues is the mismatch between completed and actually sold floor space, as reported in Figure 1.7. After years of closely aligned trends, a growing gap emerged starting in 2015 between the supply of new buildings and actual sales[of Statistics of China, 2023d]. This oversupply is symptomatic of an economy that relied for too long on real estate investment without adequate demand, leading to the emergence of "ghost cities" filled with completed but uninhabited buildings.

Taken together, these figures reveal the extent to which the real estate sector has absorbed capital, distorted investment allocation, and created systemic vulnerabilities within the broader Chinese economy. Looking ahead, the goal will be to reduce the excessive weight of real estate in the economy, reallocating capital toward more

Figure 1.7: Oversupply and signs of oversupply in the Chinese property market



Source: Author's elaboration based on data from National Bureau of Statistics of China (2023), indicators: Floor Space of Buildings Completed and Floor Space of Commercialized Buildings Sold (10,000 sq.m).

productive sectors, in line with the principles of the Dual Circulation Strategy and the need to rebalance domestic growth. Given its scale and interconnectedness with other sectors, the real estate issue will be crucial in shaping China's economic trajectory over the coming decades.

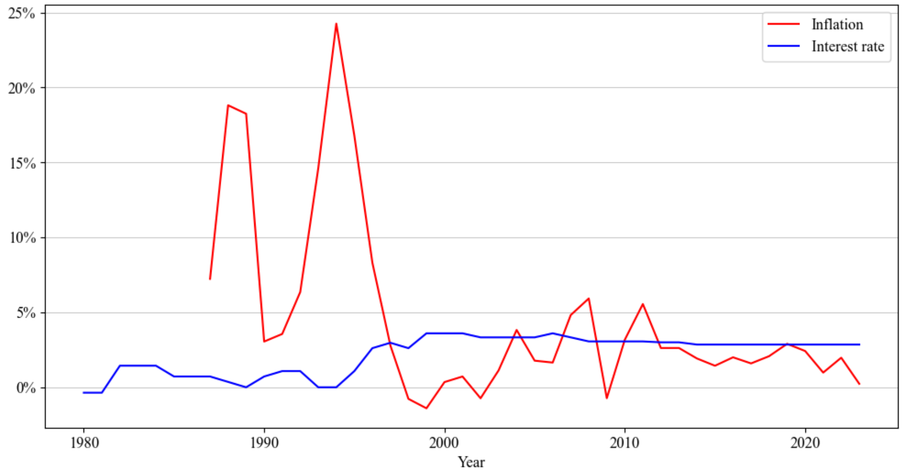
1.2.5 Role of monetary and financial policy

China's economic growth over recent decades has been significantly influenced by the macro-financial environment, in which monetary policy and credit dynamics have played a central role. In a rapidly transforming economy, long characterized by capital movement restrictions, the domestic banking system, dominated by public institutions, has acted as the main channel for resource allocation.

One of the key macroeconomic features of the Chinese model is the tight control over nominal variables. The following figure illustrates the long-term evolution of inflation and interest rates, which have remained remarkably stable in the face of rapid real growth.

One of the most relevant aspects of China's macroeconomic policy has been the strong degree of control over nominal variables. As shown in Figure 1.8, since the mid-1990s China has maintained stable and low inflation, often below 3%, despite

Figure 1.8: Great ability to control: inflation and interest rates in the Chinese real estate sector

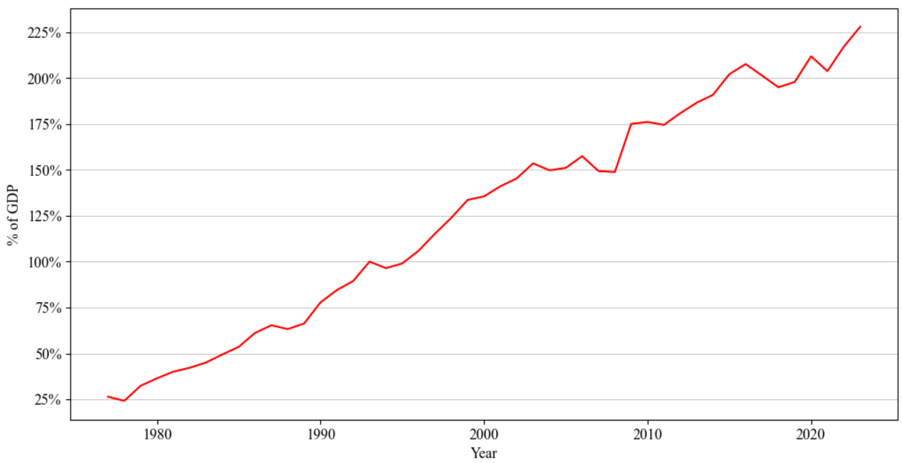


Source: Author's elaboration based on data from World Bank (2024), indicators: FP.CPI.TOTL.ZG and FR.INR.LNDP.

high real growth rates [Bank, 2024n]. At the same time, nominal interest rates have remained moderate, supporting favorable financing conditions. However, the combination of low rates and robust growth has encouraged credit expansion and excessive debt accumulation in certain sectors.

Monetary expansion has also been accompanied by rising liquidity in the system. The next figure shows the rapid growth of the M2 money aggregate relative to GDP.

Figure 1.9: Monetary expansion and excess liquidity: growth of M2 aggregate in China



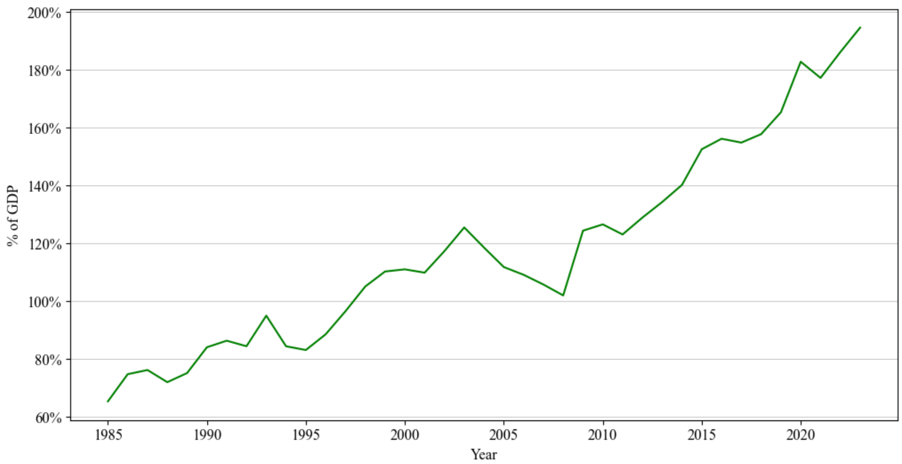
Source: Author's elaboration based on data from World Bank (2024), indicator FM.LBL.BMNY.GD.ZS.

Another important indicator is the M2 money aggregate relative to GDP. Figure 1.9

shows a persistent upward trend, with values rising from around 50% in the 1980s to over 220% in 2023 [Bank, 2024o]. This data indicates increasing liquidity in the economy, often not accompanied by a corresponding expansion in demand or productive activity. This pattern aligns with a bank-centered financial system, in which money creation primarily occurs through credit expansion, often directed towards real estate or public firms rather than innovative private enterprises.

The expansion of credit is also evident in the increasing indebtedness of the private sector. The next figure tracks the growth of bank credit relative to GDP.

Figure 1.10: Growing indebtedness of the private sector: evolution of bank credit in China



Source: Author's elaboration based on data from World Bank (2024), indicator FS.AST.PRVT.GD.ZS.

Figure 1.10 shows the growth of credit to the private sector, also as a share of GDP. This highlights the flip side of the coin. From 1985 to 2023, credit nearly tripled relative to GDP, increasing from about 70% to nearly 195% [Bank, 2024m]. This expansion reflects not only increased demand for financing from businesses and households, but also an economic structure that has incentivized debt accumulation to support growth. The implicit risk is inefficient resource allocation, particularly when credit is directed toward "zombie firms," sectors with overcapacity, or low-return real estate projects.

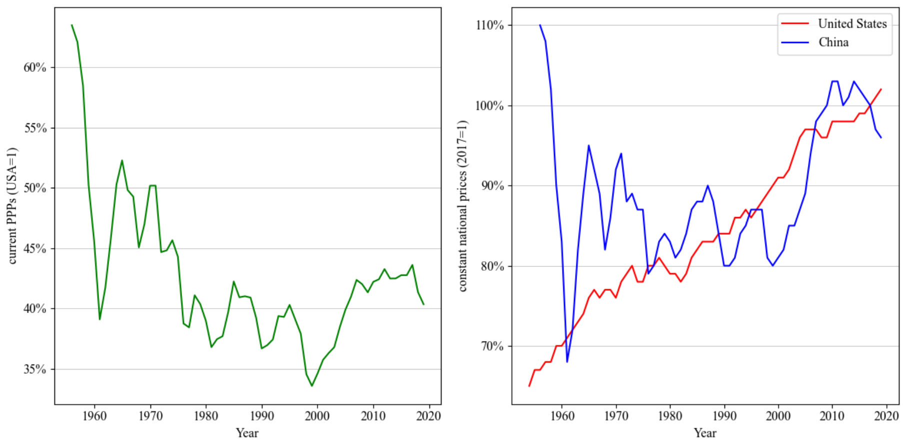
Overall, these figures show how China's financial system has contributed both to supporting rapid growth and to creating significant structural imbalances. The transition to a more sustainable model will require a requalification of financial intermediation, with greater space for market-based instruments, more selective credit criteria, and greater emphasis on supporting innovation. At the same time, it will be necessary to balance financial stability with growth objectives, avoiding systemic shocks stemming from disorderly deleveraging.

1.2.6 Total factor productivity (TFP), innovation and digital

The issue of productivity is central to evaluating the long-term sustainability of China's economic growth. After decades of expansion driven by quantitative inputs—capital, labor, and massive investments—the slowdown of Total Factor Productivity (TFP) highlights the need for a paradigm shift toward growth based on innovation, efficiency, and technological progress.

A first element to consider is the evolution of TFP in China compared to advanced economies. The figure below provides two complementary views: one based on purchasing power parity, the other in constant prices indexed to the U.S.

Figure 1.11: New challenges for the future: Total Factor Productivity (TFP) compared



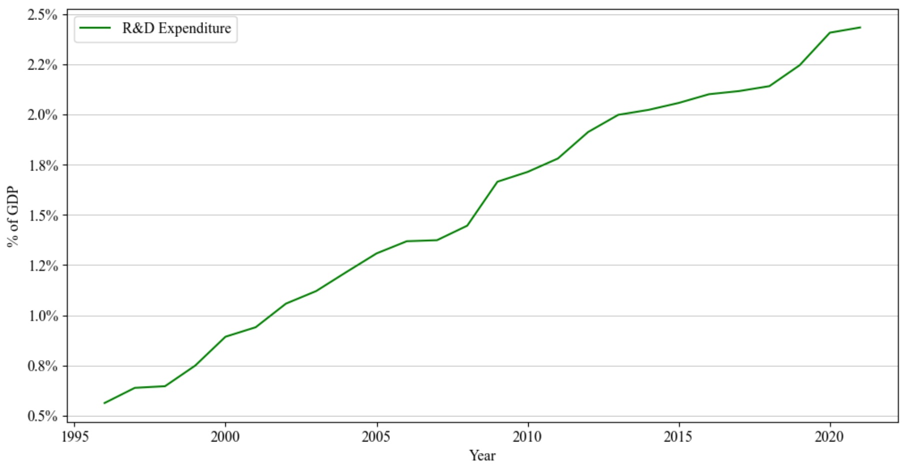
Source: Author's elaboration based on data from Penn World Table (version 10.01), indicators: `ctfp` *and* `rtfpna`*.*

In the left panel of Figure 1.11, the evolution of China's TFP in purchasing power parity with the United States as a benchmark index is shown. After a sharp decline in the 1950s and 1960s, TFP remained stagnant between 1980 and 2005, hovering around 40% of the U.S. level. Despite a slight recovery after 2010, the gap with advanced economies remains wide.

The direct comparison with the United States, in the right panel of Figure 1.11, using constant price data (2017=1), shows how China's TFP, while improving in the long term, has displayed a more unstable and volatile dynamic than that of the U.S. The halt in convergence after 2015 reflects both structural limitations and the emergence of new challenges linked to regulation, demographics, and the geopolitical context.

In response, China has launched a structural shift aimed at fostering technological innovation. One of the most relevant indicators of this strategy is the growth of R&D expenditure over time.

Figure 1.12: Investment in innovation: growth of R&D expenditure as % of GDP

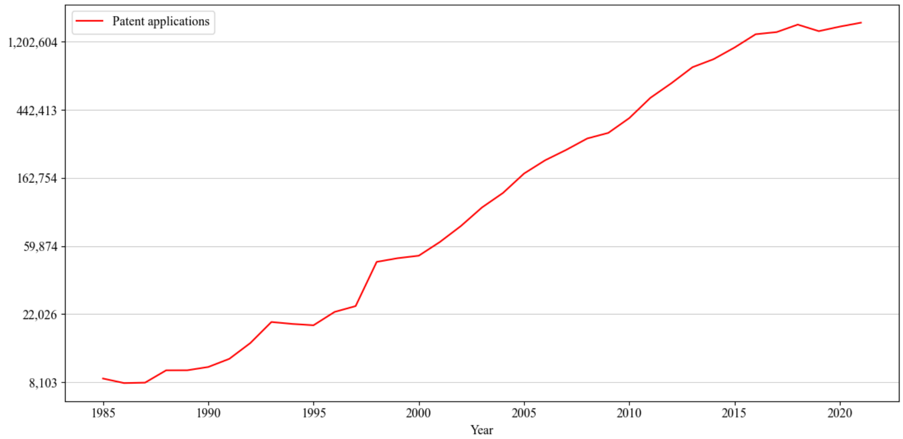


Source: Author's elaboration based on data from World Bank (2024), indicator GB.XPD.RSDV.GD.ZS.

Research and Development (R&D) expenditure has steadily grown, as shown in Figure 1.12, rising from around 0.6% of GDP in 1996 to 2.4% in 2022, surpassing the EU average[Bank, 2024h]. This effort has been supported by strong public direction and ambitious industrial plans like "Made in China 2025."

In parallel, patent activity has increased significantly. The next figure shows the evolution of patent applications filed in China, both by residents and non-residents.

Figure 1.13: Technological dynamism and intellectual property: booming patent applications in China



Source: Author's elaboration based on data from World Bank (2024), indicators IP.PAT.RESD and IP.PAT.NRES.

The number of patent applications, reported in Figure 1.13, has risen exponentially, reaching over 1.6 million annual filings, more than double that of the United States[Bank, 2024f]. However, numerous studies have raised concerns about the quality and real commercial applicability of many of these patents, often tied to distorted incentives in the academic and local bureaucratic system[OECD, 2022a]. Although China is now the second-largest country in the world in terms of total R&D spending, major qualitative challenges remain. According to the OECD, only 15% of China's R&D expenditure qualifies as "basic research"[OECD, 2022b], compared to over 40% in leading OECD countries. Furthermore, the private sector, while expanding, remains heavily dependent on centralized industrial policies.

In the context of the Dual Circulation Strategy, China aims to strengthen its technological self-reliance, particularly in sensitive sectors like semiconductors, AI, and advanced manufacturing. This strategic shift is intended to reduce dependency on foreign technologies and increase the resilience of the production system. However, recent international restrictions, such as the U.S. export ban on advanced chips, pose significant obstacles, risking a slowdown in the path toward a more dynamic and sustainable TFP[Service, 2023].

In summary, China has made significant progress in innovation capacity, digitalization, and human capital investment. However, the real test will be the ability to turn these efforts into a structural and lasting leap in total factor productivity. The country's future growth trajectory will depend not only on the quantity of inputs employed but also on the quality of output generated. In a global context that is increasingly competitive and technology-intensive, the shift from an imitative model to one based on endogenous innovation is the core strategic challenge for consolidating China's status as an advanced economic power.

1.3 The Dual Circulation Strategy

The Dual Circulation Strategy was officially introduced in May 2020 by the Standing Committee of the Political Bureau of the Chinese Communist Party. This strategy aims to create a new development paradigm in which the domestic market (internal circulation) serves as the main pillar of economic growth, while international trade (external circulation) continues to play a complementary role. The objective is to strengthen China's economic self-sufficiency by reducing its dependence on foreign markets and technologies, while maintaining an openness to global integration. This approach was outlined in the 14th Five-Year Plan (2021–2025), which emphasizes the importance of a robust domestic market and independent technological innovation[of China, 2021].

The strategy also represents a direct response to the economic imbalances highlighted in the previous chapters. As discussed in Section 1.2, China has experienced a slowdown in Total Factor Productivity (TFP) and an increasing reliance on infrastructure investment and exports. To address these concerns, the Dual Circulation Strategy aims to rebalance the economy through three main channels:

First, it aims at stimulating domestic demand by encouraging household consumption, which has historically been characterized by a high savings rate. This entails improvements in welfare, social security, and disposable income. Second, the strategy focuses on fostering domestic technological innovation, with investments in research and development to reduce dependence on foreign technologies. In 2020, China's R&D spending reached 2.4% of GDP, with plans to increase this share in the coming years. Third, it seeks to develop a unified domestic market by removing internal barriers, facilitating the free circulation of goods and services, and creating a stable, fair, and predictable business environment. In 2022, the Chinese government issued guidelines to accelerate the construction of a unified national market [of the People's Republic of China, 2022].

Nevertheless, despite its ambitious goals, the implementation of the Dual Circulation Strategy presents several challenges:

One key obstacle is the reluctance to fully liberalize the private sector. The continued dominance of state-owned enterprises (SOEs) may hinder efficiency and innovation. In addition, the low household consumption propensity remains a structural issue, as Chinese households still maintain high savings rates. According to the IMF, strengthening social safety nets would be essential to boosting consumer confidence and incentivizing spending. A third challenge stems from geopolitical tensions and technology restrictions, particularly those affecting access to key technologies in sectors like semiconductors and AI. Finally, there is a risk of economic isolation: while the strategy emphasizes self-reliance, excessive focus on the domestic market could reduce China's integration into the global economy and limit the benefits of international trade and foreign investment.

However, the Chinese government has clarified that Dual Circulation does not imply a closure to the outside world, but rather a more balanced openness[Fund, 2021].

The first chapter provided a comprehensive overview of China's macroeconomic evolution, from Deng Xiaoping's reforms to the present. The analysis highlighted an extraordinary growth path, but one marked by significant structural imbalances and emerging challenges.

After three decades of capital- and labor-intensive expansion, driven by public investment, exports, and urbanization, China's economy is entering a phase of transition. The slowdown in GDP growth, rising indebtedness, the real estate crisis, and geopolitical tensions have underscored the need for a new development model.

In detail:

- The demographic trend has reversed: the working-age population is shrinking while aging is accelerating, requiring a redefinition of the role of human capital.
- Domestic consumption remains weak relative to its potential, while the savings rate continues to be among the highest in the world.
- Although fixed investment remains high, it shows diminishing returns and increasing inefficiencies, as indicated by the rising ICOR.
- The real estate sector has shifted from a growth driver to a drag, with oversupply, rising debt, and systemic financial risks.

- Monetary and credit policy has supported growth, but also contributed to imbalances and credit dependency.
- TFP, after partially sustaining post-crisis growth, is showing signs of stagnation, despite massive efforts in innovation, digitalization, and R&D.

To address these challenges, China has launched the Dual Circulation Strategy, which aims to rebalance growth by strengthening the domestic market and technological self-reliance, while maintaining openness to the global economy. However, difficulties in reforming the public sector, liberalizing consumption, and overcoming geopolitical constraints make implementation of this strategy complex.

The framework laid out in Chapter 1 sets the stage for Chapter 2, where the Solow model will be applied to formally interpret China's growth trajectory. In particular, the chapter will analyze the theoretical determinants of long-term GDP: capital, labor, and TFP, and assess whether China has reached a steady-state. The model will also provide a useful tool to simulate future growth scenarios and test the expected effects of structural reforms.

Chapter 2

Growth Modeling with Solow Framework

This chapter applies the Solow growth framework to formally analyze China's long-term economic trajectory. Building on the macroeconomic dynamics outlined in Chapter 1, it provides a theoretical structure to evaluate the roles of capital accumulation, labor dynamics, and total factor productivity (TFP) in shaping GDP growth.

The chapter is organized as follows. Section 2.1 presents the foundations of the Solow model and justifies its selection over alternative frameworks. Section 2.2 describes the data and parameter calibration used to implement the model empirically for China. It also evaluates China's current position relative to its steady state. Section 2.3 extends the basic framework by incorporating trade openness, simulating the differences between a closed and open economy setting. Finally, the chapter concludes by discussing how structural parameters influence growth projections and steady-state outcomes.

Throughout the chapter, the model is used not only to interpret China's past growth, but also to provide insights into the potential impact of current and future policy reforms—particularly in the context of the Dual Circulation Strategy.

2.1 The Solow Model and Its Applications

2.1.1 Justification for the Solow Model

The previous chapter outlined the key macroeconomic dynamics of China's development, highlighting the role of capital accumulation, demographic changes, and productivity trends.

The analysis of economic growth processes requires the use of theoretical models capable of capturing the underlying dynamics of capital accumulation, labor expansion, and technological progress. Choosing the appropriate model is therefore a crucial methodological step, as it influences not only the interpretation of observed data but also the implications derived from simulations and policy assessments.

In the specific case of China, an economy that has undergone profound structural transformations since the 1980s, the modeling challenge becomes particularly pressing: can China's exceptional growth be interpreted through the traditional tools of economic theory, or is it necessary to resort to more complex frameworks? Most importantly, which approach is most suitable for evaluating the long-term impact of recent economic policies, such as the Dual Circulation Strategy?

Economic literature has developed a wide range of growth models that differ in theoretical structure, level of complexity, and approach to innovation.

Among the most prominent, the following can be identified:

- **The Ramsey-Cass-Koopmans model:** This model introduces intertemporal consumption optimization by representative agents. While more rigorous from a microeconomic perspective, it entails high computational costs and relies on strong assumptions about agent preferences, which limit its empirical applicability in contexts where resource allocation does not fully follow market mechanisms, such as in China [Barro and i Martin, 2004].

- **Endogenous growth models (AK, Romer):** These emphasize the role of human capital, innovation, and externalities. They are particularly suited to explain sustained growth in advanced economies, but tend to overestimate the autonomous innovation capacity of transitional economies, where technological progress is often imported or driven by public intervention. Moreover, they pose significant empirical challenges in terms of calibration and identification [Jones, 1995][Aghion and Howitt, 1998].

- **Human capital-based models (Lucas):** These assign a key role to human capital formation in sustaining long-term growth. Although relevant, such models require robust and comparable measures of human capital, which are often missing or distorted in the case of China [Lucas, 1988].

- **Institutional models (Acemoglu, Johnson, and Robinson):** These place political and economic institutions at the core of development trajectories. However, they rely on variables that are difficult to quantify or compare in China due to limited data transparency and a deeply different institutional structure compared to Western standards [Acemoglu et al., 2001].

Within this context, the Solow model [Solow, 1956] represents a methodologically sound and operationally effective choice. Its simple structure, based on a neoclassical production function and the accumulation of physical capital, allows for a direct analysis of the contribution of core production factors to growth. At the same time, the model can be easily extended to incorporate features relevant to the Chinese context, such as trade openness, imported technological progress, or accelerated capital accumulation. Furthermore, the Solow model is widely used in the empirical literature on emerging economies [Mankiw et al., 1992][Bosworth and Collins, 2008], offering a valuable comparative framework for international benchmarking.

In light of these considerations, the choice of the Solow model satisfies a dual objective: on the one hand, to provide a robust yet manageable theoretical framework; on the other, to ensure consistency with the aims of this thesis, which include analyzing the long-term growth trajectory of China and the effects of public policies—particularly the Dual Circulation Strategy. The following section will outline the foundations of the model and its main growth determinants.

2.1.2 Foundations and Growth Drivers in the Solow Model

The Solow model represents one of the foundational pillars of modern economic growth theory. Developed as a dynamic extension of the Keynesian framework, it aims to explain long-term income growth through the accumulation of capital, population expansion, and exogenous technological progress. The strength of the model lies in its ability to isolate the fundamental mechanisms driving economic expansion over time and to provide testable predictions regarding growth rates and steady-state income levels [Solow, 1956].

Basic model assumptions

The model is based on a set of crucial assumptions:

- Markets are perfectly competitive: production factors are remunerated according to their marginal productivity.

- Saving is a constant and exogenous fraction of income: agents do not engage in intertemporal optimization.

- All savings are fully converted into investment: $S(t) = I(t)$.

- The population growth rate (n), capital depreciation rate (δ), and technological progress (g) are exogenous and constant.

- Technological progress is *labour-augmenting* (Harrod-neutral): it increases labor efficiency.

- The economy is closed: there is no international trade or capital movement.

- Human capital is not included in the basic model: labor is treated as a homogeneous factor.

The theoretical structure of the model

The starting point is an aggregate Cobb-Douglas production function, characterized by the capital and labour production factors alone:

$$Y(t) = K(t)^{\alpha}[A(t)L(t)]^{1-\alpha}, \quad \alpha \in (0,1) \tag{2.1}$$

where:

- $Y(t)$ is total output at time t;
- $K(t)$ is the stock of physical capital;
- $L(t)$ is the labor force;
- $A(t)$ represents the level of total factor productivity (TFP);
- α is the capital share in income.

This functional form is widely used in growth models due to its analytical tractability and several important theoretical properties. In particular, the Cobb-Douglas production function exhibits:

- **Constant returns to scale**: doubling both capital and labor results in a doubling of output;
- **Diminishing marginal productivity**: increasing capital, holding other inputs constant, leads to progressively smaller increases in output;
- **Constant factor elasticities**: the income shares of capital and labor remain stable over time.

Technological progress $A(t)$ grows exogenously at a constant rate g, while the population grows at rate n. By expressing the variables in terms of effective labor units, we define:

$$y(t) = \frac{Y(t)}{A(t)L(t)} \quad ; \quad k(t) = \frac{K(t)}{A(t)L(t)} \tag{2.2}$$

which yields:

$$y(t) = k(t)^{\alpha} \tag{2.3}$$

Assuming that all savings are fully converted into investment, and that savings represent a fixed share of income, the net investment per unit of effective labor is given by $sy(t) = sk(t)^{\alpha}$, where s is the savings rate. The capital accumulation equation per unit of effective labor is:

$$\frac{dk}{dt} = sk^{\alpha} - (n + g + \delta)k \tag{2.4}$$

The term $(n+g+\delta)k$ represents the investment required to keep capital per effective worker constant. The system converges toward a steady state ($\dot{k} = 0$):

$$k^* = \left(\frac{s}{n + g + \delta}\right)^{\frac{1}{1-\alpha}}, \quad y^* = (k^*)^{\alpha} \tag{2.5}$$

In the long run, output per worker grows entirely due to technological progress, while aggregate output growth reflects both population growth and technological advancement, i.e., at rate $(n + g)$.

Another important modeling choice concerns the specification of the production function. While several studies have explored the use of the Constant Elasticity of Substitution (CES) function, which allows for varying degrees of substitutability between capital and labor, the present analysis retains the standard Cobb-Douglas specification. The CES framework introduces a substitution parameter that increases the model's flexibility and can capture important differences across countries, but it also adds a level of complexity that may not be necessary for the core objectives of this thesis. The Cobb-Douglas function, by contrast, offers a more parsimonious structure, assuming unitary elasticity of substitution and constant factor shares. Its analytical tractability facilitates both the theoretical exposition and the empirical calibration of the model. Moreover, the Cobb-Douglas specification remains widely used in growth studies involving emerging economies, including applications to the Chinese case [Bosworth and Collins, 2008, Feenstra et al., 2015], allowing for clearer interpretation and comparability of results. For these reasons, simplicity, clarity, and consistency with the empirical literature, the Cobb-Douglas form is adopted as the baseline production function in this thesis.

Convergence dynamics and empirical validation

One of the central implications of the Solow model is the mechanism of conditional convergence. According to this hypothesis, economies that share similar rates of saving, population growth, and technological progress will tend, in the long run, to converge toward similar levels of per capita income. Moreover, due to diminishing marginal returns to capital, economies that are initially poorer, that is, with a lower capital stock per capita, benefit from higher returns on investment and therefore grow more rapidly. This phenomenon underlies the so-called *catch-up effect*. Convergence, however, is neither automatic nor absolute: structural differences between countries can lead to different steady states and, consequently, to different long-run income levels.

At the empirical level, the convergence hypothesis can be tested by estimating a log-linear relationship between income growth and initial income, while controlling for structural variables:

$$\log y_{i,t} - \log y_{i,0} = \beta \log y_{i,0} + \gamma X_i + \varepsilon_i \tag{2.6}$$

where $y_{i,t}$ is the per capita income of country i at time t, $y_{i,0}$ is the initial income, and the term γX_i includes a set of structural control variables (such as the savings rate, demographic growth, and human capital) and their associated coefficients, which capture how these factors affect long-term income growth across countries.

Mankiw, Romer, and Weil (1992) empirically test the augmented Solow model on a sample of 98 countries over the period 1960–1985 [Mankiw et al., 1992]. Their findings show a significantly negative β coefficient, confirming the existence of conditional convergence. The inclusion of human capital considerably improves the model's explanatory power, with the R^2 increasing from 0.33 in the basic version to 0.78 in the extended one. The main results are summarized in Table 2.1.

The theoretical mechanism described above can be visualized using a standard Solow diagram.

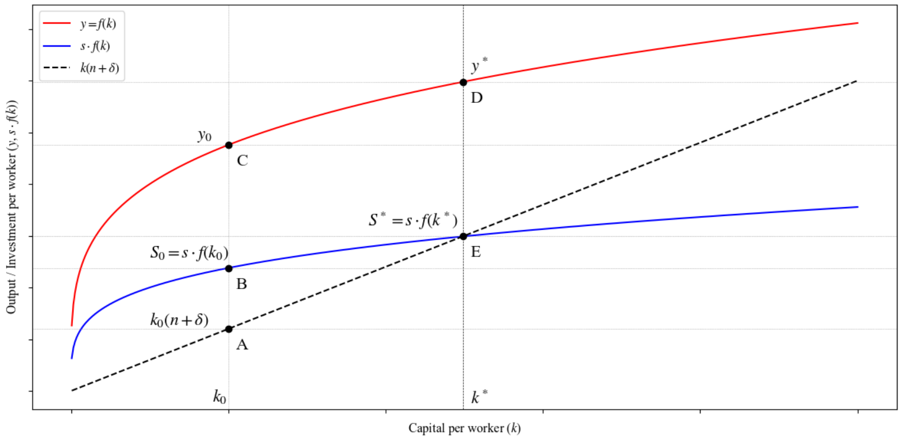
The following figure illustrates the transition dynamics of an economy moving from an initial level of capital per effective worker k_0 toward the steady-state k^*.

Table 2.1: Conditional Convergence Estimates (MRW, 1992)

Statistic	Basic Model	With Human Capital
β (initial income coefficient)	-0.013	-0.011
t-statistic	3.2	4.1
R^2	0.33	0.78

Source: Author's elaboration based on Mankiw, Romer, and Weil (1992). Sample: 98 countries, period: 1960–1985.

Figure 2.1: Solow Growth Model – Transition to Steady State



Source: Our Elaboration. The figure is based on theoretical functions and simulated data for pedagogical purposes.

As shown in Figure 2.1, the curve represents the accumulation dynamics of capital per effective worker. The economy starts from an initial point k_0, below the steady-state. The points A, B, and C represent intermediate stages of capital accumulation over time. At each stage, the economy invests more than is required to keep k constant, so k increases. Over time, diminishing returns and the effects of depreciation, population, and technology growth reduce the net addition to capital until the economy stabilizes at point k^*, corresponding to the steady-state. Points D and E indicate this long-run equilibrium, where net investment equals zero and per effective worker variables grow at rate g.

This graphical representation reinforces the prediction of conditional convergence: countries with lower initial capital per effective worker (lower k_0) tend to grow faster as they accumulate capital, until they reach their long-run path. However, the actual position of k^* can vary across countries depending on structural variables such as saving rate, depreciation, population growth, and technology, consistent with the empirical estimation model outlined above.

A useful concept in this context is the *speed of convergence*, i.e., the rate at which an economy approaches its steady-state. Empirical estimates (e.g., [Barro and i Martin, 2004]) typically suggest a convergence rate of around 2% per year, implying a half-life of approximately 35 years. However, under favorable conditions (e.g., strong institutions or capital inflows), higher speeds of 2.5 to 3% have been observed, reducing the convergence horizon to 15 to 30 years [Islam, 1995]. This aspect will be further explored in Section 2.2, where we assess China's position relative to its own steady state.

These transitional dynamics are particularly relevant for economies undergoing structural transformation, such as China. The interaction between capital accumulation and policy shifts, like the Dual Circulation Strategy, can significantly influence the trajectory toward the steady state. In this context, the transition path is not merely theoretical, but directly tied to the sequencing and effectiveness of institutional and economic reforms.

The role of human capital

The original Solow model explicitly neglects the role of human capital, assuming that all labor is homogeneous. However, several theoretical extensions, most notably the so-called augmented Solow model, have emphasized the importance of education, training, and skills in explaining differences in income levels and growth rates across countries. In particular, [Mankiw et al., 1992] extend the basic model by including human capital as an additional factor of production:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} [A(t)L(t)]^{1-\alpha-\beta} \tag{2.7}$$

where $H(t)$ denotes the stock of human capital, typically proxied by variables such as average years of schooling. In this framework, β captures the elasticity of output with respect to human capital, i.e., the percentage change in output resulting from a one percent change in the human capital stock, holding other inputs constant.[1] The inclusion of this additional input significantly improves the model's explanatory power in accounting for cross-country income disparities and offers a more comprehensive understanding of the drivers of long-term growth.

Empirical implications and limits

The Solow model offers a powerful analytical framework, yet it is not without limitations. In particular:

- it assumes a closed economy, thereby ignoring international trade and financial flows, factors that are especially relevant for many emerging markets;
- technological progress is treated as exogenous;
- institutions, public policies, and allocative efficiency are not explicitly modeled;
- the model does not incorporate a dynamic treatment of human capital in its original formulation.

Nonetheless, despite these limitations, the model remains a fundamental reference in growth analysis and serves as the foundation for the empirical investigations developed in Chapter 2 and Chapter 3.[2]

Several scholars have addressed these limitations by incorporating trade openness into the Solow framework. For instance, [Edwards, 1998] and [Harrison, 1996] show how trade liberalization can enhance productivity and accelerate convergence. Similarly, [Ben-David, 1993] provides evidence that countries integrated into global markets tend to exhibit stronger convergence patterns. These extensions are particularly relevant for emerging economies like South Korea, which leveraged international

[1] It is important to note that this parameter β is distinct from the convergence coefficient used in the empirical estimation equation 2.6 in the previous section.

[2] The terminology and formal structure follow primarily [Solow, 1956] and [Mankiw et al., 1992]. Empirical estimations and specific calibrations for China will be presented in Chapter 2 and Chapter 3.

openness to sustain rapid growth, in contrast to cases like Argentina, where limited openness and institutional weaknesses hampered long-term development. A modified Solow model accounting for trade dynamics will be discussed in Section 2.3.

2.2 Empirical Implementation for China

2.2.1 Data and Parameter Calibration

This section presents the data used to calibrate the Solow growth model, applied to the case of China for the period 1953–2019. All variables were extracted from the *Penn World Table* (version 10.01), one of the most widely used international sources for comparative growth analysis, following the methodology outlined in [Feenstra et al., 2015].

Specifically, the calibration relies on the following core variables:

– Output-side real GDP: variable `cgdpo`, in 2017 PPP terms;

– Gross capital formation as a share of GDP (GCF): variable `csh_i`;

– Capital depreciation rate: variable `delta`;

– Employment: variable `emp`, in millions of people;

– Population growth rate: derived from the variable `pop`;

– Human Capital Index: variable `hc`;

– Labour share of GDP: variable `labsh`.

Additional derived variables, such as capital per effective worker and total factor productivity (TFP), will be computed in the next Section 2.2.2. Unless otherwise stated, all values are expressed in real terms at constant 2017 prices (PPP-adjusted).

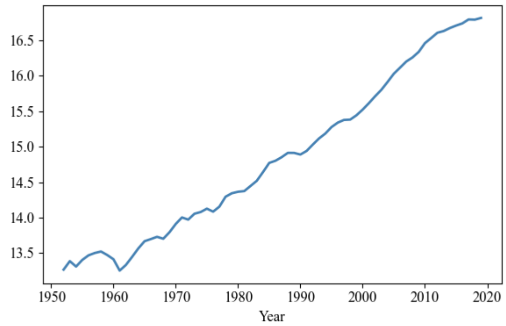
In the following subsections, each variable is presented through a descriptive statistics table and a time-series plot, providing an empirical foundation for the model calibration process.

Output-Side Real GDP (at current PPPs)

Table 2.2: Descriptive Statistics

Statistic	Value
Mean	5,281,143
Median	2,680,800
Std. Dev.	5,949,815
Min	569,135
Max	20,118,080

Figure 2.2: Trend over time



Source: Author's elaboration based on Penn World Table (version 10.01), indicator: `cgdpo`

Gross Domestic Product (GDP), measured in international dollars at purchasing power parity (PPP) and constant 2017 prices, is the core indicator of aggregate output in the economy. Within the Solow model, it corresponds to the variable $Y(t)$. Using a constant PPP-adjusted series, rather than nominal or local currency GDP, ensures better comparability over time and across countries by removing inflation and exchange rate effects [Feenstra et al., 2015].

Over the sample period (1953–2019), China's GDP_PPP increased exponentially, from under 600 billion international dollars in 1953 to more than 20 trillion in 2019, as shown in Table 2.2. The average value over the period was around 5.3 trillion, while the median was substantially lower (2.7 trillion), indicating a right-skewed distribution and a strong acceleration in later decades. The high standard deviation (nearly 6 trillion) also reflects this expansionary pattern, particularly from the 1990s onward, coinciding with major economic reforms and China's integration into global markets. This growth trajectory is consistent with the historical trends discussed in Section 1.1, where China's rapid post-reform expansion and structural transformation contributed to an average annual growth rate of nearly 10% during the reform era.

Methodologically, the variable used is `cgdpo` from the Penn World Table (version 10.01), which measures real output using the output-side GDP approach at 2017 PPP prices. This indicator is widely used in international growth comparisons and is constructed through a combination of harmonized national accounts data and

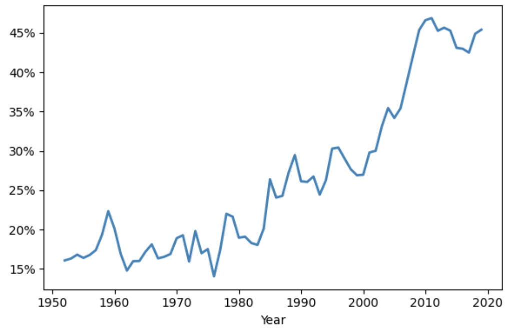
International Comparison Program (ICP) estimates [Feenstra et al., 2015].
Adopting this measure ensures full consistency with the other model inputs, namely, capital and labor, and provides a reliable basis for decomposing growth drivers and running simulations in the following chapters.

Gross Capital Formation as a Share of GDP

Table 2.3: Descriptive Statistics

Statistic	Value
Mean	26.54%
Median	24.30%
Std. Dev.	10.29%
Min	14.07%
Max	46.88%

Figure 2.3: Trend over time



Source: Author's elaboration based on Penn World Table (version 10.01), indicator: `csh_i`

Gross Capital Formation (GCF), expressed as a percentage of GDP at constant PPP 2017 prices, represents the share of national income devoted to physical investment. Within the Solow framework, this variable is directly associated with the saving rate s, under the standard assumption that all savings are converted into investment [Solow, 1956].
During the 1953–2019 period, China's average GCF share stood at 26.54% of GDP, with peaks close to 47%, as reported in Table 2.3. As noted in Section 1.2.2, China's saving rate has consistently exceeded 45% of GDP in recent decades, reflecting a deep-rooted investment-led growth model. This empirical regularity validates the use of a high and persistent GCF/GDP ratio in the calibration. These values are exceptionally high by international standards, well above the historical OECD average (typically 20 to 25%) [Barro and i Martin, 2004], and highlight the investment-led nature of China's growth model [Vilaverde and altri, 2022].
From a methodological perspective, the values derive from the `csh_i` variable in the Penn World Table 10.01, which provides a harmonized estimate of the share of output allocated to investment. Using PPP-adjusted values ensures consistency

with the GDP series and allows for intertemporal and international comparability [Feenstra et al., 2015].

Although high investment rates are typically associated with capital deepening and output expansion, they do not automatically guarantee productive growth. Several studies, including [Bosworth and Collins, 2008] and [Easterly and Levine, 2001], show that many developing countries have allocated large shares of output to capital accumulation without achieving proportional gains in income, often due to institutional inefficiencies and low marginal returns to capital.

These issues will be further examined in later sections. For the purpose of model calibration, however, the GCF/GDP ratio remains a reliable proxy for the saving rate s, in line with the standard identity $S = I$. The methodological alignment with recent empirical applications of the Solow model in emerging economies (e.g., [Vilaverde and altri, 2022]) reinforces the soundness of this approach.

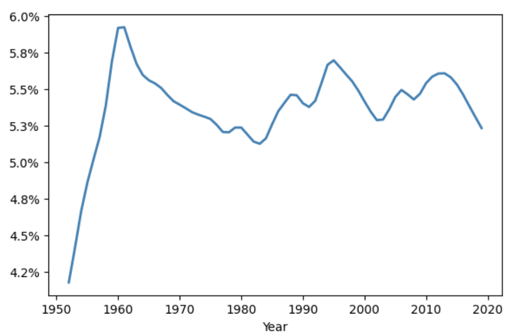
Investment alone, however, does not fully explain capital accumulation. The rate of capital depreciation must also be taken into account.

Capital Depreciation Rate

Table 2.4: Descriptive Statistics

Statistic	Value
Mean	5.39%
Median	5.41%
Std. Dev.	0.25%
Min	4.41%
Max	5.92%

Figure 2.4: Trend over time



Source: Author's elaboration based on Penn World Table (version 10.01), indicator: `delta`

The depreciation rate (δ) represents the proportion of the physical capital stock that becomes obsolete, loses economic value, or deteriorates each year. In the Solow model, this parameter plays a critical role in determining the level of net investment required to maintain the capital stock per effective worker, and therefore influences the position and attainment of the steady state.

Unlike many theoretical studies that assume a fixed depreciation rate for simplicity, this analysis uses an annual historical series specific to China, based on the `delta` variable from the Penn World Table (version 10.01). This choice is aligned with the approach proposed by [Vilaverde and altri, 2022], who advocate for the use of country-specific empirical values to improve the accuracy of model calibration in emerging economies.

As shown in Table 2.4, the average depreciation rate in China over the period 1953–2019 is 5.39%, with a median of 5.41% and a standard deviation of just 0.25%. The observed range lies between 4.41% and 5.92%, consistent with estimates found in the literature: for instance, [Barro and i Martin, 2004] suggest rates between 4% and 6% for rapidly growing economies, and [Bosworth and Collins, 2008] report similar values in cross-country comparisons involving China and India.

The `delta` series of PWT (Penn World Table) is derived from the sectoral composition of capital and the average useful life of productive assets, under internationally consistent assumptions [Feenstra et al., 2015]. Using a time-varying, empirically derived rate allows us to better capture structural shifts in the Chinese economy, such as its transition from agriculture to industry, and more recently to services and knowledge-intensive sectors.

In the calibration of the Solow model, the average depreciation rate (5.39%) will be used as a benchmark. However, sensitivity analysis will be conducted to assess the robustness of the results to variations in δ, in line with best practices in applied growth modeling.

After capital and depreciation, we now turn to the labor input: the dynamics of the employed workforce.

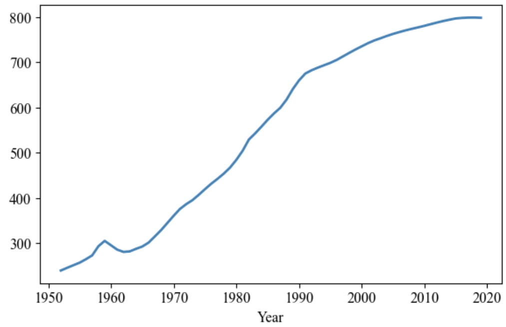
Employment

Source:

Table 2.5: Descriptive Statistics

Statistic	Value
Mean	554.99
Median	587.22
Std. Dev.	200.09
Min	245.70
Max	799.31

Figure 2.5: Trend over time



Author's elaboration based on Penn World Table (version 10.01), indicator: `emp`

Employment, measured in millions of people, represents one of the two fundamental inputs in the Solow production function. Combined with physical capital, it determines aggregate output through a Cobb-Douglas structure. Using actual employment rather than total population allows for a more accurate estimate of labor productivity and capital accumulation dynamics, as it better reflects the effective contribution of labor to the production process [Vilaverde and altri, 2022, Barro and i Martin, 2004]. The evolution of employment levels is closely tied to the demographic transition discussed in Section 1.2.1, where China's working-age population peaked in 2015 and has begun to decline—raising important questions about the sustainability of labor-driven growth. The data used in this section come from the `emp` series in the Penn World Table 10.01 and are based on harmonized census and survey information [Feenstra et al., 2015]. The unit of measurement is millions of employed individuals (not hours worked), and the level of aggregation is consistent with that of GDP used as output $(Y(t))$. The PWT methodology ensures international comparability and time consistency, which are essential for long-run growth analysis.

As shown in Table 2.5, China experienced sustained growth in employment between 1953 and 2019, with an average of approximately 555 million workers. The median value is slightly higher (587 million), and the range spans from 245 million in the early years to nearly 800 million in recent decades. These figures reflect China's demographic transition and its rapid structural transformation.

The growth in employment was shaped by several structural factors: rural-to-urban migration, the market-oriented reforms launched in 1978, the rapid development of the manufacturing sector, and more recently, population aging. These trends will be discussed further in the following chapters, especially in relation to human capital and sectoral shifts in labor demand.

For model calibration purposes, the `emp` series is used to derive two central variables: capital per effective worker $k(t)$ and output per effective worker $y(t)$. It also enters the computation of the Solow residual for total factor productivity (TFP). Compared to population-based measures, using actual employment allows for a more realistic modeling of productive capacity and growth potential.

Population Growth Rate

Table 2.6: Descriptive Statistics

Statistic	Value
Mean	1.36%
Median	1.37%
Std. Dev.	0.88%
Min	–0.92%
Max	3.24%

Figure 2.6: Trend over time

Source: Author's elaboration based on Penn World Table (version 10.01), indicator: `pop`

The population growth rate (n) is one of the three fundamental exogenous variables in the Solow model, along with the savings rate (s) and the rate of technological progress (g). It reflects the pace at which the labor force expands over time and directly influences the trajectory of capital per effective worker and the speed of convergence toward the steady state.

The data for this variable are derived from the `pop` series in the Penn World Table 10.01, which reports the total resident population in millions. The annual growth rate is computed as the percentage change in population from one year to the next, thereby aligning the empirical measure with the theoretical interpretation of the n parameter in the model.

As shown in Table 2.6, China recorded an average population growth rate of 1.36% between 1953 and 2019, with a median of 1.37% and a standard deviation of 0.88%. The range is quite broad, with a minimum of –0.92% and a maximum of 3.24%. These fluctuations reflect the effects of historical shocks and demographic policies, such as the 1960–61 famine and the implementation of the one-child policy in the 1980s [Barro and i Martin, 2004].

From a theoretical perspective, a higher population growth rate requires greater investment efforts to maintain constant capital per worker, while lower demographic expansion facilitates capital deepening. However, China's recent demographic slowdown, combined with a rapidly aging population, poses important challenges to the country's long-term growth prospects. These issues will be explored in greater depth in the subsequent chapters.

For calibration purposes, the average value over the sample (1.36%) is adopted as a benchmark, consistent with the approach proposed by [Vilaverde and altri, 2022] in their long-run growth analysis of emerging economies.

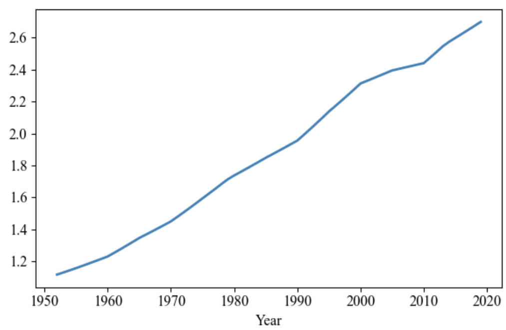
Human Capital Index

Source:

Table 2.7: Descriptive Statistics

Statistic	Value
Mean	1.876
Median	1.859
Std. Dev.	0.493
Min	1.117
Max	2.699

Figure 2.7: Trend over time



Author's elaboration based on Penn World Table (version 10.01), indicator: `hc`

Human capital is a fundamental component in extended growth models, particularly in the framework proposed by [Mankiw et al., 1992], where education and skills directly affect labor productivity and the capacity to absorb technological progress.

This analysis employs the `hc` variable from the Penn World Table (version 10.01), which summarizes the average level of education of the working-age population, weighted by expected efficiency. The index is built following the methodology developed by [Feenstra et al., 2015] and [Lutz et al., 2018], combining years of schooling with a concave transformation that reflects diminishing returns to education.

As shown in Table 2.7, the Human Capital Index for China averaged 1.876 over the period 1953–2019, with a median of 1.859 and a standard deviation of 0.493. The lowest value (1.117) was observed in the early years of the sample, while the index peaked at 2.699 in the most recent period, highlighting a significant improvement in educational attainment. As shown in Figure 1.2 and Section 1.2.1, China has significantly expanded access to tertiary education in recent decades, with tertiary enrollment rates rising above 70% by 2023. This upward trend in educational attainment underpins the rising level of the human capital index captured in this dataset.

This trend is consistent with China's educational reforms since the 1980s, particularly the expansion of higher education, the establishment of technical schools, and increased investment in science and technology training. The accumulation of human capital has played a critical role in the country's transition toward a more innovation-driven, knowledge-based economy, a key objective of the Dual Circulation strategy.

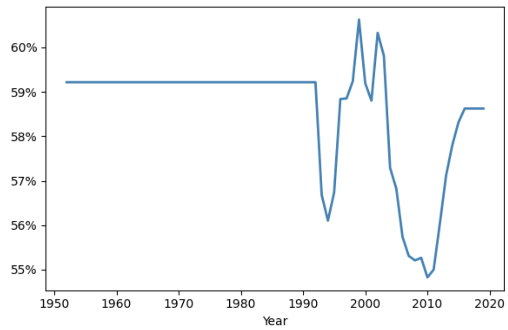
While the human capital index is a relevant input in extended growth models, it is not included in the baseline Solow model estimated in Section 2.2.2. Nonetheless, its evolution is presented here to offer a broader perspective on China's development and to enable a comparative assessment of model performance, as discussed at the end of that section.

Labour Share of GDP

Table 2.8: Descriptive Statistics

Statistic	Value
Mean	0.586
Median	0.592
Std. Dev.	0.013
Min	0.548
Max	0.606

Figure 2.8: Trend over time



Source: Author's elaboration based on Penn World Table (version 10.01), indicator: `labsh`

The variable `labsh`, or labour share, measures the share of total GDP allocated to labor compensation. It plays a central role in estimating a time-varying capital share ($\alpha_t = 1 - \texttt{labsh}$) and is used in dynamic TFP calculations, particularly in growth accounting exercises that relax the assumption of constant factor shares.

As shown in Table 2.8, the average labour share in China over the period 1953–2019 is approximately 58.6%, with values ranging from a minimum of 54.8% to a maximum of 60.6%. The series displays moderate variation, with a standard deviation of 1.35 percentage points, and a median value very close to the mean, confirming a relatively stable distribution over time.

Methodologically, `labsh` is sourced directly from the Penn World Table 10.01 and reflects national accounts estimates of total labor compensation as a share of GDP at current national prices. This series is constructed following internationally harmonized definitions and is widely used in empirical growth studies to infer the capital income share in a given economy [Feenstra et al., 2015].

The evolution of the labor share is particularly relevant in the Chinese context, as discussed in Section 1.2.1 and Section 1.2.6. While the working-age population is declining, improvements in education and workforce specialization have reshaped the composition of labor input. Incorporating the observed labor share into the model allows us to adjust capital income estimates and refine the calculation of TFP as a residual.

In this thesis, the `labsh` series is used to compute the empirical, time-varying capital share α_t, which in turn allows for a dynamic specification of the TFP residual. This methodological choice enhances the realism of the growth decomposition and provides an alternative to fixed-α assumptions typically adopted in neoclassical models [Vilaverde and altri, 2022]. The comparison between fixed and dynamic TFP trajectories is presented in Section 2.2.3.

Having outlined and discussed in detail the evolution of the model's core variables, we now proceed to estimate and calibrate the key parameters of the standard Solow model. A comparison with the augmented version is included at the end of Section 2.2.2 to assess whether the inclusion of human capital materially improves model accuracy.

2.2.2 Empirical Estimation of the Growth Model

After calibrating the main parameters in Section 2.2.1, this section empirically applies the Solow model to the Chinese economy to assess the long-run relationship between output, physical capital, labor, and human capital, and to evaluate the convergence dynamics toward the steady state.

This empirical analysis builds directly on the diagnostic presented in Section 1.2.6, where Total Factor Productivity (TFP) was identified as a key constraint on China's long-term growth potential. Despite significant efforts in innovation and human capital development, recent data suggest a deceleration in TFP gains, highlighting the importance of decomposing output growth and isolating the productivity component within the Solow framework.

The chosen approach relies on an ARDL (Autoregressive Distributed Lag) model, which allows for the analysis of non-stationary but cointegrated time series.[3]

As discussed in Section 2.1.2, the theoretical model assumes a two-factor Cobb-

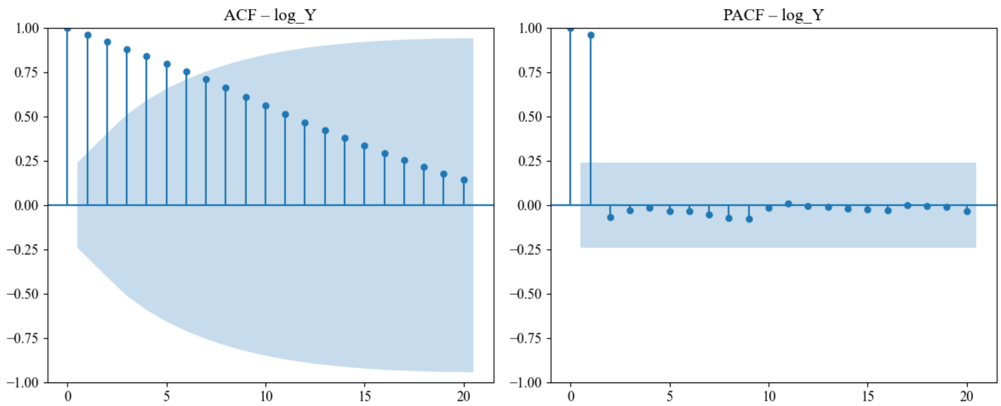
[3] The four logarithmic series (`log(GDP)`, `log(Capital)`, `log(Employment)`, `log(Human Capital)`) are non-stationary in levels but stationary in first differences, as confirmed by the ADF tests: `log(GDP)` – stat = 0.51 ($p = 0.985$), `log(Capital)` – stat = 1.28 ($p = 0.996$), `log(Employment)` – stat = –1.80 ($p = 0.379$), `log(Human Capital)` – stat = –1.43 ($p = 0.567$). The ADF test on the residuals of the ARDL model including human capital yields a statistic of –8.19 ($p < 0.001$), well below the critical thresholds (–2.59 at 10%, –2.91 at 5%, –3.54 at 1%), confirming the existence of a long-run cointegrating relationship among the variables.

Douglas production function in logarithmic form:

$$\log Y(t) = \alpha \log K(t) + (1-\alpha) \log [L(t)A(t)] \tag{2.8}$$

In this formulation, A_t represents Harrod-neutral technical progress, which enhances labor efficiency without affecting capital. This specification is essential to ensure the stability of the steady state in the Solow model and to guarantee balanced long-term growth, in which output per worker increases at the rate of technical progress.

Figure 2.9: Correlogram of the logarithmic series of GDP



Source: Author's elaboration based on Penn World Table (version 10.01), indicator: cgdpo.

The correlogram shown in Figure 2.9, which plots the ACF and PACF functions for the $\log Y$ series, confirms strong serial persistence, with autocorrelations decaying slowly and a single significant spike in the PACF at lag one. This pattern is typical of non-stationary time series. However, within the ARDL framework, such features are consistent with the existence of cointegrating relationships.

Based on these observationsm, and in line with the automatic lag selection procedure using the Akaike Information Criterion (AIC) and the other computed performance metrics, the estimated ARDL model includes up to four lags for the dependent variable and the explanatory regressors. This configuration provides a balance between predictive performance and model parsimony, while mitigating risks of overfitting.

The estimated ARDL(2,2,0) model takes the following empirical form:

$$\log Y_t = \alpha_0 + \phi_1 \log Y_{t-1} + \phi_2 \log Y_{t-2} + \beta_0 \log K_t + \beta_1 \log K_{t-1} + \beta_2 \log K_{t-2} \\ + \gamma_0 \log L_t + \varepsilon_t \tag{2.9}$$

The ARDL(2,2,0) specification was selected using a mixed approach that combines the Akaike Information Criterion (AIC) with in-sample accuracy metrics such as MAE, MAPE, MSE, and RMSE. This methodology balances model parsimony with the ability to fit the observed data, ensuring a robust representation of Chinese GDP dynamics.

Table 2.9: ARDL(2,2,0) model: estimated coefficients

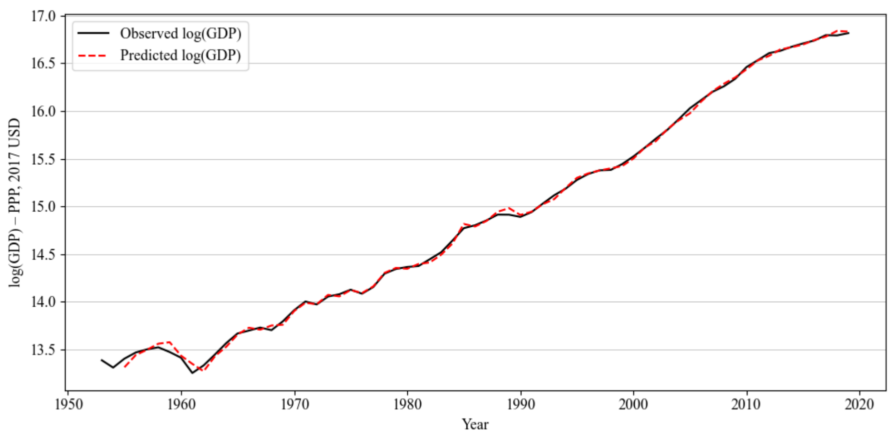
Variable	Coefficient	Std. Error	z-Statistic	p-value
Constant	0.4414	0.272	1.624	0.110
$\log(\text{GDP})_{t-1}$	0.9499	0.121	7.871	0.000
$\log(\text{GDP})_{t-2}$	-0.1418	0.088	-1.611	0.113
$\log(\text{Capital})_{t}$	2.7639	0.337	8.210	0.000
$\log(\text{Capital})_{t-1}$	-4.3780	0.572	-7.655	0.000
$\log(\text{Capital})_{t-2}$	1.7552	0.356	4.926	0.000
$\log(\text{Labor})_{t}$	0.0299	0.033	0.900	0.372
Summary statistics				
AIC		-246.5		
MAE		100,565		
MAPE		2.37%		
MSE		32,474,416,222		
RMSE		180,207		
Observations		67		

Source: Author's elaboration based on ARDL(2,2,0) estimation.

As shown in Table 2.9, the coefficients associated with physical capital are highly significant (z-statistics above 4 in absolute value) and display alternating signs, indicating a rather complex short-run adjustment dynamic. The cumulative effect of capital on output is clearly positive, consistent with the prevailing interpretation that China's economic expansion has been primarily driven by physical capital accumulation. In contrast, the contemporaneous coefficient on labor is not statistically significant, confirming the marginal role of demographic dynamics in explaining the observed growth. This result aligns with the discussion in Chapter 1, where a progressive weakening of labor input contributions was highlighted in favor of greater relevance for productive investment and technological accumulation.

The in-sample performance metrics (MAE = 100,565; MAPE = 2.37%; MSE = 32.47 billion; and RMSE = 180,207) confirm the model's strong ability to reproduce observed output with limited errors, as expected for an economy characterized by highly autocorrelated structural dynamics. The value of the Akaike Information Criterion (AIC = –246.5) indicates a good trade-off between precision and simplicity, avoiding the risk of overfitting despite the inclusion of multiple lags in the explanatory variables.

Figure 2.10: Observed vs estimated log(GDP) – ARDL(2,2,0) model

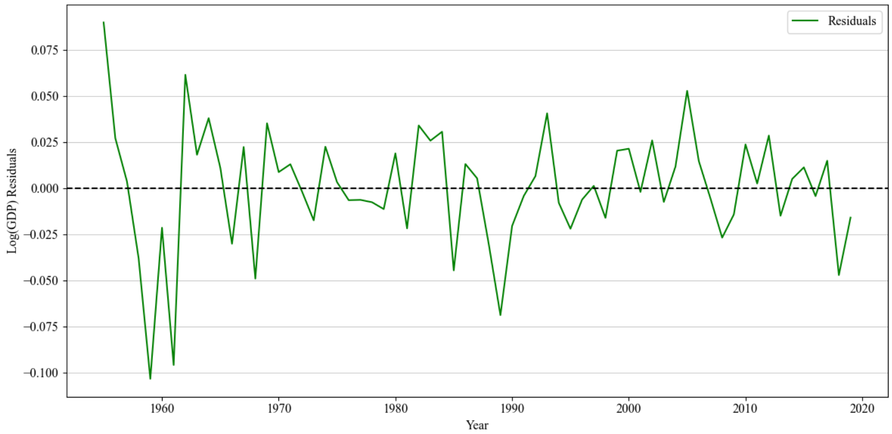


Source: Author's elaboration based on ARDL(2,2,0) model.

Figure 2.10 shows the close correspondence between observed and estimated log-GDP, confirming the adequacy of the adopted ARDL specification. The model's ability to track the evolution of output suggests that physical capital accumulation and the inertial dynamics of GDP account for much of China's economic development.

Figure 2.11 displays the residuals from the ARDL(2,2,0) model, which fluctuate around zero without systematic autocorrelation, further confirming the validity of the dynamic specification. The cointegration test performed on the residuals returns an ADF statistic of –7.64 with a p-value < 0.001, confirming the existence of a long-run relationship between GDP, capital, and labor.

Figure 2.11: Residuals of ARDL(2,2,0) model



Source: Author's elaboration based on ARDL(2,2,0).

To test robustness, an alternative ARDL(4,4,1,0) model including human capital was also estimated using the same selection criteria.
The corresponding empirical specification is:

$$\begin{aligned}\log Y_t &= \alpha_0 + \phi_1 \log Y_{t-1} + \phi_2 \log Y_{t-2} + \phi_3 \log Y_{t-3} + \phi_4 \log Y_{t-4} \\ &\quad + \beta_0 \log K_t + \beta_1 \log K_{t-1} + \beta_2 \log K_{t-2} + \beta_3 \log K_{t-3} + \beta_4 \log K_{t-4} \\ &\quad + \gamma_0 \log L_t + \gamma_1 \log L_{t-1} + \theta_0 \log H_t + \varepsilon_t\end{aligned} \tag{2.10}$$

Table 2.10 reports the comparison between the two models.

Table 2.10: Comparison of ARDL models with and without human capital

Statistics	ARDL(2,2,0)	ARDL(4,4,1,0) with HC
AIC	-246.5	-263.1
BIC	-229.1	-233.1
MAE	100,565	91,485
MAPE	2.37%	1.86%
MSE	32,474,416,222	30,015,006,844
RMSE	180,207	173,248
Observations	67	67

Source: Author's elaboration on ARDL estimates.

Although the inclusion of human capital leads to an improvement in the main in-sample performance metrics (MAE, MAPE, MSE, and RMSE), the absolute gain remains limited. The information criteria (AIC and BIC) are more favorable for the extended model, but the increased complexity, particularly regarding the number of estimated parameters, reduces the elegance and parsimony of the specification. Given the goal of consistency with the standard theoretical formulation of the Solow model, the ARDL(2,2,0) is adopted as the benchmark model for the empirical growth analysis. However, due to its higher statistical accuracy, the extended model with human capital will be used for the forecasting simulations in Chapter 3, as this application does not require additional assumptions on the elasticity of human capital.

2.2.3 Estimation of total factor productivity (TFP)

In this section, total factor productivity (TFP) is estimated using a residual approach, based on the Cobb-Douglas production function introduced in Section 2.1.2. This methodological choice is grounded in a well-established theoretical tradition and widely adopted in the empirical growth literature. It is appreciated both for its analytical simplicity and for its effectiveness in isolating the contribution of capital and labor accumulation from other drivers of output growth, such as innovation, allocative efficiency, and technological progress.

The residual method relies on time series data for output, capital, and employment, and defines TFP as the portion of output not accounted for by observed inputs. Specifically, the residual is computed as the difference between actual output and the output predicted by capital and labor, conditional on the chosen elasticity parameter α (capital).

Formally, TFP is defined as:

$$A(t) = \frac{Y(t)}{K(t)^{\alpha} L(t)^{1-\alpha}} \tag{2.11}$$

This methodology, introduced by [Solow, 1956], has been refined and widely applied in subsequent studies, and remains one of the principal tools in empirical growth analysis. It is particularly suited to contexts in which productivity cannot be observed directly, but must instead be inferred as the residual component that explains output growth beyond the accumulation of capital and labor inputs.

In the case of China, this approach enables transparent quantification of the contribution of technological progress and economic efficiency to GDP growth, and allows for an assessment of the extent to which China's expansion has relied on input accumulation rather than genuine productivity gains. This question is central to the debate on China's long-term growth sustainability, particularly in light of the deceleration observed in the last decade.

Operationally, the residual approach is consistent with the empirical framework adopted in this thesis, which relies on data from the Penn World Table (PWT 10.01), providing harmonized and internationally comparable estimates of output, capital, and employment. This methodology is also aligned with key reference studies on Chinese growth, such as [Bosworth and Collins, 2008], which apply similar approaches to decompose the sources of growth and estimate the long-term evolution of TFP.

The capital stock $K(t)$ is built recursively based on the standard capital accumulation identity:

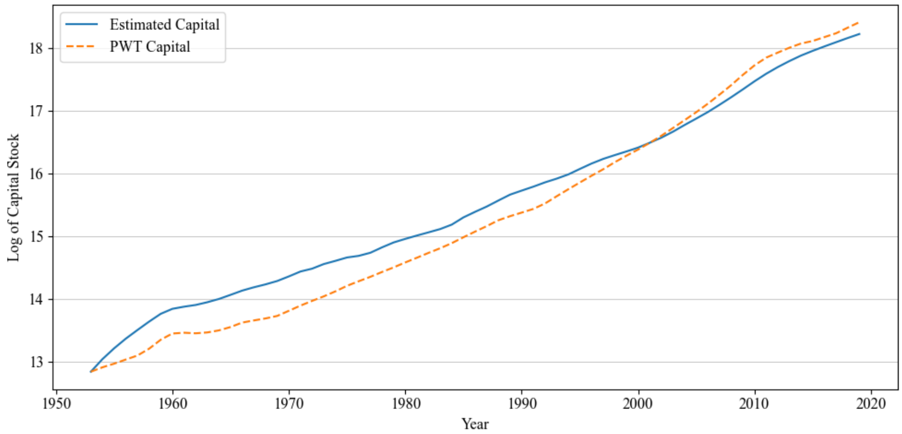
$$K(t) = (1 - \delta) \cdot K(t - 1) + I(t) \tag{2.12}$$

where δ is the average depreciation rate and $I(t)$ represents annual investment, calculated as a share of GDP $Y(t)$, based on the investment-to-GDP ratio from the Penn World Table. The initial value of capital is anchored to the first year of the sample, and subsequent values are derived iteratively. This method, widely adopted in the empirical literature, yields a capital series that is consistent with observed output.

As Figure 2.12 illustrates, the two logarithmic series follow a very similar path over time, confirming the internal coherence between the accumulation method adopted and the official PWT data. This visual confirmation validates the estimated capital series used in the TFP calculation, mitigating concerns about potential bias due to mismeasured inputs.

A central element in the estimation of TFP is the choice of the parameter α, which represents the share of income attributed to physical capital. This parameter directly

Figure 2.12: Validation of Estimated Capital: Comparison with Penn World Table



Source: Author's elaboration based on data from Penn World Table (version 10.01), indicators: `cgdpo`, `csh_i`, `delta`, `emp`.

influences the decomposition of growth.

The literature proposes different estimates for α, depending on the economic context and empirical strategy adopted. In advanced economies, typical values range between 0.3 and 0.35, while in emerging economies—especially those with investment-led models like China's—the capital share tends to be higher.

Table 2.11: Values of α used in the literature on China

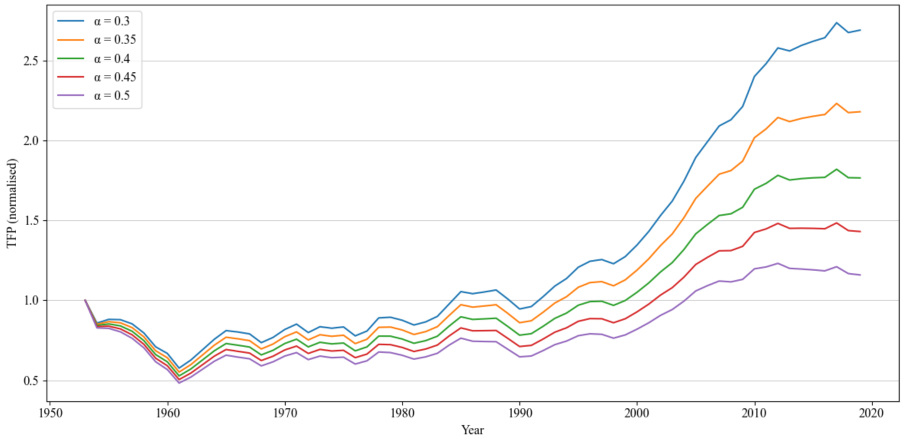
Source	Year	α used
Bosworth & Collins	2008	0.40
Zhu	2012	0.35 – 0.45 (up to 0.50)
Maddison & Wu	2008	0.35
Feenstra et al. (PWT)	2015	dynamically estimated
Barro & Sala-i-Martin	2004	0.30 – 0.33 (cross-country average)

Source: Author's elaboration based on Bosworth and Collins (2008), Zhu (2012), Maddison and Wu (2008), Feenstra et al. (2015), and Barro and Sala-i-Martin (2004).

The values reported in Table 2.11 summarise the diversity of capital share estimates adopted in key studies on China. The chosen value of $\alpha = 0.4$ aligns with [Bosworth and Collins, 2008] and represents a midpoint between conservative and high-end estimates, ensuring comparability with the relevant literature.

To test the sensitivity of TFP estimates to the choice of α, the analysis considers values ranging from 0.3 to 0.5, consistent with those most frequently used in the literature. Figure 2.13 shows the normalized TFP trajectories for each value, highlighting any divergence in long-term trends.

Figure 2.13: Robustness of TFP Estimates Across Different α Values



Source: Author's elaboration based on data from Penn World Table (version 10.01), indicators: `cgdpo`, `csh_i`, `delta`, `emp`.

Although the choice of α affects the level of TFP, the similarity in trends across different specifications suggests that the dynamics of productivity over time are robust to this parameter variation. This robustness strengthens the validity of the conclusions drawn from TFP analysis.

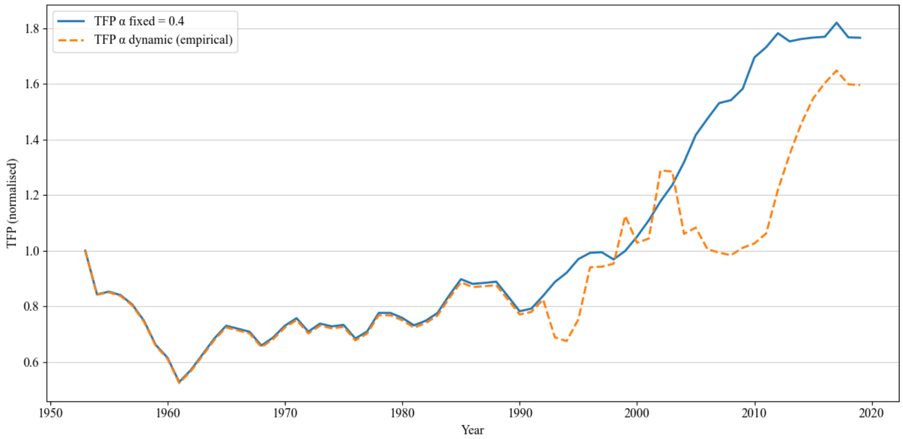
Beyond testing fixed values of α, a dynamic version of the parameter can also be estimated using national accounts data.

Based on the neoclassical identity $\alpha_t = 1 - \text{labour share}$, a time series for α_t is constructed from the share of labor compensation in GDP, as reported in the Penn World Table (PWT 10.01).

Figure 2.14 shows that while the empirical α_t introduces short-term fluctuations, the overall path of TFP remains consistent with the fixed-α specification. This supports the argument that a constant capital share provides a reliable approximation for long-run analysis, while also highlighting the added precision offered by dynamic estimates in capturing cyclical deviations.

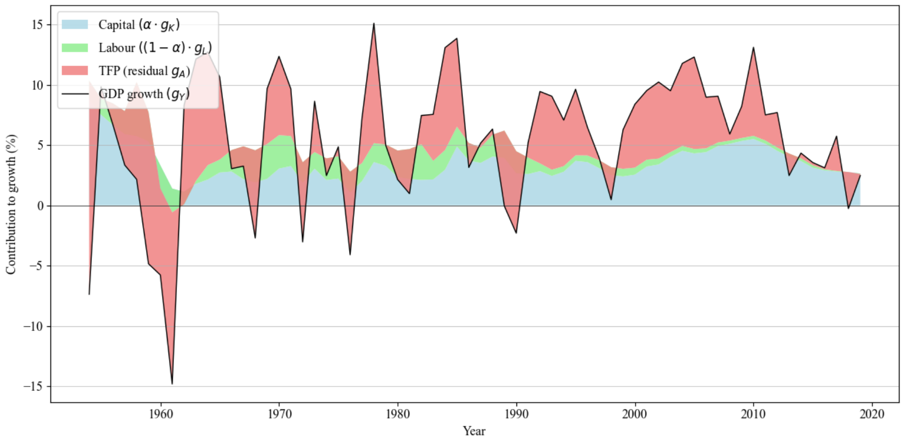
Finally, Figure 2.15 presents a growth accounting decomposition of China's real GDP growth, illustrating the contributions of capital, labour, and TFP.

Figure 2.14: Normalised TFP: comparison between fixed $\alpha = 0.4$ and empirical α_t



Source: Author's elaboration based on data from Penn World Table (version 10.01), indicators: `cgdpo`, `csh_i`, `delta`, `emp`, `labsh`.

Figure 2.15: Drivers of China's Real GDP Growth: Capital, Labour, and TFP



Source: Author's elaboration based on data from Penn World Table (version 10.01), indicators: `cgdpo`, `csh_i`, `delta`, `emp`.

The data confirm that capital accumulation was the dominant driver of growth during the early reform period and throughout China's investment-led expansion. However, the figure also reveals that TFP growth has been the key determinant of inflection points in the growth trajectory, most notably the acceleration in the early 2000s and the deceleration observed in the last decade. Labour contributions, by contrast, have remained relatively modest and stable over time, reflecting both demographic shifts and the diminishing role of labour-intensive growth.

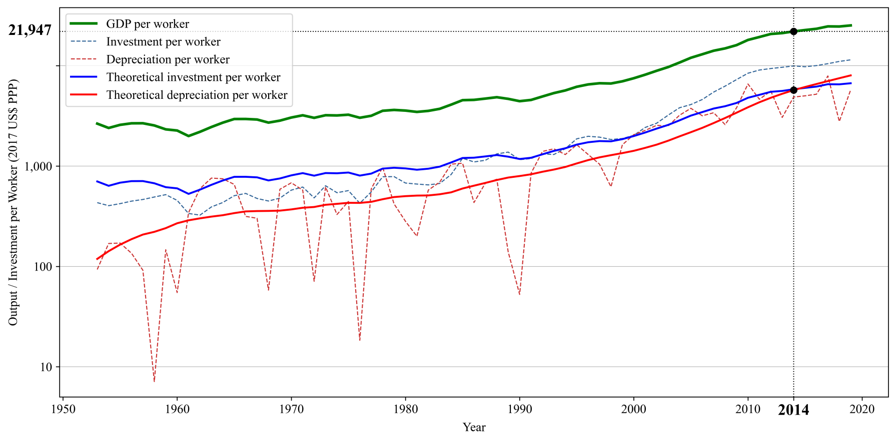
In conclusion, the results presented in this section underscore the central role of total factor productivity in explaining China's long-term growth. While physical capital has been a consistent contributor, it is the evolution of TFP that captures the country's structural transformation and the sustainability of its development path.

2.2.4 Steady-State Assessment and Output per Effective Worker

The empirical analysis conducted so far allows for an evaluation of China's positioning relative to its theoretical steady-state, using the standard Solow growth framework. In particular, the focus is on the evolution of GDP per unit of effective labor, where effective labor is defined as the product of employment and the efficiency of labor, modeled through exogenous technological progress.

To better illustrate the underlying dynamics, this section presents a graphical comparison between the historical trajectory of output per effective worker and the theoretical steady-state paths derived from the Solow model. The goal is to assess the extent of China's convergence toward its long-run equilibrium.

Figure 2.16: Tracking China's Path to the Steady State: GDP per Effective Worker vs Theoretical Benchmarks



Source: Author's elaboration based on data from Penn World Table (version 10.01), indicators: `cgdpo`, `csh_i`, `delta`, `emp`, `pop`.

As shown in Figure 2.16, the historical trajectory of GDP per effective worker is compared with both the theoretical investment and depreciation curves, constructed using historical averages for the saving rate, population growth, technological progress, and depreciation.

A complete summary of the average values used for the theoretical investment and depreciation curves is provided in Appendix 3.3.4.

When considering series based on average parameters, the convergence to the steady-state appears clear and occurs around 2014. This is consistent with the Solow model's prediction: when investment per effective worker equals depreciation-adjusted capital requirements, the economy reaches its steady-state. The graphical intersection of theoretical investment and depreciation lines highlights this equilibrium condition.

However, when analyzing the actual historical series—without assuming constant parameters—the situation appears more complex. Multiple intersections between investment and depreciation curves are observed over time, suggesting the possibility of transient conditions compatible with the steady-state. Notably, from the early 2000s onward, investment per effective worker persistently exceeds depreciation needs, indicating a phase of sustained capital accumulation beyond steady-state requirements.

This phenomenon reflects the historical trajectory of China's growth model, characterized by hyper-accumulation of physical capital, driven by high savings rates, expansive public investment policies, and a pronounced bias toward real estate and infrastructure development [Bosworth and Collins, 2008]. These trends were documented in previous sections, such as the persistently high fixed investment rates (Figure 1.4) and the increasing real estate exposure (Figure 1.5).

Comparing the two constructions, based on average parameters versus dynamic actual data, provides important insights. On one hand, using average parameters captures the long-term equilibrium trend; on the other hand, historical data highlight phases of structural overinvestment and misalignment relative to the steady-state path.

This structural deviation is particularly relevant given its implications for the sustainability of China's growth model. The persistent excess of investment over effective depreciation-adjusted needs suggests that China's expansion has been more input-driven than productivity-driven. This interpretation is consistent with the TFP patterns discussed earlier (Figure 2.12), where productivity contributions remained relatively modest compared to factor accumulation [Zhu, 2012].

Furthermore, the fact that the steady-state is theoretically reached only around 2014 is emblematic: this timing coincides with the emergence of structural growth headwinds, including the real estate crisis, workforce contraction, and declining marginal returns on investment. These elements, discussed in previous sections, mark the beginning of China's transition from an extensive, quantity-driven growth model to a more qualitative, efficiency-driven one, in line with the Dual Circulation Strategy objectives [Bank, 2022a].

At the theoretical point of convergence, the GDP per effective worker reaches approximately 21,947 international dollars (2017 PPP). While this represents substantial progress relative to historical levels, it remains considerably below the standards of advanced economies, where GDP per effective worker frequently exceeds 80,000–100,000 international dollars (2017 PPP) [Bank, 2024l]. This gap underscores China's incomplete convergence and highlights the need for continued improvements in innovation, productivity, and allocative efficiency to sustain long-term growth.

The analytical framework thus confirms that reaching the steady-state is a necessary but not sufficient condition for achieving high-income status. While capital accumulation is crucial, sustaining growth beyond the steady-state requires endogenous technological progress, institutional quality, and effective policy interventions, dimensions that will be explored in the next sections and extended in Section 2.3 with an open-economy version of the Solow model.

2.3 Extending the Model: Openness and Trade Effects

2.3.1 Extending the capital accumulation equation to an open economy

This section relaxes several of the standard assumptions of the basic Solow model introduced in Section 2.1. In particular, it introduces an open economy setting and trade balance dynamics, modifying the framework to better reflect the structural features of the Chinese economy. The key assumptions that are relaxed include:

- Autarky: the model is extended to include international trade, allowing imports and exports to affect investment and growth;
- Closed capital account: the saving-investment identity is relaxed to account for current account imbalances;
- Sectoral homogeneity: the potential for trade-driven technological spillovers and sectoral asymmetries is acknowledged, although not fully modeled.

These extensions help capture the empirical reality of China's integration into global markets, persistent trade surpluses, and the role of foreign demand and technology in driving growth.

Recent empirical studies confirm the ongoing importance of international openness in sustaining productivity and income growth. For example, [Yang and Liu, 2023] document how trade liberalization in high-tech sectors has contributed to TFP improvements in China, while [Chen and Zhang, 2021] highlight the complementary role of digital trade infrastructure in boosting export performance and domestic value creation.

As already mentioned, the canonical Solow model is conceived for a closed economy in which domestic saving fully finances investment. In this context, the capital accumulation equation is expressed as:

$$K(t) = (1-\delta) \cdot K(t-1) + I(t) \tag{2.13}$$

where $K(t)$ denotes the capital stock at time t, δ is the depreciation rate, and $I(t)$ is gross investment.

However, in an open economy, investments need not be financed solely by domestic saving: they can be supplemented or replaced by foreign capital, as reflected in the current account balance or, more specifically, in the trade balance. In this context, it is natural to extend the accumulation function to include the net contribution of foreign trade.

The explicit inclusion of international trade is particularly relevant for China, whose extraordinary growth trajectory has been strongly influenced by integration into global markets. Since the late 1970s, China has progressively liberalized trade and attracted massive inflows of productive capital through economic opening. The high incidence of net exports, especially of capital and intermediate goods, has been a crucial channel supporting physical capital formation and technological accumulation. Neglecting this dimension in a growth model would significantly understate the role of trade openness in explaining China's growth.

Following the literature on trade openness in growth models (e.g., [Barro and i Martin, 2004] and [Feenstra et al., 2015]), we propose to modify the capital accumulation equation by including the net balance of exports and imports of capital and intermediate goods, in order to capture the direct effects of trade on physical capital accumulation.

The new formulation becomes:

$$K(t) = (1 - \delta) \cdot K(t-1) + I(t) + NX_K(t) \tag{2.14}$$

where the additional term $NX_K(t)$ represents the net trade balance of capital and intermediate goods at time t. This specification aims to capture not the entire trade balance of the economy, but only the component most directly related to capital accumulation.

In particular, including foreign trade in the accumulation function reflects two fundamental channels:

- **Quantitative channel**, whereby a positive trade balance allows for a higher level of capital accumulation than domestic saving alone,
- **Qualitative channel**, since the importation of advanced capital goods and intermediate inputs can improve production efficiency and promote capital deepening.

This choice is directly inspired by the approach adopted by [Fernández-Villaverde et al., 2023], in which capital accumulation is analyzed separately from the aggregate trade balance, focusing on components relevant to capital formation. In particular, they construct a synthetic indicator given by the ratio of domestic investment plus the trade balance of capital and intermediate goods to GDP:

$$\frac{GCF_t + NX_K(t)}{GDP_t} \tag{2.15}$$

which represents a natural extension of the investment-to-GDP ratio in the presence of trade openness.

In a neoclassical context, this expression can be interpreted as a generalization of the saving rate under trade openness, where domestic investment is supplemented by the net contribution of foreign trade in capital and intermediate goods. The corresponding time series will be presented and analyzed in detail in Section 2.3.3 to assess the evolution of China's effective saving behavior over the long term.

The trade data used to construct $NX_K(t)$ are drawn from the World Bank's WITS database and reflect aggregated values of exports and imports of capital and intermediate goods. These values are employed in aggregated form, consistent with the approach adopted in the empirical literature.

This approach is consistent with the theoretical framework of open-economy neoclassical models, as discussed by [Barro and i Martin, 2004], and allows the integration of trade dynamics into the accumulation function without altering the model's basic structure. The introduced modification thus enables a more accurate capture of the effects of trade integration on capital dynamics and, consequently, on long-run growth.

In the following section, this extension will be implemented empirically through comparative simulations between closed and open economy scenarios.

2.3.2 Simulations: closed versus open economy

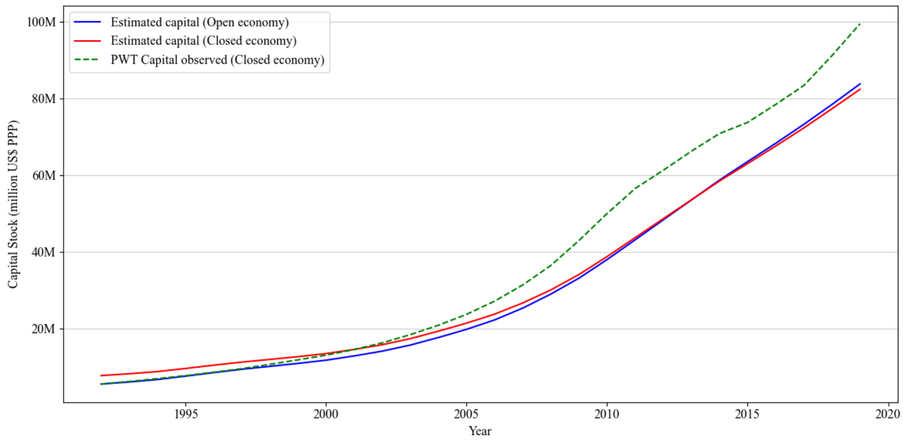
After introducing in the previous subsection the modification to the capital accumulation function to include the trade component, this section implements the extension empirically by comparing the results obtained with those of the standard closed-economy model. The objective is to highlight the benefits of trade openness and assess the extent to which international trade has contributed positively to Chinese growth, even if such contribution may not be immediately evident or significant in macro-synthetic indicators.

The simulation is based on annual data for the period 1992–2019, using information provided by the World Integrated Trade Solution (WITS) on imports and exports of capital and intermediate goods [Bank, 2024j, Bank, 2024k]. Following the approach of Fernandez-Villaverde et al. (2023), the analysis focuses exclusively on these categories of goods, as they are directly linked to the capital formation process and technology transfer, excluding consumer goods that have a more indirect impact.

Figure 2.17 compares the estimated capital trajectories under two scenarios: the closed-economy scenario, i.e., the canonical Solow model, and the open-economy scenario, with the inclusion of the net trade balance of capital and intermediate goods. Although the capital accumulation dynamics in the open economy follow a trend similar to that of the closed economy, the trajectory remains consistently aligned with or slightly below it. This result, far from representing a weakness of openness, suggests that international trade has enabled a more efficient and sustainable accumulation trajectory, avoiding unproductive overinvestment and promoting better resource allocation.

Furthermore, the negative balance in capital and intermediate goods, recorded for much of the period, should not be interpreted as a limitation, but rather as a channel through which China could import advanced technologies and innovative machinery, accelerating the qualitative improvement of the physical capital stock. In this sense, trade has played a facilitating role by providing access to technological inputs that have contributed to the modernization of the production system, even if the quantitative impact on aggregate capital accumulation is not immediately visible in the data.

Figure 2.17: Capital Stock Evolution with and without Trade Integration



Source: Author's elaboration based on data from Penn World Table (2024) and WITS – World Bank (2024).

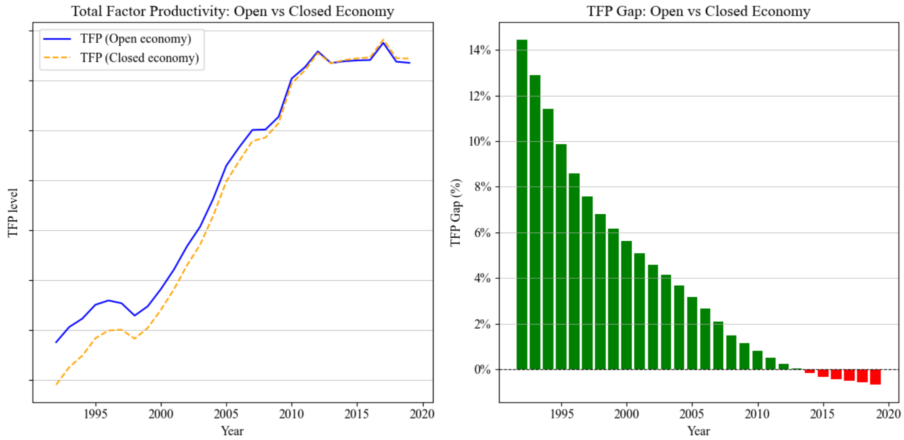
To further explore the impact of these dynamics on productivity, Figure 2.17 shows the evolution of estimated TFP according to the standard formula:

$$TFP_t = \frac{Y_t}{K_t^{\alpha} \cdot L_t^{1-\alpha}} \tag{2.16}$$

where $\alpha = 0.4$. Here too we compare the two scenarios: one in which capital follows the closed-economy trajectory, and one in which the trade component is accounted for.

The results highlight that, despite very similar aggregate TFP levels in the two scenarios, trade integration has likely operated through indirect channels that the neoclassical model tends to underestimate. These include facilitated access to foreign technologies, competitive pressure exerted by international markets, and productivity spillovers arising from participation in global value chains. It is also observed that the TFP trajectory in the open-economy scenario is initially higher than in the

Figure 2.18: Impact of Trade Openness on Total Factor Productivity



Source: Author's elaboration based on data from Penn World Table (2024) and WITS – World Bank (2024).

closed economy, suggesting that trade liberalization has accelerated technological convergence and fostered a more rapid absorption of international best practices. Although this effect does not translate into a persistent gap in aggregate TFP levels, it attests to the propulsive role of openness in supporting the modernization and productive efficiency of the Chinese system.

In conclusion, it is essential to interpret these results in light of China's strategic position within Global Value Chains (GVCs). Trade integration has represented a key vehicle for technology transfer and productivity enhancement, as discussed in [Grossman and Helpman, 1991]. According to the World Trade Report [Organization, 2021], China is today the world's leading exporter of intermediate and capital goods, confirming its centrality in global value chains. Moreover, between 2000 and 2022, the value of Chinese exports rose from approximately USD 280 billion to over USD 3.5 trillion, despite mounting trade tensions with the United States [OECD, 2024].

It should be noted that the influence of trade openness may become more evident over the medium to long term and less visible in annual aggregate data or simple quantitative comparisons. The results presented here, therefore, do not contradict the positive role of openness but suggest the need for a broader evaluation that also takes into account qualitative effects, productivity spillovers, and China's growing centrality within global production networks.

These results, while maintaining the analytical framework of the neoclassical Solow model, extend its explanatory capacity in the presence of trade openness. Indeed, the inclusion of international trade occurs without altering the fundamental structure of the model, ensuring methodological coherence and comparability with the standard scenario.

In the next subsection, the impact of trade openness will be further analyzed through counterfactual simulations and steady-state assessments, in order to quantify more precisely the dynamic influence of trade on China's growth trajectory.

Ultimately, international trade has been an indispensable engine for China's growth and structural transformation, whose scope goes beyond what is detectable from the dynamics of capital and aggregate TFP alone.

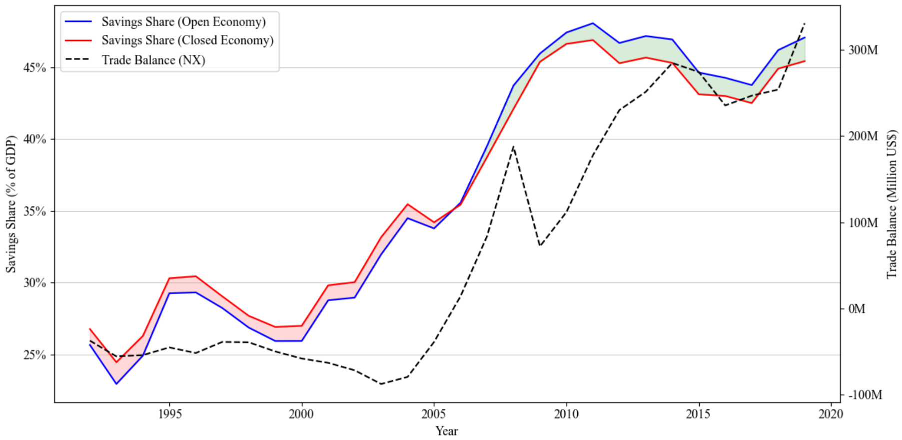
2.3.3 The impact of trade integration on growth

In this subsection, we analyze two key aspects for understanding China's long-term economic dynamics: the evolution of the effective saving rate in an open economy and the distance from the theoretical steady state under the extended Solow model. These analyses allow us to evaluate not only the current level of development relative to the theoretical trajectory but also the role of trade openness in determining the sustainability of the growth process.

Figure 2.19 compares the saving rate in two alternative scenarios, closed and open economy, based on equation (2.15). This expression, introduced in Section 2.3.1, can be interpreted as a proxy for the effective saving rate in the presence of trade openness.

It is observed that the saving rate in the open-economy scenario is generally higher than in the closed-economy scenario, especially after 2005. This aligns with the trade balance trend: the progressive increase in the trade surplus has contributed to expanding the resources available for capital accumulation. The fact that effective saving has risen more than expected suggests that trade openness has complemented domestic saving, broadening the economy's growth potential. However, the difference between the two series, although present, is not always pronounced; this may

Figure 2.19: Saving Behavior and Trade Balance under Alternative Openness Scenarios



Source: Author's elaboration based on data from Penn World Table (2024) and WITS – World Bank (2024).

reflect a convergence between domestic saving and the net trade balance during periods of stable surplus.

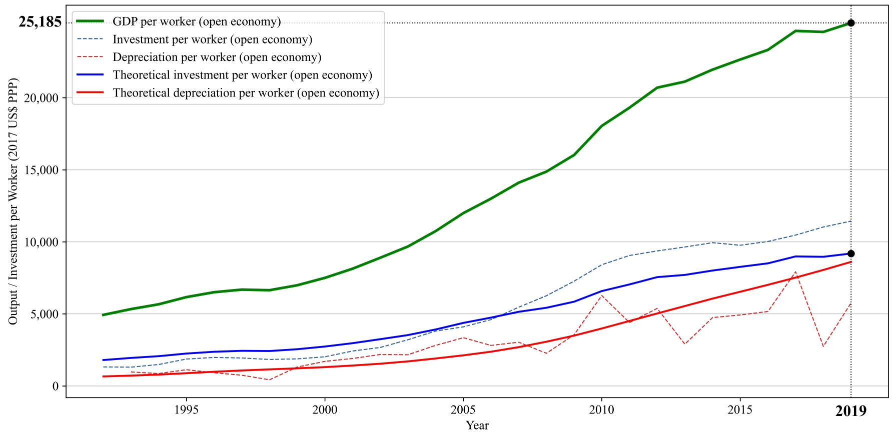
The relationship between the saving rate and capital dynamics can be further analyzed through the concept of the steady state.

Figure 2.20 shows in green the evolution of GDP per worker, the dashed blue line represents investment per worker, the dashed red line represents depreciation per worker, and the solid blue and red lines represent the corresponding theoretical values predicted by the extended Solow model. The dashed lines use observed annual parameter values (actual series), while the solid theoretical lines are computed assuming historical average values for the saving rate, TFP growth rate, and population growth rate, following the standard Solow approach.

The average values used to construct the theoretical investment and depreciation curves in the open economy scenario are also summarized in Appendix 3.3.4.

It is, however, important to emphasize that 2019 does not represent an actual convergence point, but rather the year in which the two theoretical curves come closest. The investment and depreciation trajectories do not exactly coincide, suggesting that the steady state has not yet been strictly attained. This implies that China is in an advanced transition phase, but has not yet reached full economic maturity according to the model's logic.

Figure 2.20: Tracking China's Path to the Steady State under Trade Openness: GDP per Worker vs Theoretical Benchmarks



Source: Author's elaboration based on data from Penn World Table (2024) and WITS – World Bank (2024).

Moreover, the theoretical GDP per worker under the open-economy scenario, estimated at USD 25,485, provides a useful benchmark for evaluating the sustainability of the growth path. Although this represents substantial progress compared to the closed-economy scenario, this level still falls below the typical thresholds of advanced economies, suggesting that China's convergence potential remains partly unexplored and dependent on exogenous factors such as technological progress, institutional quality, and global integration.

It is informative to compare this result with the steady state estimated for the closed economy (Figure 2.16), where the theoretical equilibrium was reached as early as 2014, but at a lower GDP per worker level of USD 21,947. This comparison reinforces the role of trade openness as a factor raising long-term potential, even if it has partially slowed the speed of convergence. In other words, openness has shifted the growth target (steady state) higher, but required a longer path to reach it.

Finally, from a geopolitical perspective, the evolution of the saving rate and capital per worker takes on particular relevance. China's ability to maintain high levels of domestic saving while also benefiting from a positive trade balance has allowed the country to finance capital accumulation without excessive dependence on foreign capital. In a context of increasing tensions with the West, such financial autonomy constitutes a significant strategic advantage. However, the slowdown in convergence suggests that in the coming years it will be necessary to improve not only the quantity but also the quality of investments, promoting innovation and enhancing the allocative efficiency of the production system.

In Chapter 2, we extended and calibrated the Solow growth model for the Chinese context, incorporating trade openness, capital accumulation, and productivity dynamics. Through theoretical exposition and empirical simulations, we highlighted how physical investment, net trade in capital goods, and technological progress jointly determine China's long-run growth path and steady-state outcomes.

Although the inclusion of trade openness in the extended Solow model provides interesting insights on the role of international integration, its practical implementation in the ARDL-based forecasting framework presents several limitations. First, the availability of trade data is restricted to the period 1992–2019, which would significantly reduce the sample size and potentially undermine the statistical power of the estimates. Second, the comparative analysis conducted in this section shows that the added complexity does not yield substantial forecasting improvements in terms of trajectory or explanatory power. Therefore, in the following sections, the trade openness variable will not be included in the ARDL simulations and scenario analysis.

Based on these results, Chapter 3 will focus on policy simulations and forecasting. We will examine the impact of strategic interventions—particularly the Dual Circulation Strategy—on key aggregates such as investment, consumption, and output. The analysis will be complemented by econometric validations and robustness checks to ensure the reliability of forecasts and to inform the design of sustainable growth policies.

Chapter 3

Forecasting and Policy Impact Analysis

This chapter aims to analyze the growth prospects of the Chinese economy and to assess the potential effectiveness of policies associated with the Dual Circulation Strategy, through long-term simulations based on the empirical Solow model estimated in Chapter 2.

Section 3.1 introduces the methodological framework adopted, illustrating the rationale behind the choice of the ARDL model for forecasting purposes and its main features. It also describes the model calibration strategy, based on in-sample analysis and performance metrics, and outlines the key assumptions underpinning the forecasting exercise.

Section 3.2 presents the growth projections under a baseline scenario, which assumes the continuation of current macroeconomic fundamentals and a gradual extension of historical trends.

Finally, Section 3.3 develops a series of alternative scenarios by modifying key parameters such as the savings rate, demographic growth, physical capital accumulation, and trade openness. The objective is to assess the sensitivity of the results and estimate the potential impact of Dual Circulation policies on China's future growth path.

3.1 Methodological Overview

3.1.1 Objective and Model Selection

This section has a dual objective: first, to provide a forecast of China's medium- to long-term growth trajectory based on the empirical Solow model estimated in Chapter 2; second, to assess the effectiveness of policies associated with the Dual Circulation Strategy through counterfactual simulations. The approach adopted allows for the integration of historical evidence and forecasting tools, offering a quantitative interpretation of the challenges ahead for China's economic growth.

Macroeconomic forecasting plays a crucial role in policy analysis. Leading international institutions, including the IMF, World Bank, and OECD, regularly publish updated projection scenarios, highlighting how the sustainability of China's growth increasingly depends on structural factors such as innovation, productivity, and the rebalancing of the development model. The academic literature has also begun to examine the effectiveness of the reforms promoted under the Dual Circulation Strategy, emphasizing the need to strengthen domestic demand and reduce dependence on foreign technologies, as shown in [Liu et al., 2022] and [Zhang and Huang, 2023].

In this context, a structured econometric approach was adopted, based on the estimation of an ARDL (Autoregressive Distributed Lag) model. This choice addresses the need to flexibly model both short- and long-term dynamics among non-stationary but cointegrated variables. Unlike purely differenced models (such as VARs in differences) that eliminate information in levels, the ARDL framework preserves the theoretical structure of the Solow model and directly estimates the relationship between output, capital, labor, and productivity.

The effectiveness of this approach has been confirmed in recent literature on China, where several ARDL applications have demonstrated good forecasting performance even with limited annual time series. Moreover, the ARDL model allows for the projection of counterfactual scenarios without requiring full transformation or differencing of all variables, making it suitable for simulating the effects of structural policies such as those aligned with the Dual Circulation Strategy.

Based on the accuracy metrics and information criteria discussed in Chapter 2, the

ARDL(4,4,1,0) model including human capital is selected for forecasting simulations. While the ARDL(2,2,0) remains the benchmark for theoretical analysis, the extended version allows for greater forecasting precision without requiring additional assumptions on the elasticity of human capital.

The following sections will outline the main assumptions, the calibration strategy, and the resulting growth projections. Alternative simulations will then be used to assess the impact of economic reforms and exogenous shocks on the core drivers of growth.

3.1.2 Assumptions and calibration of the forecast model

This section outlines the operational assumptions and the calibration strategy adopted to transform the ARDL(4,4,1,0) model into a forecasting tool. After empirically estimating the model in Chapter 2, the next step is to validate its reliability through backtesting exercises and to define a consistent set of assumptions for the exogenous variables. These elements are essential for generating the baseline growth trajectory, from which the simulations analyzed in the remainder of the chapter are derived.

The ARDL model employed for forecasting, as previously described in Section 2.2.2, assumes the following functional form in its *restricted dynamic* version:

$$\begin{gathered}\log(Y_t) = \alpha_0 + \sum_{i=1}^{4} \alpha_i \log(Y_{t-i}) + \sum_{j=0}^{4} \beta_j \log(K_{t-j}) + \\ \gamma_0 \log(L_t) + \delta_0 \log(H_t) + \varepsilon_t\end{gathered} \tag{3.1}$$

To validate the robustness of the ARDL(4,4,1,0) model as a forecasting tool, a backtesting exercise was conducted: the model was estimated using data up to and including 2010, and then tested on an independent sub-sample covering the period 2011–2019. This approach allows for the simulation of an ex-ante forecast and the comparison of predicted values with those actually observed, providing an objective measure of the model's out-of-sample predictive power.

Table 3.1 summarizes the main out-of-sample performance metrics.

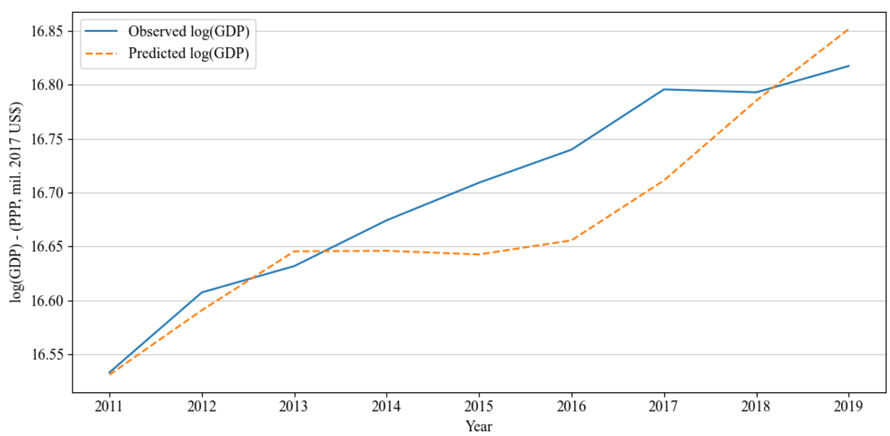
Table 3.1: Out-of-Sample Forecasting Performance (2011–2019)

Metric	Value
MAE	679,630
MAPE	3.65%
MSE	778,169,753,518
RMSE	882,139

Source: Author's elaboration based on ARDL(4,4,1,0) model estimates.

The out-of-sample performance metrics reported in Table 3.1 provide a quantitative assessment of the reliability of the ARDL(4,4,1,0) model beyond the estimation sample. The MAE (Mean Absolute Error), approximately 679,630, indicates that the average absolute error between the observed and predicted values of `log(GDP)` is below 700,000 units in million USD PPP, a scale consistent with the logarithmic transformation. The MAPE (Mean Absolute Percentage Error) stands at 3.65%, suggesting that the average relative percentage error is low and well below the 5% threshold often considered acceptable in the literature for annual macroeconomic models. Finally, although the MSE and RMSE values are high in absolute terms due to the logarithmic scale of the data, they confirm that the model maintains a good level of accuracy in forecasting GDP. The following section presents a graphical comparison of the model's out-of-sample performance, contrasting observed values with those predicted for the 2011–2019 period.

Figure 3.1: Out-of-sample backtesting: observed vs predicted log(GDP), 2011–2019



Source: Author's elaboration based on ARDL(4,4,1,0) model estimates.

Figure 3.1 provides a visual comparison between the observed and predicted values of `log(GDP)` for the period 2011–2019. The model successfully captures the overall output trend, although it slightly underestimates actual growth in some years (e.g., between 2015 and 2017). Nevertheless, the forecast closely follows the evolution of the target variable, showing good alignment in both levels and year-over-year changes. This result reinforces the robustness of the model selected for the baseline growth scenario, justifying its use for long-term projections in the following sections.

A crucial component of the forecasting exercise involves defining a consistent set of assumptions for the ARDL model's exogenous variables—namely physical capital, labor, human capital, and total factor productivity (TFP)—for the period 2020–2035. In the literature, the choice of forecasting assumptions varies depending on the analytical purpose and data availability. Common approaches include projecting historical trends via regressions, using recent moving averages, or directly incorporating official forecasts published by international organizations such as the IMF, World Bank, and OECD.

This study adopts a strategy based on linear OLS regressions, estimated separately for each log-transformed variable (`log(K)`, `log(L)`, `log(H)`), using data from 2010 to 2019. This time window was selected to reflect more recent structural dynamics, marked by a progressive slowdown in growth starting around 2010, as shown in Figure 1.1. Including the years of rapid expansion before 2008 could have distorted the projection paths. The use of a linear trend ensures stability and consistency in the assumptions, offering greater precision than historical averages, especially in the presence of gradual and persistent dynamics.

The simple model underpinning the forecast assumptions is as follows:

$$\log(X_t) = \alpha + \beta t + \varepsilon_t \tag{3.2}$$

Where X_t represents each of the exogenous variables (K, L, H), t is the time index, and ε_t is the error term. The regression is estimated separately for each productive input. Despite its simplicity, this linear specification effectively captures recent trends, avoids overfitting, and ensures that forecasting assumptions remain easily replicable.

Several studies have adopted similar strategies to build baseline growth trajectories. For instance, [Fernández-Villaverde et al., 2023] and [Barro, 1991] estimate projections for each input (physical capital, labor, human capital, and TFP), calibrated over short but representative time windows that reflect the post-transition growth regime. [Maddison, 2007] recommends using post-2000 data for China to better reflect structural changes in the functioning of the economy. The OLS approach, although simple, ensures transparency, replicability, and methodological consistency, and is particularly appropriate in the absence of disaggregated official forecasts.

As for TFP, a constant annual growth rate of 1.5% is assumed, in line with the most recent estimates available in the literature. For example, [Zhu, 2012] estimates Chinese TFP growth between 1.5% and 2.5% in the post-reform period, while [Bosworth and Collins, 2008] report a range between 1.2% and 2.0% for the 1995–2005 period. More recent studies, such as [Fernald, 2015], document a slowdown below 1.5% after 2010, which is consistent with the assumption adopted in this work. Fixing the TFP growth rate ex ante allows the model structure to remain parsimonious and helps isolate the effect of the other productive factors on GDP dynamics. The projection horizon (2020–2035) reflects a trade-off between analytical relevance and forecast realism. On one hand, a 15-year interval is long enough to capture the cumulative effects of structural policies and macroeconomic shifts. On the other hand, it avoids extending projections too far, where uncertainty would render simulations overly speculative. This time frame is consistent with those adopted in macroeconomic scenarios by institutions such as the International Monetary Fund (IMF), the World Bank, and the Organisation for Economic Co-operation and Development (OECD), which frequently publish projections extending to 2035–2040. Moreover, this horizon is sufficient to incorporate the medium-term implications of the Dual Circulation Strategy, which require time to unfold their full impact.

Once the model calibration is completed and the forecasting assumptions are defined, it is possible to construct the baseline growth scenario for the Chinese economy over the 2020–2035 period. The following section presents the results generated by the ARDL model, highlighting the expected evolution of GDP and the contribution of the main productive inputs to overall growth.

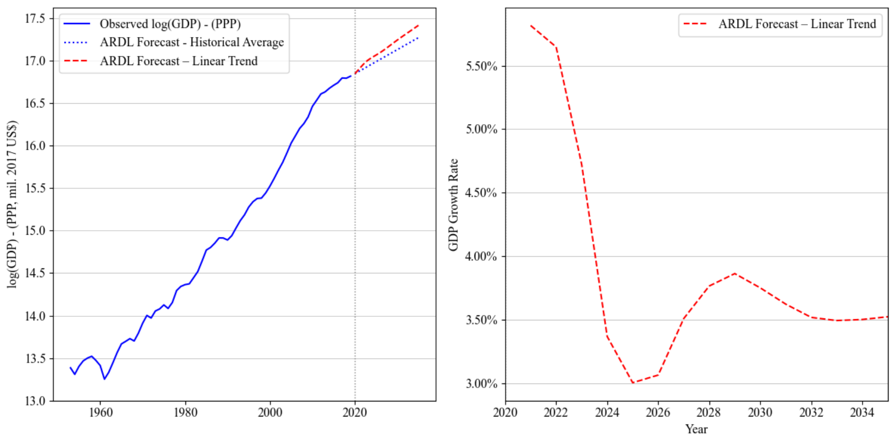
3.2 Forecasting China's Growth Trajectory

3.2.1 Baseline Projection with Solow Model

The objective of this section is to present the forecasting assumptions underlying the simulations of China's GDP growth through 2035, focusing on the scenario obtained via linear extrapolation of the productive variables. This approach, already introduced in Section 3.1, is based on the idea that the Chinese economy has entered a structurally declining trajectory since 2010, marking the peak of its expansionary cycle.

All key variables in the extended Solow model (physical capital, labor force, human capital, investment share, and depreciation rate) are projected by estimating a linear trend on data from the 2010–2019 period, in order to capture recent post-boom dynamics. The only exception is the TFP growth rate, which is assumed to be exogenous and fixed at 1.5% per year, in line with recent estimates in the literature for advanced Asian economies.

Figure 3.2: China GDP Forecast–ARDL: Linear Trend vs Historical Average (2020–2035)



Source: Author's elaboration based on ARDL(4,4,1,0) model simulations.

Figure 3.2 presents the results of this scenario. In the left panel, the level of GDP in logarithmic terms (adjusted for purchasing power parity) continues to grow, though with a significantly flatter slope compared to the pre-2010 phase. The right panel highlights the dynamics of the implicit annual growth rate, which gradually stabilizes around 3.5% from 2020 onward, consistent with the hypothesis of convergence toward a more mature steady-state.

Table 3.2: Forecasted GDP Growth Rates under Alternative Assumptions (2020–2035)

Scenario	CAGR (2020–2035)
ARDL – Linear Trend	3.88%
ARDL – Historical Average	4.10%

Source: Author's elaboration based on ARDL(4,4,1,0) model simulations.

As shown in Table 3.2, the compound annual growth rate (CAGR) estimated for the period 2020–2035 stands at 3.88% under the linear trend scenario. For comparison purposes, an alternative scenario was also estimated based on the historical average (2010–2019) of the input growth rates, which yields a slightly higher CAGR of 4.10%. However, this latter estimate tends to overstate the growth potential, as it disregards the slowdown already evident in the pre-COVID period.

Interestingly, the CAGR associated with the historical average projection (4.10%) exceeds that of the linear trend (3.88%), even though in the left panel of Figure 3.2 the linear trend projection appears to lie visually higher in the final part of the forecast horizon. This apparent discrepancy is explained by the fact that the initial GDP value estimated for 2020 is slightly higher under the historical average scenario than under the linear trend scenario. This initial advantage accumulates over time, leading to a larger cumulative delta between 2020 and 2035 and, consequently, a higher average annual growth rate. It follows that the CAGR more accurately reflects the overall percentage increase over the analysis period, regardless of the final visual trajectory.

The consistency between the linear trend model results and the forecasts published by international institutions strengthens the robustness of the adopted approach. For example, the IMF World Economic Outlook [Fund, 2024a] projects a deceleration of China's GDP growth toward 3.5–4.0% by the mid-2030s, due to demographic decline, slower investment, and limited productivity in the public sector. Similarly, the OECD and World Bank [OECD, 2024, Bank, 2022a] forecast a structural slowdown linked to institutional and environmental constraints. Our estimate therefore falls in an intermediate position between these two projections, suggesting a cautiously optimistic outlook under stable macroeconomic conditions. The pessimistic and optimistic scenarios deviate by approximately ±0.5 percentage points, outlining a plausible confidence interval around the central path.

In summary, the linear trend scenario represents a prudent yet realistic forecast, anchored in structural economic dynamics observed since 2010. This approach makes it possible to evaluate GDP evolution in a post-export-driven transition context, providing a solid basis for the simulations and impact analyses presented in the following section.

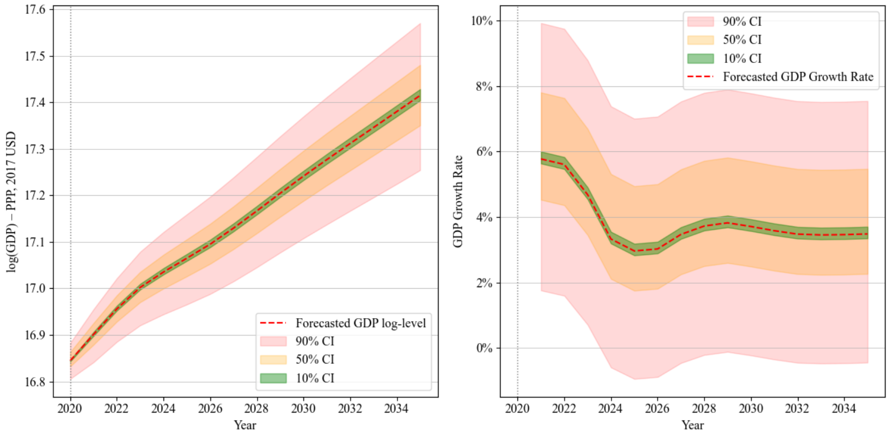
3.2.2 Sensitivity and Robustness Analysis

To assess the robustness of the forecasts produced by the ARDL model estimated under the linear trend assumption, a stochastic analysis was conducted using a bootstrap simulation with 1,000,000 iterations. The objective is to construct a fan chart representing the possible distribution of future GDP values and the corresponding growth rates, based on the residuals from the model estimated in the previous section. This approach makes it possible to incorporate uncertainty stemming from random shocks while maintaining the deterministic structure of the forecasting model. For a detailed description of the simulation procedure used, see Appendix 3.3.4.

The two graphs in Figure 3.3 show, respectively, the forecasted levels of the logarithm of GDP (left) and the implied annual growth rates (right), each accompanied by confidence bands constructed from the percentiles of the bootstrap distribution. The shaded areas indicate symmetric confidence intervals at the 90%, 50%, and 10% levels, while the central dashed line represents the model's point forecast.

It is important to note that the continuous growth observed in the left-hand graph (GDP in logs) is not in contradiction with the flat pattern in the right-hand graph (growth rates). This apparent discrepancy reflects the exponential nature of economic growth: even a constant growth rate results in an increasing GDP level over time. Thus, while the fan chart of levels reflects steady expansion, the growth rate chart shows stabilization of the annual growth dynamics, consistent with a long-run

Figure 3.3: ARDL Forecasted GDP Growth Rate with Fan Chart (2020–2035)



Source: Author's elaboration based on ARDL(4,4,1,0) forecast and 1,000,000 bootstrap simulations.

steady-state regime.

The growth rate graph clearly reveals a phase of economic slowdown in China up to the mid-2020s, followed by partial stabilization at annual values between 3.5% and 3.8%. This pattern mirrors the trend highlighted in the previous graph, Figure 3.2, which showed a structural decline in growth starting around 2010, consistent with the phase-shift hypothesis discussed in Section 3.1 regarding China's economic development.

Moreover, the fan chart underscores an important analytical feature: the future distribution of growth is not symmetric, with downside (lower-tail) scenarios appearing more dispersed and volatile. This is particularly evident in the early years of the forecast period, where the combination of post-pandemic uncertainty and structural vulnerabilities may generate greater volatility than the historical average. Such asymmetry in fan charts is widely documented in the macroeconomic forecasting literature [Britton et al., 1998, Benigno et al., 2021], and justifies the use of probabilistic tools to assess long-term growth trajectories.

Table 3.3 summarizes the Compound Annual Growth Rate (CAGR) values for the baseline scenario and the extremes of the distribution (5th and 95th percentiles). The baseline forecast suggests an average annual growth rate of 3.88% over the 2020–2035 period, with a range between a minimum of 3.12% (worst case) and a maximum

Table 3.3: Compound Annual Growth Rate (CAGR) under ARDL Forecast (2020–2035)

Scenario	CAGR (2020–2035)
Baseline Forecast (ARDL – Linear Trend)	3.88%
Worst Case Scenario (5° percentile)	3.12%
Best Case Scenario (95° percentile)	4.67%

Source: Author's elaboration based on ARDL(4,4,1,0) forecast and 1,000,000 bootstrap simulations.

of 4.67% (best case). These results are fully consistent with the projections published by international organizations cited earlier: the IMF (2024) expects China's GDP growth to range between 3.5% and 4.0% by the mid-2030s, while the World Bank and OECD point to a structural slowdown driven by demographic stagnation, slower capital accumulation, and institutional constraints on efficient resource allocation [Fund, 2024a, OECD, 2024, Bank, 2023a].

In summary, the fan chart based on the ARDL bootstrap approach not only illustrates the expected GDP trajectory, but also quantifies the degree of uncertainty and vulnerability associated with the central scenario—a particularly relevant factor for an economy like China's, which is transitioning toward a development model less dependent on investment and exports.

3.3 Policy Scenarios and Dual Circulation Strategy

3.3.1 Introduction to Policy Scenarios

The recent slowdown in China's economic growth, analyzed in Section 3.2 through baseline simulations and sensitivity analysis, has highlighted the need for a structural shift in the country's development model. Against this backdrop, the present section introduces a set of counterfactual scenarios aimed at evaluating the long-term effects of policy choices consistent with the objectives of the Dual Circulation Strategy (DCS).

The Dual Circulation Strategy, examined in detail in Section 1.3, seeks to strengthen domestic demand, promote technological self-sufficiency, and reduce dependence on external factors and international vulnerabilities. However, the implementation of this strategy requires overcoming significant structural constraints, including low consumption propensity, rigidities in the production system, and increasing geopolitical tensions.

In this context, three alternative policy scenarios are modeled, each reflecting different combinations of structural reforms and degrees of international openness:

- a scenario focused on *internal circulation*, aiming to reduce dependence on exogenous factors
- a scenario focused on *external circulation*, emphasizing international openness and integration into global value chains
- a scenario based on a *mixed strategy*, combining elements of both previous approaches to balance self-sufficiency with international cooperation

The scenarios were constructed using a deterministic approach, with the aim of isolating the effect of active policy interventions on the key variables of the Solow model: investment share, human capital growth, and employment growth. In each scenario, these variables are exogenously modified within a plausible range of values, selected based on empirical considerations, academic literature, and consistency with the declared objectives of the DCS. In particular, the ranges were defined based on the research papers by [Bosworth and Collins, 2008, Fernández-Villaverde et al., 2023] and the analyses of international organizations [Fund, 2024a, Bank, 2022b, OECD, 2024].

A detailed explanation of the forecasting equation and the underlying simulation assumptions is provided in Appendix 3.3.4.

The choice of the three variables reflects a precise theoretical consistency with the extended Solow model and with the strategic priorities of the DCS. In particular:

– the **investment share** represents the main lever to stimulate physical capital accumulation and enhance the productive capacity of the economy;

– the **growth of human capital**, captured through aggregate indicators (e.g., average education, years of schooling), directly affects labor productivity and the ability to absorb technological progress;

– the **growth of employment**, instead, reflects the contribution of the increasing available labor force to the dynamics of potential output.

These three dimensions effectively summarize the channels through which public policies can influence the supply side of the economy, while maintaining consistency with the neoclassical structure of the model.

The remaining model variables—such as the initial capital stock, depreciation rate, and total population—are held constant over the entire 2020–2035 horizon, in order to isolate the marginal effect of the policy-relevant variables.

Table 3.4 summarizes the assigned ranges for the three selected variables:

The *internal circulation* scenario aims to strengthen domestic resilience through the expansion of human capital and labor force participation. For this reason, it assumes an acceleration in the growth rates of these two variables, while maintaining a relatively contained investment share. Conversely, the *external circulation* scenario is designed to reflect a strategy driven by international openness, industrial competitiveness, and foreign direct investment (FDI); thus, the focus is on increasing the investment share, while human capital and employment follow more conservative

Table 3.4: Policy Scenario Overview and Assigned Ranges for Key Growth Variables

Selected Variable	Baseline	Internal	External	Mixed
Investment share	41,02%	(39,5–41,9%)	(39,5–42,5%)	(39,5–41,5%)
Human Capital growth	1,10%	(0,95–1,45%)	(0,95–1,15%)	(0,95–1,25%)
Employment growth	0,26%	(0,20–0,40%)	(0,20–0,32%)	(0,20–0,35%)

Source: Author's elaboration based on projections consistent with IMF (2024), World Bank (2022), OECD (2024), and Fernández-Villaverde et al. (2023).

trajectories. Finally, the *mixed strategy* scenario seeks a balance between the two approaches, simulating a moderate and simultaneous improvement across all three variables, in line with a gradual internal-external rebalancing policy.

The numerical ranges assigned to the three variables reflect not only theoretical considerations but also empirical evidence drawn from the Chinese case and comparable experiences. For example, China's investment share has fluctuated between 38% and over 45% of GDP over the past two decades, making a simulated range between 39.5% and 42.5% plausible. Similarly, although employment growth has gradually declined, it is still possible to estimate gradual improvements through greater female participation or increases in marginal labor productivity.

The choice of a deterministic approach—rather than stochastic or bootstrap-based methods—allows for transparent and easily comparable counterfactual scenarios, avoiding interference from uncertainty in the estimated parameters. However, this approach also has limitations: in particular, it does not allow for the endogenous modeling of total factor productivity (TFP), which is instead a fundamental channel in the external circulation strategy.

In this regard, it is important to emphasize that the "DCS 0%" line, used as a common starting point for all scenarios, does not coincide with the baseline estimated in Section 3.2. The baseline reflects the projected GDP path derived from the ARDL regression based on 2010–2019 data, incorporating the historical evolution and dynamic inertia of the variables. The DCS 0% scenario, by contrast, is built in a purely deterministic manner, with fixed values independent of the OLS estimates. Nonetheless, the starting point of the simulated scenarios was aligned as closely as possible with the initial values of the baseline, to ensure coherence in levels and

CAGR. This choice enables a more transparent comparison across scenarios, isolating the impact of simulated policies relative to a realistic and comparable growth path.

It should be noted that the proposed simulations should not be interpreted as point forecasts, but rather as counterfactual exercises aimed at exploring the theoretical implications of the policies under examination. The results obtained depend on the structure and parameters of the model and should be interpreted as a proxy for the potential macroeconomic impact of the reforms.

Finally, it is worth noting that the *internal circulation* scenario is more compatible with the theoretical framework of the Solow model, which is centered on the growth of production factors. In contrast, the *external circulation* scenario relies largely on gains in productivity and international trade—elements that are not fully captured by the model. For this reason, a separate sensitivity analysis focusing on the long-term impact of TFP will be presented in Section 3.3.3.

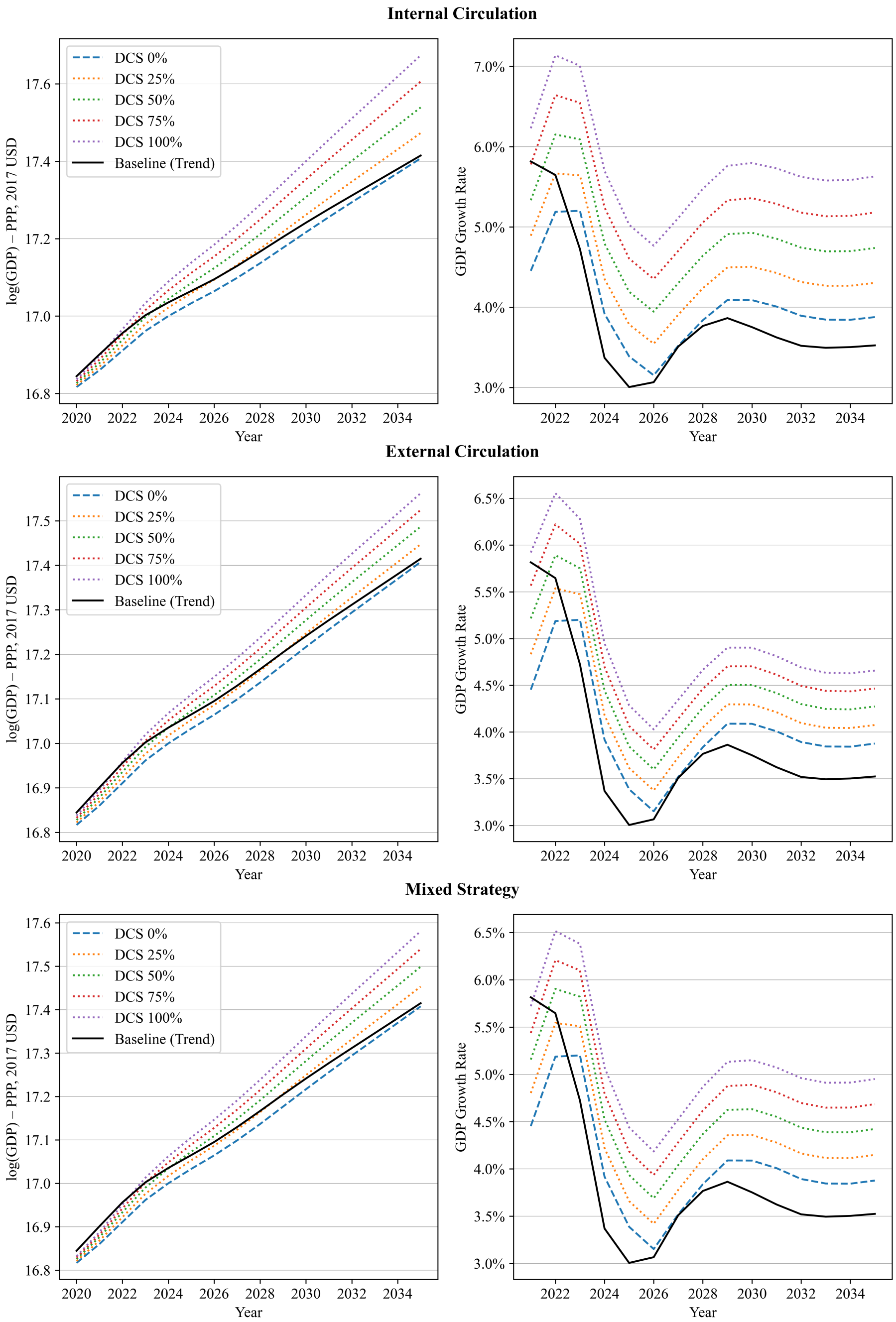
3.3.2 Growth Outlook under Policy-Driven Scenarios

Based on the assumptions outlined in the previous section, this part presents the results of deterministic simulations conducted for the three alternative policy scenarios inspired by the Dual Circulation Strategy: Internal Circulation, External Circulation, and Mixed Strategy. The objective is to assess how different combinations of structural reforms may affect China's real GDP growth trajectory over the 2020–2035 period.

The simulations rely on the extended Solow model, calibrated to the structure of the Chinese economy, and assume exogenous values for the three policy-relevant variables—investment share, human capital growth, and employment growth—according to the ranges shown in Table 3.4. The remaining variables, such as the depreciation rate, initial capital stock, and total population, are held constant, in line with a controlled simulation framework.

Each scenario has been evaluated across five levels of Dual Circulation Strategy (DCS) implementation intensity: 0%, 25%, 50%, 75%, and 100%. As shown in Figure 3.4, the simulated trajectories are presented both in logarithmic form (log of GDP, left panels) and as annual GDP growth rates (right panels), allowing for a dual interpretation of the dynamic evolution over time.

Figure 3.4: Forecasted GDP Trajectories under Different DCS Implementation Scenarios (2020–2035)



Source: Author's deterministic simulations based on Solow model and calibrated according to historical data and policy targets.

The distinction between Internal, External, and Mixed strategies enables a comparison of the different channels through which DCS policies could influence long-term growth. This structure offers a comprehensive overview of the potential effects associated with different levels of ambition and directionality in reform implementation.

As shown in Figure 3.4, the *Internal Circulation* scenario generates the most robust growth trajectory, with the compound annual growth rate (CAGR) of GDP increasing progressively from 4.02% in the DCS 0% case to 5.74% under full strategy implementation. This outcome reflects the combined effect of strengthened human capital formation and labor force participation—core elements of the domestic demand strategy—which directly influence the production factors in the Solow model. The growth profile also appears more balanced over time, with a progressive convergence toward a new stable trajectory.

The *External Circulation* scenario shows more moderate growth, with a CAGR ranging from 4.02% (DCS 0%) to 4.95% (DCS 100%). In this case, the main improvement stems from a selective increase in the investment share, while human capital and employment remain nearly unchanged. Despite the expansion of productive capacity, the absence of an endogenous TFP dynamic limits the full effectiveness of external openness policies within the adopted model. Nonetheless, the trajectory still displays moderate acceleration, consistent with a growth-led model oriented toward allocative efficiency and export enhancement.

Finally, the *Mixed Strategy* scenario presents an intermediate profile, with a CAGR ranging between 4.02% and 5.12% depending on the intensity of implementation. The path reflects a compromise among productive investment, skill development, and labor market participation. The growth trajectory appears stable, sustained, and more resilient to external shocks, thanks to the balance of internal and external policy levers. From a forward-looking perspective, the mixed strategy aligns with a gradual transition toward a more efficient, inclusive, and sustainable development model.

Table 3.5 summarizes the simulation results in terms of CAGR for each scenario.

The simulations therefore indicate that reforms aimed at strengthening internal productive factors—namely human capital and labor—could generate a more significant impact on growth than policies focused solely on investment. This outcome reflects the structure of the Solow model, where the contribution of exogenous human capi-

Table 3.5: Projected Average Annual GDP Growth Rate (2020–2035) under Different DCS Implementation Levels

% DCS	Internal Circulation	External Circulation	Mixed Strategy
0%	4,02%	4,02%	4,02%
25%	4,44%	4,26%	4,30%
50%	4,87%	4,49%	4,59%
75%	5,30%	4,72%	4,85%
100%	5,74%	4,95%	5,12%

Source: Author's elaboration based on projections consistent with IMF (2024), World Bank (2022), OECD (2024), and Fernández-Villaverde et al. (2023).

tal growth has persistent long-term effects, while capital accumulation is subject to diminishing returns.

Beyond the final levels of GDP—which are of limited explanatory value if considered without reference to the underlying factor relationships—it is essential to analyze the quality and composition of growth. The simulated scenarios show that achieving more balanced and sustainable long-term growth depends not only on the magnitude of investment but, more importantly, on the quality of the activated production factors. In particular, strategies that enhance human capital and labor participation tend to produce a more stable growth path, less exposed to cyclical fluctuations, while also reducing reliance on intensive physical capital accumulation.

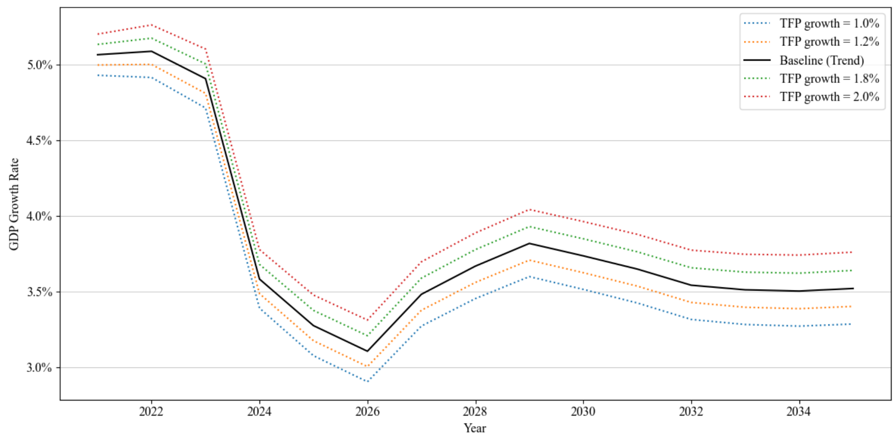
This qualitative rebalancing of growth also translates into indirect effects on key macroeconomic variables. For example, improvements in human capital and productivity tend to raise real wages, thereby stimulating domestic consumption and reducing the need to maintain high precautionary saving rates. This generates a virtuous cycle in which growth becomes increasingly driven by innovation, allocative efficiency, and domestic demand, rather than by excessive investment. This transition represents a core objective of the Dual Circulation Strategy, and the simulation results suggest that balancing the growth drivers may be just as important as their absolute intensity.

Nevertheless, it is important to interpret these results with caution. The model does not incorporate feedback mechanisms between growth and TFP, nor endogenous effects stemming from learning-by-doing, technological spillovers, or institutional reforms. For this reason, a supplementary sensitivity analysis focused on total factor productivity dynamics will be conducted in Section 3.3.3.

3.3.3 TFP Sensitivity and Structural Reforms

Once the effects of the main policy-relevant variables have been isolated, it becomes appropriate to separately analyze the role of Total Factor Productivity (TFP)—a crucial element that cannot be directly addressed in the previous deterministic scenarios. Figure 3.5 illustrates the impact of different exogenous and constant TFP growth rates on the GDP growth trajectory, while keeping all other model parameters fixed.

Figure 3.5: Simulated GDP Growth Path under Different TFP Growth Rates (2021–2035)



Source: Author's deterministic simulations based on Solow model and calibrated according to historical data and policy targets.

The simulation results, shown in Table 3.6 in terms of CAGR, indicate that an increase in TFP from 1.0% to 2.0% leads to a rise in GDP CAGR from 3.62% to 4.04%. However, what matters most is not the absolute level reached, but rather the structural role of TFP in supporting stable, sustained, and qualitatively superior growth. Unlike physical capital, TFP does not suffer from diminishing marginal returns: each productivity improvement accumulates over time, enhancing the system's efficiency and the economy's competitiveness without generating imbalances.

Table 3.6: Sensitivity of China's GDP Growth to TFP Assumptions (2020–2035)

TFP growth	GDP CAGR (2020–2035)
1,00%	3,62%
1,25%	3,72%
1,50%	3,83%
1,75%	3,93%
2,00%	4,04%

Source: Author's elaboration based on projections consistent with IMF (2024), World Bank (2022), OECD (2024), and Fernández-Villaverde et al. (2023).

This aspect is particularly crucial in the Chinese context: in an economy historically driven by capital overaccumulation and high saving rates, placing greater emphasis on TFP represents the key to transitioning toward a more balanced development model. Even relatively modest TFP growth rates—such as those considered in the simulation—are sufficient to ensure solid and sustainable long-term expansion, avoiding continued reliance on massive, and often inefficient, investment.

Moreover, the effects of TFP extend to the macroeconomic level, generating important indirect impacts:

– **Higher productivity**, leading to increased real wages, which in turn reduce the need for precautionary household savings and stimulate a greater propensity for domestic consumption;

– **Rebalancing of aggregate demand**, with a gradual shift from an investment-led model to one driven by consumption and human capital;

– **Allocative efficiency**, thanks to reduced reliance on low-productivity sectors (e.g., construction) and the expansion of the high-tech sector.

These mechanisms reinforce the "rebalancing" process promoted by the Dual Circulation Strategy and advocated by numerous international institutions. Projections from the IMF, World Bank, and OECD indicate a physiological slowdown in China's growth to around 3.5–4.0% by the mid-2030s [Fund, 2024a, Bank, 2022b, OECD, 2024]. In this context, TFP is not merely a growth accelerator, but a fundamental lever to make growth more stable, less dependent on forced saving, and more consistent with the characteristics of a mature and resilient economy.

However, fostering TFP requires deep structural reforms: investments in human capital and R&D, selective technological openness, protection of intellectual property rights, and improvements in the institutional environment. Only through such measures can China consolidate the transition from extensive to intensive growth, based on quality rather than quantity of inputs.

3.3.4 Summary and Policy Implications

Understanding the implications of the growth strategies hypothesized within the context of the Dual Circulation Strategy (DCS) is crucial for guiding Chinese economic policy in the coming decades.

The results presented in the previous sections clearly indicate that China's future growth path will critically depend on the nature of the structural reforms implemented in the years ahead. The simulated deterministic scenarios suggest that policies aimed at strengthening productive factors—particularly human capital and employment—can generate more sustainable, balanced, and resilient growth compared to strategies based solely on investment expansion.

In particular, the Internal Circulation scenario, which emphasizes human capital accumulation and labor inclusion, yielded the most favorable outcomes in terms of GDP growth, with compound annual growth rates (CAGR) increasing progressively with the level of policy implementation. This highlights the effectiveness of reforms focused on factor quality, in line with a structural shift from an investment-led to an efficiency-, innovation-, and productivity-driven model.

By contrast, the External Circulation scenario, while improving output levels, shows more limited potential, as the most relevant policy levers—such as trade openness and technological innovation—primarily affect total factor productivity (TFP), a variable that cannot be directly modeled within the deterministic framework adopted. Nonetheless, the sensitivity analysis in Section 3.3.3 confirmed that even modest increases in TFP produce significant effects on GDP growth, reinforcing the critical role of productivity in determining long-term potential.

From a macroeconomic perspective, higher productivity stimulated by structural reforms has important indirect effects: higher real wages can reduce precautionary savings and encourage domestic consumption, contributing to the rebalancing of aggregate demand. This supports the central objectives of the DCS, including the transition toward a growth model less dependent on exports and infrastructure investments, and more focused on domestic demand and high-value-added sectors.

The results obtained are consistent with the long-term forecasts issued by international institutions. The International Monetary Fund and the World Bank project a gradual slowdown in China's growth rate toward the 3.5–4.0% range by 2035, due to demographic aging, slower capital accumulation, and the transition to a more mature economy [Fund, 2024a, Bank, 2022b]. The estimates produced in this study, calibrated over the 2020–2035 period, are therefore aligned with the international consensus and confirm the plausibility of the simulated growth paths.

Despite these encouraging theoretical perspectives, it is important to stress that the concrete implementation of the DCS faces significant challenges. These include the need for deep pension system reforms to stimulate consumption, the reduction of inequalities between urban and rural areas, the promotion of innovation through a more competitive ecosystem, and the downsizing of the real estate sector's weight in the economy. Moreover, the international geopolitical environment, with the rise of trade and technological restrictions, poses additional challenges to China's global integration.

From a political-economic standpoint, the choice between an internal- or external-oriented strategy entails a number of important trade-offs. While internal reforms require deep interventions in the institutional framework, labor market, and welfare system, they offer prospects for greater long-term stability and strategic autonomy. Conversely, a strategy centered on external openness may deliver more immediate benefits in terms of efficiency and capital inflows but exposes the economy to greater risks linked to global market volatility and geopolitical tensions. This creates a temporal trade-off between the speed and the quality of growth, which Chinese authorities will need to manage with balance and foresight, seeking a sustainable synthesis between the two trajectories.

In summary, the findings highlight that the sustainability of China's growth will increasingly depend on its ability to reform the economic system toward a model focused on quality rather than quantity. Active policies aimed at boosting productivity, social mobility, and human capital formation will emerge as key levers to ensure stable, inclusive, and development-aligned growth for China's next phase.

Conclusion

This analysis has systematically addressed China's macroeconomic evolution, the dynamics of its main productive factors, and its future growth prospects, by combining empirical investigation with counterfactual simulations based on an extended version of the Solow model. The results point to a clear finding: China has now moved beyond the typical phase of an emerging economy, although it is not yet fully comparable to traditional advanced economies. This intermediate position—best described as "post-emerging"—is the outcome of a profound structural transformation, whose effects are visible both in historical trends and in forward-looking projections.

From a macroeconomic perspective, the data reveal a gradual slowdown in real GDP growth, associated with the maturation of several internal drivers: demographic deceleration, saturation of physical capital investment, increasing relevance of human capital, and the diminishing demographic dividend. The contribution of total factor productivity (TFP) has been positive but moderate, indicating a transition from accumulation-led growth toward a model based on efficiency and innovation.

The empirical adaptation of the Solow model to the Chinese context has made it possible to measure these transformations with greater precision. The evidence gathered shows that the Chinese economy is gradually converging toward a steady-state characterized by lower—but potentially more stable and sustainable—growth rates over the long term. Scenario simulations confirmed that, even with active policies such as the Dual Circulation Strategy, China's future growth potential remains well below the levels observed in previous decades. However, this does not imply a failure of the development model, but rather its natural evolution: slower, yet more sophisticated growth, driven by high value-added sectors, advanced urbanization, and technological innovation.

Moreover, the inclusion of endogenous parameters and alternative assumptions in the simulation phase has highlighted the increasing importance of the qualitative composition of capital and labor, as well as the central role of policy choices. The results obtained show a strong sensitivity of growth to human capital, R&D expenditure, and employment dynamics, suggesting that the main challenge for China is no longer "how much" to grow, but rather "how" to grow.

In light of the analyses developed in the previous chapters, it is possible to provide a structured answer to the questions that guided this research. The resulting picture is that of an economy that has progressively moved away from the typical characteristics of emerging markets, while still retaining some elements of structural transition.

1. Is China Still an Emerging Economy?

From a functional perspective, China can no longer be considered an emerging economy. The main indicators that have historically characterized *catching-up* countries—such as high real GDP growth, accelerated capital accumulation, demographic expansion, and large productivity gaps—have significantly diminished. The simulations conducted suggest that China's potential growth trajectory for the next decade lies between 2.5% and 4% per year, far from the double-digit rates recorded in the early 2000s. In this sense, China now resembles a mature advanced economy more than a developing one.

However, from a formal standpoint, China's classification remains ambiguous. Major agencies (such as MSCI and S&P) continue to treat it as an emerging market, mainly due to regulatory barriers, limited financial transparency, capital controls, and institutional shortcomings. This gap between economic reality and classificatory status represents one of the most intriguing challenges of contemporary China.

2. What Factors Explain the Slowdown in China's Economic Growth?

The results obtained through the empirical extension of the Solow model clearly identify the main drivers of China's economic slowdown. The first is demographic:

population growth has peaked and is now in decline, gradually reducing the contribution of labor to output. The second concerns investment dynamics: although the gross fixed capital formation share remains high, it has stopped increasing and shows signs of allocative inefficiency, particularly in the real estate sector. The third factor is productivity: total factor productivity (TFP) continues to grow, but at a slower pace than in previous decades, due to sectoral rigidities, reduced integration with global markets, and diminishing returns from structural reforms.

The inclusion of human capital in the model has revealed an additional weakness: although increasing, the average level remains below that of advanced economies, and its growth appears insufficient to offset demographic decline. In this context, China faces a qualitative rather than quantitative transformation of growth, in which productivity and innovation become indispensable.

3. Can the Dual Circulation Strategy Make Growth Sustainable in the Long Term?

The counterfactual simulations presented in Chapter 3 indicate that effective implementation of the Dual Circulation Strategy (DCS) can contribute to stabilizing China's potential growth rate, but is not sufficient on its own to reverse the underlying slowdown. Scenarios with high DCS intensity display greater long-term resilience of real GDP, particularly due to the strengthening of domestic demand, increased technological self-sufficiency, and the enhancement of human capital. However, these benefits prove more substantial when such interventions are accompanied by broad-based structural reforms, especially in the institutional and industrial competitiveness domains.

The effectiveness of the DCS thus lies in its ability to support a paradigm shift: from an export- and over-investment-driven model to a more balanced one based on innovation, domestic consumption, and services. This transition, however, is subject to both internal constraints (industrial structure, urban transition) and external constraints (global economic conditions, geopolitical tensions). In this sense, the DCS does not represent an automatic guarantee of growth, but rather a necessary condition to avoid stagnation and ensure long-term economic sustainability.

The emergence of a more moderate yet qualitatively more sophisticated growth regime raises crucial questions for China's economic policy. The transition from an emerging to a post-emerging economy requires a comprehensive rethinking of the entire macroeconomic architecture. The development model based on physical capital accumulation and exports has become unsustainable; in its place, a new paradigm is emerging—one centered on innovation, human capital, and internal resilience. Within this context, the balance between domestic demand, macro-financial stability, and geopolitical positioning becomes the cornerstone of China's strategic agenda.

From an aggregate demand perspective, domestic consumption represents the main weak link. Although China has implemented measures to stimulate household spending, the saving rate remains structurally high, due to shortcomings in the welfare system, uncertainty about the future, and persistent income inequality. Without a significant strengthening of the social safety net, the consumption component is unlikely to offset the slowdown in investment. The latter has shown signs of saturation, particularly in the real estate sector, where excess capacity and corporate indebtedness pose substantial systemic risks.

Monetary policy plays a crucial role in this rebalancing context. The objective of the People's Bank of China (PBoC) can no longer be limited to ensuring the stability of the renminbi and inflation; it must also act as a lever for qualitative growth. In recent years, the PBoC has progressively expanded its arsenal of medium-term liquidity tools and sector-specific refinancing mechanisms, seeking to channel credit toward strategic areas such as innovation, small and medium-sized enterprises (SMEs), and the energy transition. However, the room for maneuver on interest rates is constrained by two main factors: on one hand, the risk of fueling financial or real estate bubbles; on the other, the need to maintain a stable yield differential with foreign-currency assets, in a context where capital controls remain only partially in place.

In terms of prices and macroeconomic stability, the Chinese economy exhibits mixed signals. On one hand, core inflation has remained subdued, reflecting still-weak domestic demand; on the other, there are latent tensions in asset prices and production costs, linked both to commodity price volatility and to inefficiencies in distribution channels. In this context, public spending plays a crucial role not only as a cyclical stimulus, but also as a strategic allocation tool: the consolidation of human capital, the digitalization of public services, and investments in green infrastructure represent key priorities for a selective expansion of fiscal expenditure.

An additional and decisive factor is China's geopolitical positioning. The international context has become increasingly uncertain and fragmented, marked by rising strategic tensions between the United States and China, growing technological decoupling, and global competition over control of critical value chains (e.g., semiconductors, batteries, AI). Although China's relative exposure to exports has declined, its vulnerability to external shocks remains high—especially in sectors with strong foreign dependency or subject to restrictions (e.g., chips, cloud technology, artificial intelligence).

Strategic alliances with emerging economies and Global South countries—such as Russia, Iran, but also Brazil and South Africa—represent attempts to build an alternative bloc to the Western system. However, these relationships do not yet provide a solid foundation for global economic leadership, nor can they replace developed markets in the short term in terms of absorption capacity and innovation. The impact of geopolitics on China's growth path will therefore be more evident in the pace of the transition rather than its direction: slowdowns, obstacles, or accelerations will depend on China's ability to simultaneously manage internal structural adjustment and external risks.

Overall, the sustainability of China's growth will depend on the country's ability to navigate three parallel transitions: the internal one (from investment to consumption, from industry to services, from quantity to quality), the institutional one (toward more transparent and market-oriented governance), and the global one (from manufacturing powerhouse to technological leader in a multipolar order). None of these transitions is guaranteed, yet all are already underway. Precisely for this reason, China is no longer simply an economy that "grows fast," but a complex system that is growing differently.

One of the distinguishing features of this work lies in the methodological choice to combine the theoretical Solow model with a flexible empirical approach capable of capturing the complexity of China's economic transition. In particular, the use of an ARDL (Autoregressive Distributed Lag) model made it possible to estimate the log-linearized Cobb-Douglas production function over an extended period (1953–2019), accounting for the dynamic structure of the economy.

Compared to the classical approach, in which productive inputs affect output instantaneously, the version implemented in this thesis incorporates time lags that more accurately reflect the adjustment mechanisms of the real economy: capital formation, human capital accumulation, and employment responses are never immediate, but unfold with a certain degree of inertia. By design, the ARDL model is capable of capturing both long-run and short-run components, thereby improving the model's adherence to observed economic dynamics.

From an operational standpoint, several calibration choices were made based on Chinese data:

- the capital accumulation equation was maintained in its canonical form, but the parameters were calibrated using historical series from the Penn World Table;
- human capital—often neglected in applied growth models—was explicitly included, making the model better suited to capture the qualitative transition phase of the Chinese economy;
- TFP growth was assumed to be exogenous but calibrated to values consistent with recent literature (1.5% annually), as in [Fernández-Villaverde et al., 2023].

Following the identification of the model, deterministic simulations were conducted on counterfactual scenarios. These simulations incorporated varying degrees of implementation of the Dual Circulation Strategy by systematically adjusting key growth drivers—investment, human capital, and employment—in order to assess growth sensitivity. The theoretical consistency with the Solow model was preserved, but enriched with a realistic and policy-relevant component, a fundamental element for generating results that are valuable not only from an academic standpoint but also in practical policy terms.

Overall, the choice of the ARDL model proved to be methodologically appropriate, theoretically consistent, and operationally effective. It allowed for overcoming the limitations of static or purely cross-sectional approaches, offering a dynamic perspective on Chinese growth during a phase of profound transformation. In this sense, the thesis contributes not only to the empirical analysis of China but also to the methodological literature on modeling economies in transition, demonstrating that a classical framework, when properly adapted, can still provide valuable insights into complex economic systems.

The analysis carried out in this thesis leads to a clear yet carefully reasoned conclusion: China is no longer an emerging economy—and has not been for several years. The evidence supporting this claim is not episodic or cyclical, but rather structural, widespread, and persistent. The results obtained through the ARDL model, grounded in the theoretical framework of the Solow model, indicate a growth trajectory that has now stabilized at moderate annual rates, incompatible with the expansionary dynamics typical of *catching-up economies*.

This moderation in growth rates, far from being a symptom of stagnation, reflects a systemic evolution. China is transforming into a major *post-emerging* economy, committed to upgrading its production model, addressing demographic and environmental challenges, and strengthening its strategic autonomy. In many respects, this phase is comparable to the one experienced in the past by Japan and South Korea, which underwent a “virtuous” growth slowdown following the completion of their industrialization process.

Surpassing the status of an emerging economy does not imply that China is already a fully advanced economy in all respects. Significant asymmetries persist in terms of per capita income levels, institutional quality, and the openness of the financial market. However, from a functional standpoint, China today is a systemic player with an economic, technological, and industrial sophistication comparable to—if not exceeding, in certain sectors—that of the major developed economies.

The transition process will inevitably be long, non-linear, and subject to both internal and external frictions. Precisely for this reason, the real question today is not whether China will emerge, but rather how it will manage its past emergence, and through what mechanisms it will stabilize its new equilibrium. The central challenge lies in the orderly exit from the old model based on investment and manufacturing, and the entry into a new stage founded on consumption, innovation, and institutional resilience.

In light of this evidence, the classification of China as an "emerging market" appears increasingly outdated. Analytical tools, risk metrics, and policy frameworks that continue to treat China as such risk producing flawed diagnoses and distorted forecasts. Recognizing the new nature of the Chinese system is not merely a theoretical exercise, but an analytical and economic imperative.

In summary, China has already crossed the threshold of emergence. The signals observed in recent years—from the maturation of human capital to the restructuring of public spending, from the recalibration of industrial strategies to the structural slowdown of growth—constitute converging evidence of a profound and irreversible transformation. Understanding this transition does not merely mean updating a definition, but rather reading with clarity the trajectory of the world's second-largest economy. And today, more than ever, the balance of the global economy in the coming decades will depend on this very trajectory.

Bibliography

[Acemoglu et al., 2001] Acemoglu, D., Johnson, S., and Robinson, J. A. (2001). The colonial origins of comparative development: An empirical investigation. *American Economic Review*, 91(5):1369–1401.

[Aghion and Howitt, 1998] Aghion, P. and Howitt, P. (1998). *Endogenous Growth Theory*. MIT Press, Cambridge, MA.

[Bank, 1981] Bank, W. (1981). *World Development Report 1981*. The World Bank, Washington, D.C. Accessed: 2025-03-28.

[Bank, 2022a] Bank, W. (2022a). China economic update: Navigating uncertainty. Technical report, World Bank. Accessed April 2024.

[Bank, 2022b] Bank, W. (2022b). China economic update – demographics and labor. Accessed: 2025-03-28.

[Bank, 2022c] Bank, W. (2022c). *Poverty and Shared Prosperity Report 2022*. The World Bank, Washington, D.C. Accessed: 2025-03-28.

[Bank, 2023a] Bank, W. (2023a). Global economic prospects, january 2023. Accessed: 2025-06-23.

[Bank, 2023b] Bank, W. (2023b). Total reserves (includes gold, current us$) - china. Accessed: 2025-03-28.

[Bank, 2023c] Bank, W. (2023c). World development indicators – gdp per capita (current us$), china (1978). Accessed: 2025-03-28.

[Bank, 2024a] Bank, W. (2024a). Age dependency ratio, old (% of working-age population) – china. Accessed: 2025-03-28.

[Bank, 2024b] Bank, W. (2024b). Final consumption expenditure (% of gdp) – china. Accessed: 2025-03-28.

[Bank, 2024c] Bank, W. (2024c). Gross fixed capital formation (% of gdp) – china. Accessed: 2025-03-28.

[Bank, 2024d] Bank, W. (2024d). Gross savings (% of gdp) – china. Accessed: 2025-03-28.

[Bank, 2024e] Bank, W. (2024e). Household consumption (% of gdp) – china. Accessed: 2025-03-28.

[Bank, 2024f] Bank, W. (2024f). Patent applications by residents and non-residents – china. Includes: IP.PAT.RESD and IP.PAT.NRES. Accessed: 2025-03-28.

[Bank, 2024g] Bank, W. (2024g). Population ages 15–64 (% of total) – china. Accessed: 2025-03-28.

[Bank, 2024h] Bank, W. (2024h). Research and development expenditure (% of gdp) – china. Accessed: 2025-03-28.

[Bank, 2024i] Bank, W. (2024i). School enrollment, tertiary (% gross) – china. Accessed: 2025-03-28.

[Bank, 2024j] Bank, W. (2024j). Wits - exports profile for china (1992–2022). Accessed: May 2025.

[Bank, 2024k] Bank, W. (2024k). Wits - imports profile for china (1992–2022). Accessed: May 2025.

[Bank, 2024l] Bank, W. (2024l). World development indicators - gdp per capita, ppp (constant 2017 international $). Accessed April 2025.

[Bank, 2024m] Bank, W. (2024m). World development indicators: Domestic credit to private sector (% of gdp) – china. Accessed: 2025-03-28.

[Bank, 2024n] Bank, W. (2024n). World development indicators: Inflation and interest rates – china. Accessed: 2025-03-28.

[Bank, 2024o] Bank, W. (2024o). World development indicators: M2 (% of gdp) – china. Accessed: 2025-03-28.

[Bank, 2025] Bank, W. (2025). World bank country and lending groups. Accessed: 2025-07-08.

[Barro, 1991] Barro, R. J. (1991). Economic growth in a cross section of countries. *The Quarterly Journal of Economics*, 106(2):407–443.

[Barro and i Martin, 2004] Barro, R. J. and i Martin, X. S. (2004). *Economic Growth*. MIT Press, Cambridge, MA, 2nd edition.

[Belt and Portal, 2024] Belt and Portal, R. (2024). Belt and road cooperation. Accessed on July 6, 2025.

[Ben-David, 1993] Ben-David, D. (1993). Equalizing exchange: Trade liberalization and income convergence. *Quarterly Journal of Economics*, 108(3):653–679.

[Benigno et al., 2021] Benigno, P., Canova, F., Ferroni, F., and Sala, L. (2021). The future of macroeconomic forecasting: Methods and implications. *Journal of Economic Literature*, 59(4):1105–1153.

[Bloomberg, 2023] Bloomberg (2023). China's housing market slump deepens. Accessed: 2025-03-28.

[Bosworth and Collins, 2008] Bosworth, B. and Collins, S. M. (2008). Accounting for growth: Comparing china and india. *Journal of Economic Perspectives*, 22(1):45–66.

[Britton et al., 1998] Britton, E., Fisher, P., and Whitley, J. (1998). The inflation report projections: Understanding the fan chart. Quarterly Bulletin Q1, Bank of England. Bank of England Quarterly Bulletin, February 1998.

[Chen and Zhang, 2021] Chen, Y. and Zhang, F. (2021). Digital trade and economic growth in china: A provincial-level analysis. *China Economic Review*, 68:101629.

[Dikötter, 2010] Dikötter, F. (2010). *Mao's Great Famine: The History of China's Most Devastating Catastrophe.* Walker & Company, New York.

[Division, 2023] Division, U. N. P. (2023). World population prospects 2023. Accessed: 2025-03-28.

[Easterly and Levine, 2001] Easterly, W. and Levine, R. (2001). It's not factor accumulation: Stylized facts and growth models. *World Bank Economic Review*, 15(2):177–219.

[Edwards, 1998] Edwards, S. (1998). Openness, productivity and growth: What do we really know? *Economic Journal*, 108(447):383–398.

[Feenstra et al., 2015] Feenstra, R. C., Inklaar, R., and Timmer, M. P. (2015). The next generation of the penn world table. *American Economic Review*, 105(10):3150–3182.

[Fernald, 2015] Fernald, J. G. (2015). Productivity and potential output before, during, and after the great recession. *European Economic Review*, 77:77–97.

[Fernández-Villaverde et al., 2023] Fernández-Villaverde, J., Ohanian, L. E., and Yao, W. (2023). The neoclassical growth of china. Working paper, University of Pennsylvania.

[for International Settlements, 2023] for International Settlements, B. (2023). Credit to the non-financial sector - china. Accessed: 2025-03-28.

[Forum, 2016] Forum, W. E. (2016). China's working-age population will fall by 23% by 2050. Accessed: 2025-03-28.

[Fund, 2021] Fund, I. M. (2021). People's republic of china: Staff report for the 2021 article iv consultation. Accessed: 2025-03-28.

[Fund, 2023a] Fund, I. M. (2023a). World economic outlook database – groups and aggregates (april 2023). Accessed: 2025-07-06.

[Fund, 2023b] Fund, I. M. (2023b). World economic outlook – april 2023. Accessed: 2025-03-28.

[Fund, 2024a] Fund, I. M. (2024a). Imf executive board concludes 2023 article iv consultation with china. Accessed: 2025-03-28.

[Fund, 2024b] Fund, I. M. (2024b). Imf executive board concludes 2023 article iv consultation with the people's republic of china. Press Release No. 24/33, February 1, 2024.

[Grossman and Helpman, 1991] Grossman, G. M. and Helpman, E. (1991). *Innovation and Growth in the Global Economy*. MIT Press, Cambridge, MA.

[Harrison, 1996] Harrison, A. (1996). Openness and growth: A time-series, cross-country analysis for developing countries. *Journal of Development Economics*, 48(2):419–447.

[Indices, 2025] Indices, S. D. J. (2025). Market classification - s&p dow jones indices. Accessed: 2025-07-08.

[Islam, 1995] Islam, N. (1995). Growth empirics: A panel data approach. *The Quarterly Journal of Economics*, 110(4):1127–1170.

[Jones, 1995] Jones, C. I. (1995). R&d-based models of economic growth. *Journal of Political Economy*, 103(4):759–784.

[Lin, 1992] Lin, J. Y. (1992). Rural reforms and agricultural growth in china. *American Economic Review*, 82(1):34–51.

[Liu et al., 2022] Liu, Y., Chen, W., and Zhang, L. (2022). The dual circulation strategy and china's economic resilience: Evidence from structural reforms. *China Economic Review*, 73:101763.

[Lucas, 1988] Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22(1):3–42.

[Lutz et al., 2018] Lutz, W., Goujon, A., KC, S., and Sanderson, W. (2018). Global human capital: Integrated scenarios and sustainable development. *PNAS*, 115(33):8072–8079.

[Maddison, 2007] Maddison, A. (2007). *Contours of the World Economy, 1-2030 AD: Essays in Macro-Economic History*. Oxford University Press, Oxford.

[Mankiw et al., 1992] Mankiw, N. G., Romer, D., and Weil, D. N. (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics*, 107(2):407–437.

[MSCI, 2025] MSCI (2025). Emerging markets indexes – unique characteristics. Accessed: 2025-07-06.

[OECD, 2022a] OECD (2022a). *OECD Science, Technology and Innovation Outlook 2023*. OECD Publishing, Paris. Accessed: 2025-03-28.

[OECD, 2022b] OECD (2022b). Research and development statistics (rds). Accessed: 2025-03-28.

[OECD, 2024] OECD (2024). *OECD Economic Outlook, Volume 2024 Issue 2*. OECD Publishing, Paris. Accessed: 2025-03-28.

[of China, 2021] of China, G. (2021). Outline of the 14th five-year plan (2021–2025). Accessed: 2025-03-28.

[of Education of the People's Republic of China, 2022] of Education of the People's Republic of China, M. (2022). China statistical yearbook on education. Accessed: 2025-03-28.

[of International Finance, 2023] of International Finance, I. (2023). Global debt monitor – china section. Accessed: 2025-03-28.

[of Statistics of China, 2023a] of Statistics of China, N. B. (2023a). Assets and liabilities of real estate development enterprises. Accessed: 2025-03-28.

[of Statistics of China, 2023b] of Statistics of China, N. B. (2023b). Average selling price of commercialized buildings. Accessed: 2025-03-28.

[of Statistics of China, 2023c] of Statistics of China, N. B. (2023c). China statistical yearbook 2023. Accessed: 2025-03-28.

[of Statistics of China, 2023d] of Statistics of China, N. B. (2023d). Floor space completed and sold by use. Accessed: 2025-03-28.

[of the People's Republic of China, 2022] of the People's Republic of China, S. C. (2022). Guidelines on building a unified national market. Accessed: 2025-03-28.

[Organization, 2021] Organization, W. T. (2021). World trade report 2021: Economic resilience and trade. Accessed: 2025-03-28.

[Rogoff and Yang, 2020] Rogoff, K. S. and Yang, Y. (2020). Peak china housing. NBER Working Paper 27697, National Bureau of Economic Research. Accessed: 2025-03-28.

[Rogoff and Yang, 2021] Rogoff, K. S. and Yang, Y. (2021). The real estate sector and china's growth model. NBER Working Paper 29448, National Bureau of Economic Research. Accessed: 2025-03-28.

[Russell, 2025] Russell, F. (2025). Ftse equity country classification – march 2025 update. Accessed: 2025-07-08.

[Service, 2023] Service, C. R. (2023). China's economic rise: History, trends, challenges, and implications for the united states. Accessed: 2025-03-28.

[Solow, 1956] Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, 70(1):65–94.

[TG24, 2010] TG24, S. (2010). La cina supera il giappone e diventa la seconda economia mondiale. Accessed: 2025-03-28.

[UNCTAD, 2023] UNCTAD (2023). *World Investment Report 2023*. United Nations Conference on Trade and Development. Accessed: 2025-03-28.

[Vilaverde and altri, 2022] Vilaverde, J. and altri (2022). Neoclassical growth in china: A generalized solow model. *Journal of Asian Economics*.

[Yang and Liu, 2023] Yang, X. and Liu, W. (2023). Trade openness and tfp growth in china: Evidence from sector-level data. *Journal of Asian Economics*, 84:101574.

[Zhang and Huang, 2023] Zhang, X. and Huang, Y. (2023). Strategic rebalancing under dual circulation: Implications for innovation and domestic demand. *Journal of Chinese Economic and Business Studies*, 21(1):1–18.

[Zhu, 2012] Zhu, X. (2012). Understanding china's growth: Past, present, and future. *Journal of Economic Perspectives*, 26(4):103–124.

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Appendix A – Construction of Data Series and Steady-State Methodology

A.1 Calculation of ICOR (Incremental Capital-Output Ratio)

Figure 1.4 displays the evolution of the ICOR for China, computed as the ratio between Gross Fixed Capital Formation (GFCF) and the real GDP growth rate:

$$\text{ICOR}_t = \frac{\text{GFCF}_t}{\Delta\text{GDP}_t}$$

Where:

- $\mathbf{GFCF_t}$ is gross fixed capital formation as a percentage of GDP for year t;
- $\mathbf{\Delta GDP_t}$ is the annual real GDP growth rate.

Both series were retrieved from the World Bank. The indicators used are: `NE.GDI.FTOT.ZS` for GFCF and `NY.GDP.MKTP.KD.ZG` for GDP growth. This calculation provides an approximate measure of investment efficiency: higher ICOR values indicate lower efficiency in translating capital investment into economic growth. *Source: World Bank (2024), World Development Indicators.*

A.2 Construction of the Real Estate Investment Ratio

Figure 1.5 presents the share of real estate investment over total fixed asset investment in China. Since this ratio is not directly available from international databases, it was constructed manually using two series provided by the National Bureau of Statistics of China (NBSC):

- **Real Estate Development Investment**, measured in 100 million yuan;
- **Total Investment in Fixed Assets in the Whole Country**, also measured in 100 million yuan.

The ratio was calculated as follows:

$$\text{Real Estate Investment Ratio}_t = \frac{\text{Real Estate Development Investment}_t}{\text{Total Investment in Fixed Assets}_t}$$

This ratio expresses the relative weight of the real estate sector within the broader national investment structure. It helps to capture the growing dependence of China's economy on property-related investment during the post-2000 period. *Source: National Bureau of Statistics of China (2023), author's calculations.*

A.3 Construction of Steady-State Dynamics for China

This appendix provides a detailed explanation of the methodology adopted to construct the historical series used in the estimation of China's steady-state dynamics, as described in Section 2.2.3.

Capital Stock Estimation

Capital stock was estimated recursively based on the perpetual inventory method:

$$K(t) = (1 - \delta_t) \times K(t-1) + I(t)$$

where $K(t)$ is the capital stock at time t, δ_t is the observed annual depreciation rate, and $I(t)$ is the gross investment.
Investment was obtained by multiplying the share of gross capital formation (`csh_i`) by the level of GDP at PPP prices (`cgdpo`), both sourced from the Penn World Table (version 10.01) [Feenstra et al., 2015].

Total Factor Productivity Calculation

Total Factor Productivity (TFP) was computed as the residual of a Cobb-Douglas production function with constant returns to scale:

$$A(t) = \frac{Y(t)}{K(t)^{\alpha} \times L(t)^{1-\alpha}}$$

where $Y(t)$ is output, $K(t)$ is capital stock, $L(t)$ is employment (`emp`), and α is the elasticity of output with respect to physical capital. Following Section 2.2.2, the model assumes $\alpha = 0.4$, consistent with standard growth literature for emerging economies [Bosworth and Collins, 2008, Vilaverde and altri, 2022].

Effective Investment and Depreciation Flows

Observed investment and depreciation per effective worker were computed as follows:

– **Investment per effective worker:**

$$\text{Investment}(t) = \frac{s(t) \times Y(t)}{L(t)}$$

– **Depreciation per effective worker:**

$$\text{Depreciation}(t) = \frac{(\delta(t) + g(t) + n(t)) \times K(t)}{L(t)}$$

Theoretical investment and depreciation flows were constructed assuming constant mean values of the saving rate, TFP growth, and population growth over the sample period.

Identification of Steady-State

The steady-state level was identified by comparing theoretical investment and theoretical depreciation per effective worker. The steady-state year corresponds to the point where the two theoretical curves intersect:

$$\text{Theoretical Investment} = \text{Theoretical Depreciation}$$

The empirical analysis focused on the period post-2000 to better reflect China's modern growth dynamics.

Data Sources

All primary data used for the construction of the series were sourced from:

– Penn World Table (version 10.01), indicators: `cgdpo`, `csh_i`, `delta`, `emp`, `pop`, `labsh` [Feenstra et al., 2015]

– Author's elaborations based on historical series for China

The calibration choices and the methodological approach are consistent with recent applications of the Solow framework to emerging economies [Vilaverde and altri, 2022], ensuring international comparability and theoretical robustness.

Source: Author's elaboration based on Penn World Table (2024) and own calculations.

A.4 Summary Tables of Average Parameters for Steady-State Graphs

The following tables report the average values of the main parameters used to construct the theoretical investment and depreciation curves shown in the steady-state graphs of Section 2.2.4 (closed economy) and Section 2.2.3 (open economy).

Average Parameters – Closed Economy Scenario

Parameter	Description	Value
s	Saving rate (GCF/GDP)	0.2654
δ	Depreciation rate	0.0539
n	Population growth rate	0.0136
g	TFP growth rate	0.0100
α	Capital share in income	0.4000

Average Parameters – Open Economy Scenario

Parameter	Description	Value
s_{eff}	Effective saving rate ($\frac{GCF+NX_K}{GDP}$)	0.2875
δ	Depreciation rate	0.0547
n	Population growth rate	0.0066
g	TFP growth rate	0.0207
α	Capital share in income	0.4000

Source: Author's elaboration based on Penn World Table (2024) and WITS data.

Appendix B – Forecasting Methodologies and Additional Simulations

B.1 Bootstrap Simulations for ARDL Fan Chart and Confidence Intervals

To construct the confidence bands around the ARDL forecast presented in Figure 3.3, a non-parametric bootstrap simulation was performed. The goal is to capture the range of plausible future GDP trajectories under uncertainty, based on the historical variability of the model's residuals.

The procedure followed these steps:

- **1. Simulation of paths:** 1,000,000 GDP paths were generated starting from the 2019 log-level. Each year's growth was defined as the predicted trend (*linear ARDL forecast*) plus a randomly sampled residual from the historical ARDL model (1953–2019).

- **2. Conversion to levels and growth rates:** Simulated paths were converted from log-GDP to levels, and annual growth rates were computed.

- **3. Confidence bands:** Percentile bands (5–95%, 25–75%, 45–55%) were extracted for both log-levels and growth rates. These percentiles form the shaded areas of the fan chart.

- **4. Scenario evaluation:** The 5th and 95th percentile trajectories were used to compute the CAGR (Compound Annual Growth Rate) for the worst and best-case scenarios.

The following results were obtained for the 2020–2035 period:

- **CAGR (5th percentile – Worst Case):** 3.12%
- **CAGR (ARDL baseline – Linear trend):** 3.88%
- **CAGR (95th percentile – Best Case):** 4.67%

These fan charts provide a robust visual and statistical representation of forecast uncertainty, allowing for a more nuanced interpretation of policy impacts under different confidence levels.

Note: This simulation does not assume any parametric distribution of residuals. All shocks were drawn from the empirical distribution of the ARDL residuals (bootstrap with replacement).

B.2 Scenario Simulation Equation and Assumptions

This section documents the deterministic simulation approach used to estimate the long-run effects of policy-driven scenarios under the Dual Circulation Strategy (DCS), as discussed in Section 3.3.

The model implements a dynamic forecasting equation derived from the baseline ARDL specification calibrated on Chinese macroeconomic data. The equation expresses the logarithm of real output $\log(Y_t)$ as a linear function of multiple lags of output and capital, along with contemporaneous values of capital, labour, and human capital:

$$\begin{aligned}\log(Y_t) = {} & \beta_0 + \beta_1 \log(Y_{t-1}) + \beta_2 \log(Y_{t-2}) + \beta_3 \log(Y_{t-3}) + \beta_4 \log(Y_{t-4}) \\ & + \beta_5 \log(K_t) + \beta_6 \log(K_{t-1}) + \beta_7 \log(K_{t-2}) + \beta_8 \log(K_{t-3}) + \beta_9 \log(K_{t-4}) \\ & + \beta_{10} \log(L_t) + \beta_{11} \log(L_{t-1}) + \beta_{12} \log(H_t)\end{aligned}$$

where:

- K_t: physical capital stock, updated using a fixed depreciation rate and the scenario-specific investment share;

- L_t: employment level, assumed to grow exogenously at scenario-specific rates;

- H_t: human capital index, growing at constant scenario-specific rates;

- The coefficients β_i are estimated using the historical dataset 1995–2019.

Each scenario corresponds to a different set of exogenous assumptions for the growth rates of human capital and employment, and for the investment-to-GDP ratio.

Scenario Parameters – *Internal Circulation*

DCS	Investment Share	Human Capital Growth	Employment Growth
0%	0.3950	0.00950	0.0020
25%	0.4010	0.01075	0.0025
50%	0.4070	0.01200	0.0030
75%	0.4130	0.01325	0.0035
100%	0.4190	0.01450	0.0040

Scenario Parameters – *External Circulation*

DCS	Investment Share	Human Capital Growth	Employment Growth
0%	0.3950	0.00950	0.0020
25%	0.4030	0.01000	0.0023
50%	0.4110	0.01050	0.0026
75%	0.4180	0.01100	0.0029
100%	0.4250	0.01150	0.0032

Scenario Parameters – *Mixed Strategy*

DCS	Investment Share	Human Capital Growth	Employment Growth
0%	0.3950	0.00950	0.0020
25%	0.4010	0.01025	0.0023
50%	0.4070	0.01100	0.0026
75%	0.4110	0.01175	0.0029
100%	0.4150	0.01250	0.0032

These assumptions update the input variables iteratively over the forecast horizon (2020–2035), while other structural parameters — such as the depreciation rate (δ) and the initial capital stock K_0 — are held constant.

The simulation path is computed recursively. For each year:

a capital K_t is updated via the capital accumulation identity:

$$K_{t+1} = (1 - \delta)K_t + sY_t$$

b labour L_t and human capital H_t are updated via:

$$L_{t+1} = L_t \cdot (1 + g_L) \quad ; \quad H_{t+1} = H_t \cdot (1 + g_H)$$

c output is projected using the ARDL equation above.

This approach provides fully deterministic growth trajectories that allow for transparent counterfactual comparison across scenarios. It captures dynamic lag effects and input interactions, while abstracting from stochastic shocks and uncertainty. The baseline path is aligned with the ARDL forecasts under a linear trend, while all scenarios begin from a common initial level consistent with 2019 macroeconomic data.

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