Hacettepe University Graduate School of Social Sciences

Department of Economics

THE DYNAMICS OF GROWTH SLOWDOWN IN DEVELOPED ECONOMIES

İlay KURT

Ph. D. Dissertation

Ankara, 2024

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ACCEPTANCE AND APPROVAL

The jury finds that İlay KURT has on the date of 18/02/2024 successfully passed the defense examination and approves her Ph.D. Dissertation titled “The Dynamics of Growth Slowdown in Developed Economies”.

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Bu çalışmadaki bütün bilgi ve belgeleri akademik kurallar çerçevesinde elde ettiğimi, görsel, işitsel ve yazılı tüm bilgi ve sonuçları bilimsel ahlak kurallarına uygun olarak sunduğumu, kullandığım verilerde herhangi bir tahrifat yapmadığımı, yararlandığım kaynaklara bilimsel normlara uygun olarak atıfta bulunduğumu, tezimin kaynak gösterilen durumlar dışında özgün olduğunu, **Doç. Dr. M. Aykut ATTAR** danışmanlığında tarafımdan üretildiğini ve Hacettepe Üniversitesi Sosyal Bilimler Enstitüsü Tez Yazım Yönergesine göre yazıldığını beyan ederim.

İlay KURT

ABSTRACT

KURT, İlay. *The Dynamics of Growth Slowdown in Developed Economies*, Ph. D. Dissertation, Ankara, 2023.

Numerous studies have explored the dynamics and long-term effects of economic growth both theoretically and empirically. In this study, we examine the endogenous sources of economic growth and try to answer why the long-run growth rates of advanced economies have experienced secular slowdowns over the last decades. Additionally, we focus on the U.S. economy, for which we build a complex dynamic general equilibrium model to simulate and project the trajectory of its primary economic fundamentals over the long term. Our principal findings exhibit a consistent alignment with empirical data, indicating a growth slowdown in developed economies. Furthermore, according to these outcomes, our analysis suggests that the U.S. economy will experience a slowdown in the long run, establishing a new trend of GDP per capita growth rate of 1.5 per annum.

Keywords: Long run economic growth, endogenous growth, R&D, dynamic general equilibrium, firm dynamics

ÖZET

KURT, İlay. *Gelişmiş Ülkelerde Büyüme Yavaşlamasının Dinamikleri,* Doktora Tezi, Ankara, 2023.

Bugüne kadar ekonomik büyümenin dinamiklerini ve uzun vadeli etkilerini hem teorik hem de ampirik olarak inceleyen çok sayıda çalışma yapılmıştır. Bu araştırmada, ekonomik büyümenin içselleştirilmiş kaynakları inceleniyor ve gelişmiş ekonomilerin uzun vadeli büyüme oranlarında son on yılda neden kalıcı yavaşlamalar yaşandığının cevabı aranıyor. Ayrıca, bu çalışmada odak noktamız özellikle ABD ekonomisine olup, burada temel ekonomik faktörlerinin uzun vadeli seyrini simüle etmek ve tahmin etmek için karmaşık bir dinamik genel denge modeli oluşturuyoruz. Başlıca bulgularımız, ampirik verilerle tutarlı bir uyum sergiliyerek, gelişmiş ülkelerde bir büyüme yavaşlamasını işaret ediyor. Bununla beraber, bu sonuçlara göre analizimiz, ABD ekonomisinin uzun vadede bir yavaşlama yaşayacağını ve kişi başına düşen GSYİH büyüme oranının yıllık 1,5 seviyesinde yeni bir trende oturacağını öne sürüyor.

Anahtar Sözcükler: Uzun dönemli ekonomik büyüme, içsel büyüme, Ar-Ge, dinamik genel denge, firma dinamikleri

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2GS	: Second Generation Schumpeterian
BGP	: Balanced Growth Path
CBP	: County Business Patterns
DGE	: Dynamic General Equilibrium
EU	: European Union
FE	: Fixed Effects
FOC	: First Order Conditions
GDP	: Gross Domestic Product
GE	: General Equilibrium
GERD	: Gross Domestic Expenditure on R&D
ICT	: Information and Communication Technology
IMF	: International Monetary Fund
IT	: Information Technology
MDP	: Minimum Distance Problem
OECD	: Organization for Economic Cooperation and Development
OLG	: Overlapping Generations
PWT	: Penn World Table
Q-Q	: Quantity-Quality
R&D	: Research and Development
RE	: Random Effects
SEG	: Semi-Endogenous Growth
SGE	: Static General Equilibrium
SMM	: Simulated Method of Moments
TFP	: Total Factor Productivity
TFR	: Total Fertility Rate
UK	: United Kingdom
UN	: United Nations
US	: United States
WB	: World Bank
WEO	: World Economic Outlook

INTRODUCTION

The field of growth economics has garnered increased importance within the broader economics literature, particularly after the mid-1980s. The dynamic global economic milieu, marked by technological advancements, shifts in demographics, and geopolitical transformations, has prompted a renewed emphasis on comprehending the determinants, patterns, and ramifications of long-term economic growth. Researchers and policymakers alike recognize that sustained economic growth is not only crucial for improving living standards but also for addressing issues such as income inequality, unemployment and environmental sustainability.

Amidst the context of the Global Financial Crisis of 2008 and subsequent recessions, the discussion on growth economics has gained prominence as academics contend with the repercussions of secular stagnation, characterized by prolonged periods of slow growth. The experiences of diverse countries, ranging from growth miracles to disasters, have spurred a more profound investigation into the factors influencing growth rates. Furthermore, concerns regarding the sustainability of economic growth, coupled with debates on the impact of innovation, the accumulation of human capital, and structural reforms, have fueled a robust academic discussion within the realm of growth economics.

The global landscape of long-run growth rates in real GDP per capita displays substantial disparities among countries, marked by instances of both exceptional growths, exemplified by "growth miracles" such as Taiwan and South Korea, and stagnation or decline, observed in "growth disaster" economies like Congo or Chad. In contrast, developed economies, particularly early industrialized nations like the United States and the United Kingdom, exhibit more modest and positive long-run growth rates, around 2% per annum. Following the Global Financial Crisis of 2008, intensified academic scrutiny has been directed towards the long-run growth patterns of developed economies, with concerns about growth slowdown and secular stagnation. Scholars like Gordon (2015), Summers (2014), and Plosser (2014) have highlighted the significance of slow potential GDP growth, the sustainability of economic growth, and the enduring impact of reduced net investment on productivity.

Motivated by ongoing debates on secular stagnation and growth slowdown, the first part of this research is devoted to empirically examine the structure of long-run growth patterns across a diverse set of countries. Specifically, the research seeks to assess the extent of long-run growth slowdown in developed economies, comparing it to the growth dynamics in developing and least developed economies. The empirical analysis involves estimating regression models with panel data, focusing on the impact of developed economies on the long-run growth rate. Additionally, the study investigates the role of Total Factor Productivity (TFP) slowdowns in shaping the observed patterns in GDP per capita growth. The comprehensive analysis spans from 1970 to 2019, employing 5-year growth rates to mitigate the influence of annual fluctuations. The dataset encompasses 80 countries, selected for superior TFP data availability, and is sourced from the Penn World Tables. The primary finding suggests a clear decline in long-run growth rates of GDP per capita, GDP per worker, and TFP in high-income economies from 1970 to 2019, supported by robust econometric results under different classification criteria and estimation methods.

The IMF's World Economic Outlook report for October 2023 highlights a downward revision in the global economic growth forecast, projecting a decline from 3.5% in 2022 to 3.0% in 2023 and further to 2.9% in 2024. This anticipated growth rate is significantly below the historical average from 2000 to 2019, which was situated at 3.8%. Developed economies are expected to exhibit substantial reduction in growth, dropping from 2.6% in 2022 to 1.5% in 2023 and 1.4% in 2024. Approximately 90% of advanced economies are predicted to witness lower growth rates in terms of both GDP and GDP per capita in 2023, with the U.S. forecasted to grow at 2.1% in 2023 and 1.5% in 2024. Moreover, global growth projections for the next five years have markedly decreased from 4.9% in 2008 to 3.0% in 2023, making these projections the most conservative since 1990.

In response to these economic forecasts, the second part of this research introduces an analytically tractable growth model that extends beyond traditional factors. The model explicitly integrates firm dynamics, horizontal and vertical innovation processes, and a scale-invariant Schumpeterian approach. This innovative model considers inter-generational investment decisions, fertility, and human capital accumulation, addressing longstanding issues in growth literature, alongside endogenous productivity growth and R&D decisions tied to market size and innovation incentives. The model's originality lies in its comprehensive integration, combining various methodologies into a general equilibrium model, a feature often absent in existing long-term growth research. Additionally, the study presents a dynamic simulation aligning with empirical trends in long-run growth, demonstrating the model's ability to replicate the dynamics of long-run growth in the U.S. economy. Notably, the model delivers long-run estimates for parameters influencing R&D share in GDP, providing valuable insights for optimizing R&D expenditures to enhance economic growth and welfare.

The first part of this research where we conduct a direct test of the hypothesis that there exists a growth slowdown in developed economies yields the following findings: the high-income countries indeed undergo a growth slowdown in the long term. Importantly, this conclusion remains robust across various model specifications, including different criteria for country classification (D1, D2, or D3) and the choice of estimation method (fixed effects versus random effects).

The second part of the research, on the other hand, provides the following findings: considering the U.S. economy from 1950s until the rest of the 21st century, the long-term growth rate mainly depends on three things: human capital accumulation, productivity and demography in the long-term. These findings are consistent with Solow’s famous contribution to the growth literature, suggesting that capital’s influence is relatively limited in the long-run.

CHAPTER 1

ON THE GROWTH SLOWDOWN IN DEVELOPED ECONOMIES

In the aftermath of the 2008 Global Financial Crisis, the long-run growth patterns in developed economies have been under closer academic scrutiny because of dismal prospects of growth slowdown and secular stagnation. For instance, in his 2017 paper Jones asks "*how it is possible for some advanced economies to be substantially less productive today than they were in the year 2000?*".

The ongoing debate about whether this decline in growth rates started prior to the Global Financial Crisis or not, extends to the factors contributing to this slowdown, particularly to the pace of innovation.

This study empirically examines the structure of long-term growth patterns across a broad sample of countries to directly evaluate the degree to which long-term economic growth has diminished in developed economies. Our findings show that, in high-income economies, there are clear downward trends in the long-term growth rates of GDP per capita, GDP per worker, and TFP over the period spanning from 1970 to 2019. Moreover, the statistical significance of growth slowdown is not sensitive to (i) country classification criteria (*D1*: high-income countries classified by the World Bank, *D2*: high-income countries classified by United Nations, and *D3*: OECD member countries), and (ii) the estimation method (fixed effects versus random effects).

1.1. INTRODUCTION

The long-run growth rates of real GDP per capita widely differ across countries. In the postwar era, various groups of countries have exhibited dramatic changes in long-run growth rates. For instance, some countries such as Taiwan and South Korea, i.e., growth miracles, have achieved fastest growth in the postwar era with average growth rates exceeding 6% or 7% per annum. Conversely, there also have been growth disaster economies such as Congo or Chad with long-run growth rates have hovered near or even fallen below zero.

As for the present, numerous industrialized and developed economies, especially the early industrialized countries, have modest and positive long-run growth rates. In countries such as the U.S. and the U.K., for instance, real GDP per capita grows at a rate closer to 2% per annum in the very long run.

After the Global Financial Crisis of 2008, the long-run growth patterns in developed economies have been under closer academic scrutiny because of dismal prospects of growth slowdown and secular stagnation. According to Gordon (2015), "*secular stagnation is caused by the lack of innovative technologies, which are the source of the economic growth*". Various scholars have argued that sizable decreases in growth rates observed during the Global Financial Crisis are, actually related with enduring and long-term changes in the drivers of economic growth.

Gordon (2015) emphasizes the importance of slow potential GDP growth by way of its direct and indirect effects on the standard of living and slower productivity growth resulting from reduced net investment. Summers (2014) suggests that the course of advanced economies over the last two decades is quite worrisome considering sustainability of economic growth with financial stability. Plosser (2014) points out that this period of low growth accompanied with decreased productivity may last for a long time.

Motivated by the current debates surrounding secular stagnation and growth slowdown, this study aims to examine the structure of long-run growth patterns for a large set of countries through empirical methods. More specifically, our purpose is to directly assess whether and to what extent long-run growth slowed down in developed economies. The purpose of the empirical analysis is twofold: First, it tests whether the growth slowdown in developed economies is a statistically significant feature of reality relative to the growth dynamics observed in developing and least developed economies. To that end, we estimate various regression models with panel data and isolate the effect of being categorized as a developed economy on the long-run growth rate. Second, the study investigates the patterns of growth slowdown in TFP to check whether TFP slowdowns contribute to any slowdown pattern observed in the growth rate of GDP per capita.

The main sample of our analysis spans from 1970 to 2019, during which we define 5-year growth rates to disregard the role of annual fluctuations in both GDP and TFP. Our dataset comprises 80 countries, specifically chosen for their superior data availability regarding TFP. Given that we examine 5-year growth rates in different specifications, our panel of long-term growth rates encompasses a substantial number of countries as cross-sectional units but a limited number of time points. Our comprehensive dataset was acquired from the Penn World Tables, as made available by Feenstra et al. (2015).

Our main result can be summarized as follows: In high-income economies, the long-run growth rates of GDP per capita, GDP per worker and TFP exhibit clear declining trends over the period 1970-2019. This key outcome is derived from the dataset comprising 5-year intervals and is based on the classification of high-income countries according to the World Bank *(D1)*. To establish our benchmark results, we rely on the estimates derived from the random effects estimation method.

Furthermore, we provide supplementary econometric findings to illustrate the robustness of our main result. It appears that the statistical significance of the growth slowdown remains consistent regardless of (i) the criteria used for classifying countries (*D1*: high-income countries based on the World Bank, *D2*: high-income countries according to the United Nations, and *D3*: OECD member countries) and (ii) the chosen estimation method (fixed effects versus random effects). More specifically, under all of these different specifications, our estimates consistently indicate significant growth slowdowns in developed or high-income economies.

The remainder of the chapter is organized as follows. Section 2 provides an overview of the related literature. Section 3 outlines the methodology, Section 4 elaborates on the data employed. Section 5 summarizes the primary findings. Section 6 demonstrates the robustness of the main results. Finally, in Section 7, we draw conclusions and present some closing remarks.

1.2. A REVIEW OF THE RELATED LITERATURE

1.2.1. Slowdowns: Before or After the Global Financial Crisis

The 2008 Global Financial Crisis had a negative impact on the productive capacity of economies and countries have lost 8.4% of their potential output on average, as highlighted by Ball (2014). According to Plosser (2014), such a regime of low-growth and diminished productivity may continue in the future. Although the mechanisms through which the potential output shrinks following a recession remain largely unexplored and are not fully understood, the slowdown in the growth of TFP is shown to be a pertinent channel in various studies, including those by Reifschneider et al. (2015) and Hall (2015).

On the contrary, an opposing perspective asserts that the growth slowdown started prior to the Global Financial Crisis. Several studies trace the origins of the growth slowdown back to the early and mid-2000s (e.g., Baily and Lawrence, 2001). Byrne et al. (2016) present econometric evidence indicating the existence of a worldwide slowdown in economic growth that commenced in 2004. Similarly, Lusine and Cardarelli (2015) show that the growth episodes that featured an average TFP growth rate of about 1¾ percent per annum during 1996–2004 were followed by a slowdown episode. Furthermore, their findings demonstrate that the slowdown in TFP growth is not related to the IT revolution of 1990s since it is prevailing in many sectors and not restricted solely to IT-intensive or IT-producing ones.

1.2.2. Growth Slowdown or Secular Stagnation

Some research investigating into the long-run patterns of growth slowdown focus on the experiences of developed or high income economies within the context of secular stagnation. Following the repercussions of the Great Depression, Hansen (1939) contended that the US economy entered an episode of secular stagnation mainly because of diminished technological and demographic prospects. After the Global Financial Crisis, Summers (2014) revived and expanded upon Hansen's (1939) classic thesis by underlining the low levels of private investment spending observed along with excess savings. Hence, in addition to persisting obstacles in terms of technological and demographic dynamism, the US and other developed economies also confront the risk of demand-driven secular stagnation. If such a regime persists without public debt or government investment that would close the gap in aggregate demand, then the economy stays in a regime of consistently low marginal productivity of physical capital and actual growth rates below their long-run potential (Blanchard, 2019).

For the studies that tacitly acknowledge the relevance of secular stagnation in high income economies, the main controversy revolves around the question of whether the 21st century stagnation patterns are associated with demand deficiency or not. Storm (2017) argues that the most reasonable explanation for the slowdown in TFP growth is to examine the decrease of labor productivity growth, since there is no such thing as a Solow residual. In his paper, he both theoretically and empirically tests the factors contributing to the decline in labor productivity which is taken to reflect inadequate demand as the trigger of secular stagnation. His demand-side diagnosis aligns closely with the viewpoint presented by Summers (2015) as he identifies sluggish demand to be the reason behind secular stagnation. Hence, interpreting TFP growth (or slowdown) from a supply-side perspective lacks coherence.

1.2.3. Technological Progress versus Technological Stagnation

Many argue that the fall in potential output levels would impede economic activity that feeds back the technological progress (Haltmaier, 2013; Reifschneider et al., 2015).

Regarding the endogenous dynamics of TFP growth within advanced and innovative high-income economies, Gordon (2012) gathers his observations concerning the pace of growth spanning the last 250 years, which witnessed three industrial revolutions under six headwinds. He argues in favor of the so-called low-hanging fruit (or fishing out) effect. According to this thesis, innovative potential narrows down or closes in time as the most useful innovative ideas are becoming harder to find. In simpler terms, we have already harvested the easily attainable innovations since the Industrial Revolution, and the world is heading towards a situation where groundbreaking inventions may no longer be feasible (Gordon, 2012; Fernald and Jones, 2014; Aeppel, 2014). The obvious implication of this dismal scenario is that future technological progress and its impact on economic growth would be extremely limited.

While Jones (2017) accepts the fact that his research findings align with those of Gordon (2016), so that the ideas are getting harder and harder to find, and that the notion of diminishing innovation challenges is becoming increasingly prevalent, he also states that this has always been the case and there is nothing negating or disproving this in his analysis. Consequently, this idea could not be the reason behind the decrease in the productivity growth rate in the developed world.

In their more extensive and detailed analysis, Gordon and Sayed (2019) emphasize the phenomenon of catching-up effect between the U.S. and the EU, substantiating not only the growth slowdowns but also the decreases in productivity growth rates. They illustrate that just by starting at a productivity level at 50 percent of that in the U.S. in 1950, the EU coped to catch up with the U.S. by reaching 81 percent of the U.S. level by 1972. Furthermore, they intriguingly demonstrate that the EU productivity growth from 1972 to 1995 mirrored that of the U.S. from 1950 to 1972, not only in terms of identical growth rates but also through highly correlated productivity growth rates across various industries between the EU and the U.S. during the stated periods.

In contrast to Gordon (2012), the economic historian Mokyr (2018) suggests that the rate of innovation is getting faster and faster, and there is no strong evidence proving that a slowdown in innovation existed over the past decades. Moreover, he emphasizes that TFP can increase regardless of technological development and technological development can occur without TFP growth. Similarly, based on their suggestions for businesses to engage in innovative adjustments to their models and institutional frameworks in order to profit from the revolution in Information and Communication Technology (ICT), Brynjolfsson and McAfee (2014) argue that the TFP slowdown is temporary and the ICT revolution will blossom forth in the coming decades.

In this research, after examining the contributions and insights provided by numerous theoretical and structural studies regarding the argument of slower recovery, we attempt to simply demonstrate whether this slowdown in long-run growth rates can be empirically established.

1.3. METHODOLOGY

Our purpose is to develop a direct assessment method to determine the long-run growth slowdown in developed (or high-income) economies. This research objective requires a particular research design: (i) incorporating a diverse range of countries across all economic development stages to discern variations between developed (or high-income) economies and developing ones, (ii) employing five-year growth rates of relevant outcome variables so that the effects of annual fluctuations on income levels are sterilized, and (iii) employing a static panel regression to identify country and time effects (whether fixed or random) because various country-dependent and time-invariant factors, such as geography, partially determine economy's long-run growth rate.

It is crucial to highlight that quarterly data is unsuitable for analyzing long-term growth rates of real GDP per capita due to its high volatility at this frequency. Similar to the approach in studies such as Blomström (1996), Reed (2008), Barro (2015), and El Khanji and Hudson (2016), we establish long-term identification by using 5-year growth rates, and therefore construct a broad yet short and robust panel. With a large number N of countries, both random and fixed effects models can be utilized without any significant inference issues even when the period T is fixed.

Let $i \in \{1,2,\dots,I\}$ and $t \in \{1,2,\dots,T\}$ index countries and periods, respectively. The set of countries includes both high-income (or more developed) and low-income (or less developed) countries. As mentioned earlier, we have chosen 5-year intervals for our analysis, as our primary focus is on long-term growth rates, and we wish to disregard the effects of annual fluctuations. In line with Jones (2002), a linear regression model would be adequate to enable us to reach reasonable and comparable estimates that hold some theoretical relevance.

Consider, then, the linear regression model

$$G_{i,t} = \alpha_i + \beta t + \gamma D_i + \theta t D_i + \varepsilon_{i,t}$$

where $G_{i,t}$ is the long-run growth rate of a variable of interest (e.g., GDP per capita). In this model, $D_i \in \{0,1\}$ is a dummy variable which equals one if country i is among high-income economies. The term α_i stands for the country effect, and $\varepsilon_{i,t}$ is an idiosyncratic error term. The model parameters (β, γ, θ) are assumed to be fixed real numbers.

In this regression model, the interaction term $\theta t D_i$ allows us to obtain a direct estimate of growth slowdown for high-income economies. Specifically, we have

$$\frac{\partial G_{i,t}}{\partial t} = \beta + \theta D_i$$

Hence, for any given value of β, the term $\beta + \theta$ yields an estimate of whether high-income economies experience growth slowdown: The statistical inference supporting the case of $\beta + \theta < 0$ implies that the null hypothesis of growth slowdown in developed economies cannot be rejected.

In addition to the point estimation of $\beta + \theta$, we run a one-sided interval estimation of a linear combination of estimators where the null hypothesis is $\beta + \theta < 0$, therefore the alternative hypothesis is $\beta + \theta \geq 0$. The results are explained in the next section.

The advantage of using a regression model such as this one is that it enables us to isolate various effects on long-run growth: The term βt isolates the global growth momentum that affects all countries for any t. The term $\alpha_i + \gamma D_i$ isolates time-invariant country effects such as geography and culture that causally determine long-run growth rate in country i. Then, the remaining term $\theta t D_i$ isolates the temporal growth slowdown effect observed in the high-income economy i.

Let us recall that conducting stationarity tests are of no relevance here since the time dimension T is very small. Even if we run stationarity tests, they would not yield meaningful results. Besides, our outcome variables are growth rates and they are inherently stationary.

1.4. DATA

This study uses a dataset covering 80 countries over the 1970-2019 period. We compute average growth rates for 5-year intervals that begin from 1974 and end in 2017.

Table 1. *Summary Statistics*

Variables	N	Mean	Std. Dev.	Min	Max
Country	720	42.925	23.745	1	83
Time	720	5	2.584	1	9
Gpc	720	0.138	0.21	-0.859	1.921
Gpw	720	0.112	0.199	-0.861	1.844
Tfp	720	0.151	0.115	-0.394	1.273

Source: (Stata)

The econometric analysis of the model uses the long-run growth rates of GDP per capita, GDP per worker, and *TFP*. The TFP data for all countries is driven from the Penn World Table version 10. These growth rates exhibit variation across countries and time periods. We group the countries as high income and non-high income countries in the analysis and they are represented by the term D_i (where $D_i = 1$ means a high income economy and *0* otherwise).

1.5. MAIN RESULTS

We conduct estimations of the regression model described earlier under different specifications: We examine the growth slowdown effects on multiple outcome variables, such as GDP per capita and TFP. Additionally, we alter country classifications across different estimations. Finally, we report both fixed effects and random effects estimates of the model.

This section provides primary findings concerning the 5-year growth rates of GPC, GPW, and TFP. For the categorization of countries into high-income versus low-income groups, we rely on the classification criteria established by the World Bank (*D1*). Results for alternative specifications are detailed in the following section.

Table 2. *Main Results*

GPC for 5 Years		GPW for 5 Years		TFP for 5 Years	
Parameters	RE	Variables	RE	Variables	RE
γ	0.145***	γ	0.131***	γ	0.080***
	(0.035)		(0.033)		(0.019)
β	0.014***	β	0.013***	β	0.012***
	(0.004)		(0.004)		(0.002)
θ	-0.025***	θ	-0.023***	θ	-0.014***
	(0.006)		(0.006)		(0.003)
Constant	0.059**	Constant	0.039*	Constant	-0.051***
	(0.023)		(0.022)		(0.013)
# of Observations	320	# of Observations	320	# of Observations	320
# of Countries	80	# of Countries	80	# of Countries	80

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results of the random effects (RE) estimation for our simple linear regression model is presented in Table 2. As previously mentioned, the country specification corresponds to the group of high-income economies according to the World Bank's classification (D1), which comprises 36 developed economies (refer to Appendix A for details).

The parameter γ isolates the long-run growth effect of being a high-income economy. This effect is independent of time. The parameter estimates take positive values and are statistically significant for all variables. Moreover, we can state that the effect of being among high income countries is still important; in other words, when *D1* equals to *1*, annualized growth effect of being a developed country enhances by 1% GPC, by again 1% GPW and by 0.8% TFP.

The next parameter that can be observed in Table 2 is our time-trend parameter β, and, the values presented in the table show that there exists a positive and statistically significant growth effect for all the countries with respect to time. Consequently, on average, there is no growth slowdown globally. This observation aligns with the fact that a majority of countries in our sample are developing or low-income countries.

Finally, the last parameter displayed in Table 2 is θ, and it is the parameter that allows us to assess the growth slowdown effect for high-income economies decoupled from time-trend and country effects. Hence, under our null hypothesis of growth slowdown in developed economies, we expect to have $\beta + \theta$ being negative.

The main result that can be inferred from Table 2 is that, for each variable and for any given value of β, the term $\beta + \theta$ takes negative values; -0.011 points for GDP per capita, -0.01 points for GDP per worker and -0.002 points for total factor productivity, and the results are statistically significant. Therefore, based on these findings, we may infer that there exists a slowdown of the long-run growth rates of relevant variables in high-income countries.

Notice that there exists a slight variation in the slowdown findings obtained between GDP per worker and GDP per capita. This discrepancy clearly originates from the dependent population such as the children and the retired. Given that this effect is not negligible, one could argue that the pace of demographic transition is important for all high-income economies, eventually leading to more pronounced slowdown effects in GDP per capita.

In terms of the slowdown in TFP growth, we observe that the impact of being among high-income economies is less pronounced compared to GDP per capita and GDP per worker. To be precise, the overall effect with respect to time, denoted as $\beta + \theta$, indicates a 0.002 percentage points decrease in the 5-year TFP growth rate. Therefore, our findings suggest that, on average, there is a modest growth slowdown in TFP measures in the Penn World Tables.

The hypothesis test results for the interval estimation of $\beta + \theta$ reveal that, in the case of GPC and GPW, our interval estimates statistically significantly imply $\beta + \theta < 0$ under all country classification criteria and estimation methods. However, for TFP, we are unable to draw an inference based on interval estimates since the lower bound and upper bound of the confidence interval have differing signs. Nonetheless, our point estimates, remain statistically significant for the *D1*, *D2* and *D3* classifications, as well as for both RE and FE estimations.

1.6. ROBUSTNESS

The results from the preceding section hold valid with slight differences across different model specifications. First, the FE estimation does not modify the main result (the sign and significance of $\beta + \theta$) as it solely removes the rich-country effect from the model. More broadly, we acquire results that support the existence of growth slowdowns in high-income countries across all three variables (GPC, GPW and TFP) of interest. The qualitative nature of our results remains consistent even when we change the country classification criteria.

Table 3. *Fixed Effect Regression vs Random Effect Regression for GPC 5 Years*

Parameters	FE1	FE2	FE3	RE1	RE2	RE3
β	0.014***	0.009**	0.008**	0.014***	0.009**	0.008**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
θ1	-0.025***			-0.025***		
	(0.006)			(0.006)		
θ2		-0.020***			-0.020***	
		(0.006)			(0.006)	
θ3			-0.015**			-0.015**
			(0.006)			(0.006)
γ1				0.145***		
				(0.035)		
γ2					0.095**	
					(0.037)	
γ3						0.058
						(0.036)
Constant	0.125***	0.125***	0.125***	0.059**	0.094***	0.103***
	(0.017)	(0.017)	(0.017)	(0.023)	(0.021)	(0.022)
R-squared	0.028	0.017	0.010			
# of Observations	720	720	720	720	720	720
# of Countries	80	80	80	80	80	80

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Indeed, the estimates for the linear combination $\beta + \theta$ of parameters remain unchanged between FE and RE estimations. Consequently, even if we do not separately identify the sole rich-country effect γ in the FE estimations, we still arrive at identical estimates of the growth slowdown effect.

Nonetheless, given that both β and θ vary under different country classification criteria, it becomes essential to compare and contrast the magnitude changes in estimated $\beta + \theta$ values as we change the country classification criteria. For GDP per capita (GPC), we have an estimated total effect of -0.011 for *D1*, -0.011 for *D2*, and -0.007 for *D3* classifications. Similar figures within a relatively narrow range are also estimated for GDP per worker (GPW) and TFP as seen from Tables 4 and 5.

Table 4. *Fixed Effect Regression vs Random Effect Regression for GPW 5 Years*

Parameters	FE1	FE2	FE3	RE1	RE2	RE3
β	0.013***	0.009***	0.008**	0.013***	0.009***	0.008**
	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
θ1	-0.0229***			-0.023***		
	(0.006)			(0.006)		
θ2		-0.019***			-0.019***	
		(0.006)			(0.006)	
θ3			-0.014**			-0.014**
			(0.006)			(0.006)
γ1				0.131***		
				(0.033)		
γ2					0.099***	
					(0.035)	
γ3						0.060*
						(0.034)
Constant	0.098***	0.098***	0.098***	0.039*	0.066***	0.076***
	(0.016)	(0.016)	(0.016)	(0.022)	(0.020)	(0.021)
R-squared	0.027	0.017	0.011			
# of Observations	720	720	720	720	720	720
# of Countries	80	80	80	80	80	80

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Recall that the benchmark estimates with 5-year data and the World Bank classification *(D1)* suggest relatively modest slowdown effects on TFP, amounting to an average reduction of approximately 0.002 percentage points in the 5-year growth rate. When considering the United Nations and OECD classifications (*D2* and *D3*, respectively), the effects are similar; with 0.002 and 0.001 percentage point reductions, respectively.

Yet we fail to reject that there exists a growth slowdown in high-income economies. Here, the individual parameter magnitudes naturally change, and the sample size is also larger in the time dimension. However, estimated $\beta + \theta$ values remain negative for all specifications. In each scenario, we estimate the critical values for the null hypothesis of $\beta + \theta < 0$ and confirm that it cannot be rejected at 5% level of significance.

Table 5. *Fixed Effect Regression vs Random Effect Regression for TFP 5 Years*

Parameters	FE1	FE2	FE3	RE1	RE2	RE3
β	0.012***	0.010***	0.009***	0.012***	0.010***	0.009***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
θ1	-0.014***			-0.014***		
	(0.003)			(0.003)		
θ2		-0.012***			-0.012***	
		(0.003)			(0.003)	
θ3			-0.010***			-0.010***
			(0.003)			(0.003)
γ1				0.080***		
				(0.019)		
γ2					0.071***	
					(0.020)	
γ3						0.048**
						(0.019)
Constant	-0.015	-0.015	-0.015	-0.051***	-0.038***	-0.032***
	(0.009)	(0.009)	(0.009)	(0.013)	(0.011)	(0.0120)
R-squared	0.048	0.039	0.033			
# of Observations	720	720	720	720	720	720
# of Countries	80	80	80	80	80	80

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The key takeaway from the tables presented above is as follows: Irrespective of the country classification criteria (World Bank, United Nations, or OECD) and the estimation method (fixed effects or random effects), the parameter estimates suggest that the null hypothesis of a growth slowdown in high-income economies cannot be rejected at 5% significance level.

1.7. CONCLUSION

In this study, we undertake a direct test of the hypothesis that there exists a growth slowdown in developed economies. We use a panel dataset spanning 80 countries over the 1970-2019 period, we conduct estimations using both fixed and random effects regressions. Based on our findings, we can conclude that high-income countries do, in fact, experience a growth slowdown in the long term. In addition, this conclusion is not sensitive to various modelling choices, such as different definitions of the country classification criteria (D1, D2, or D3) and the estimation method (fixed effects vs. random effects).

The primary limitation of this research is that the estimated empirical models do not build upon microeconomic foundations that can elucidate the precise reasons and mechanisms behind the long-run growth slowdown in high-income economies in recent decades. Therefore, the methodology used is not entirely appropriate for formulating policy proposals, because it does not identify the microeconomic mechanisms responsible for the growth slowdown. Formulating such policy recommendations requires constructing an endogenous growth model calibrated with actual long-run data.

The growth literature provides seminal theoretical and empirical works on concepts such as secular stagnation, productivity slowdown, and/or technological progress. To attain a comprehensive understanding of these structural mechanisms in a truly satisfactory manner, it is essential to construct endogenous growth models and validate them empirically using real-world data.

However, endogenous growth models may encounter challenges when it comes to identifying the deep causal factors of long-run growth, including geography, culture, and institutions. These models should possess a level of complexity that clarifies how geography, culture, and institutions affect human capital accumulation, innovation, investment, and trade. Developing such rich models becomes imperative to assess the cause-and-effect relations around the dynamics of the growth slowdown while exploring the endogeneity of rich country effects.

CHAPTER 2

LONG-RUN ECONOMIC GROWTH IN THE UNITED STATES

According to IMF's latest World Economic Outlook report, dated October 2023, the baseline projection anticipates a decrease in worldwide economic growth, from 3.5% in 2022 to 3.0% in 2023 and further to 2.9% in 2024. This forecasted growth rate is notably lower than the historical average (from 2000 to 2019) of 3.8%. In particular, advanced economies are predicted to experience a decline in growth from 2.6% in 2022 to 1.5% in 2023 and 1.4% in 2024. Around 90 percent of advanced economies are expected to experience a lower growth both in terms of GDP and GDP per capita growth in 2023. The United States are forecasted to grow at 2.1% in 2023 and 1.5% in 2024.

2.1. INTRODUCTION

Global growth projections for the next five years, as per the World Economic Outlook, have decreased from a high of 4.9 percent in the April 2008 report, which focused on growth in 2013, to 3.0 percent in the April 2023 report, which is centered on growth in 2028. These are the most conservative projections since 1990. Additionally, forecasts from other institutions, as reported by Consensus Economics, have undergone similar reductions. The same applies to medium-term growth prospects.

We introduce an analytically tractable growth model that broadens its scope beyond the endogeneity of fertility, demography and accumulation of human capital. This model explicitly incorporates firm dynamics and encompasses both the horizontal and vertical innovation processes and scale invariant Schumpeterian approach as in Young (1998) and Peretto (1998). In particular, the model allows for inter-generational quantity and quality decisions of adults considering their children, i.e., the Q-Q trade-off as in de la Croix and Gosseries (2012), which captures fertility and human capital issues that have preoccupied the growth literature since Malthus (1798), on the one hand, there are endogenous productivity characteristics influencing R&D choices derived from entrepreneurial decisions influenced by market size and incentives for innovation. This aligns with contemporary discourse in the literature regarding idea-driven growth models, exemplified by works of Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992). On the other hand, there are challenges associated with the diminishing dynamism in business, adding another dimension to the discussion.

To the best of our knowledge, the integration of this combined methodology into a general equilibrium model has been scarce or entirely absent in the existing body of research on long-term growth. In addition, we provide a dynamic simulation of the model, contributing significantly to harmonizing with empirical trends in long-term growth. This alignment encompasses the dynamics of state variables, human capital per worker, adult population, and technology, grounded in a thorough evaluation of the long-term growth data observed in historical records. The results demonstrate the model's capacity to match a substantial portion of the non-targeted data moments, providing a rough replication of the dynamics characterizing long-term growth in the U.S. economy.

Most importantly, the model provides estimates of the parameters affecting R&D share in GDP, which in turn helps improve the growth and welfare of the economy. Thus, the model delivers new insights into how to render R&D expenditures optimal.

The remainder of this chapter is organized as follows: Section 1 introduces the literature review; Section 2 presents the model economy in detail with the equilibria dynamics; Section 3 provides the benchmark calibration and baseline scenario; Section 4 offers counterfactual experiments; and finally, Section 5 concludes.

2.2. RELATED LITERATURE

In the extensive body of growth literature, it is widely acknowledged that there is no single straightforward explanation for the phenomenon of growth slowdown, yet the slowdown itself remains irrefutable. No single causal factor or change in the underlying fundamentals has accounted for the global economic outlook, particularly in advanced economies, since the first decade of the 2000s.

In the context of advanced economies, the decrease in output per capita growth observed in recent forecasts compared to those from the early 2000s, can be primarily ascribed to a significant reduction in TFP growth. This is accompanied with the decrease in labor force participation and the deceleration in capital deepening (WEO, October 2023). Numerous quantitative and qualitative works solidify this view. According to Acemoglu, Autor, and Patterson (2023), TFP growth slowdown is mainly explained by technological progress disparities among sectors. Bloom et al. (2020), on the other hand, relate this slowdown to innovation exhibiting diminishing returns, and finally, Baqaee and Farhi (2020) emphasize the role of impediments to efficient allocations.

According to Bergeaud et al. (2016), from 1920 to 1970, advanced economies worldwide went through a period of robust and consistent Total Factor Productivity (TFP) growth. However, since 1970, there has been a notable deceleration in TFP growth. In the United States, TFP growth experienced a temporary increase in the late 1990s, but it decreased again after 2004. In the absence of the productivity growth slowdown that occurred after 2004, the United States' GDP in 2015 would have been $3 trillion higher, equivalent to 17% of the actual US GDP in 2015. This translates to an extra $9,300 per individual or $24,100 per household in the U.S., as reported by Syverson (2017).

The early literature on the concept of ideas places technological progress as the focal point of economic growth. Models presented by Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992) typically suggest that, all else being equal, an increase in the population size generates higher per capita income growth rate. While this consequence aligns with historical empirical data for most of the past as pointed out by Kremer (1993), the empirical data from the twentieth century in advanced economies contradict with this fact (Jones, 1995).

Jones (2022) shows that nearly all developed economies experienced a decline in the total fertility rate since 1950s. Moreover, he demonstrates that while the semi endogenous growth (SEG) theory posits that long-term growth is fundamentally attributable to population growth, historical data over the last 75 years contradicts this assertion. In reality, population growth has only contributed approximately 20 percent to the overall economic growth of the United States since 1950. The predominant drivers of growth, constituting more than 80 percent, include increasing educational attainment, diminishing misallocation, and heightened (global) research intensity. This finding aligns with the following argument; despite a rapid increase in research effort, the growth rate of productivity stagnates or even declines, this is the “ideas getting harder” concept à la Bloom et al. (2020).

As a result, numerous attempts have been made within the academic literature to revise the idea-based model to rectify this unexpected scale effect prediction.

Vollrath (2020), when observing the United States, identifies that the primary factor contributing to the deceleration in GDP growth is the reduction in the growth of human capital. These findings do not inherently conflict with the outcomes observed in productivity-related studies, as Vollrath's (2020) conclusions are largely attributable to the decrease in labor force participation, rather than a decline in human capital per worker. Ramey (2020) suggests that the phenomenon of population aging which may manifest as a deceleration in labor productivity growth, is linked to the anticipated decrease in the impact of labor force participation observed across developed economies. In contrast, Abiad et al. (2009) argue that, considering the decomposable nature of per capita growth into different components such as changes in capital per worker, labor force participation, employment rate, and total factor productivity (TFP), roughly 75% of the decline in global growth prospects, amounting to approximately 1.4 percentage points over the past 15 years, originates from diminished projections in per capita economic growth rather than merely a deceleration in population growth.

Abiad et al. (2009), on the contrary, state that, given the fact that per capita growth can be decomposed into various components, including changes in capital per worker, labor force participation, employment rate, and total factor productivity (TFP), approximately three-quarters of the reduction in global growth prospects equating to around 1.4% over the past 15 years, stem from diminished projections in per capita economic growth rather than a mere deceleration in population growth.

Goldin et al., in their 2021 paper, draw attention to a different and relatively important point. As per its definition, a slowdown is assessed concerning a preceding period characterized by more rapid growth. Therefore, one initial hypothesis could be that the prior growth rates were exceptional and might have arisen from an adjustment of productivity levels rather than representing a sustained upsurge in growth rates. Consequently, the ongoing decrease should be analyzed within the broader context of historical trends.

Bergeaud et al. (2016) draw attention to an extended historical timeline across which rapid productivity growth emerged as a comparatively recent phenomenon and that within the 20th century, there exist two notable accelerations, each followed by slowdowns: first, a substantial postwar upswing and a subsequent smaller acceleration circa 2000, often linked with advancements in Information and Communication Technologies (ICTs), and second, which is commonly cited as the catalyst for the slowdown in the U.S.. Given the existing sluggish growth rates in the 1980s, the relatively robust rates of the late 1990s and early 2000s are often characterized as a "productivity renaissance." Consequently, the lower rates observed around 2005 are regarded as a slowdown when compared to the resurgence. On the contrary, in Europe and Japan, higher levels of labor productivity growth were sustained throughout the 1980s. As a result, the slowdown in these regions appears more secular, although it could, in theory, simply characterize the end of convergence to the U.S. frontier.

These views are in line with the propositions of Cervellati et al. (2023). They show that it might be reasonable to anticipate a slowdown in future growth for economies that already completed their demographic transitions. This slowdown may result from the non-recurring nature of what happened during the economic and demographic transition. The mutual interplay among population, human capital, physical capital and technological progress initially triggers an upswing in growth but gradually diminishes over time. Based on common understanding of population growth fading over time, Jones and Romer’s (2010) suggestions are supported as well. These findings also contribute to founding a justification for the limited supporting evidence regarding the significance of human capital in explaining growth disparities by highlighting the fact that human capital primarily matters after the beginning of the transition, since the decrease in fertility rates accelerates education investments (Galor and Weil (2000), Galor (2012)).

Siskova et al. (2023) provide empirical evidence of the impact of decreasing fertility rates on the accumulation of human capital. They investigate the long-term implications of sustained fertility decline in advanced economies over the past five decades. They explore the question of whether the reduction in population growth can be counteracted by an increase in human capital accumulation. Drawing on the concept of the trade-off between the quality and quantity of children, as outlined by Becker (1960), the study highlights the inverse relationship between education and fertility levels. It emphasizes that the education of children contributes to the growth of human capital, ultimately shaping the future workforce as they reach adulthood. They find that the relation between individual human capital with respect to fertility becomes less elastic when examining countries with declining populations. In other words, changes in fertility have a smaller impact on human capital in countries facing population decline compared to countries with different demographic trends. Consequently, for countries undergoing a population slowdown, overcoming the adverse effects of declining fertility rates on human capital would pose a greater challenge.

Additional major implications of demographic shifts can be extrapolated to translate the declining business dynamism, as expounded by Akcigit and Ates (2018, 2021). Their noteworthy empirical and theoretical contributions within the domain of endogenous growth literature integrate enlightening insights derived from a novel new firm framework, developed thanks to micro-data availability. This framework is instrumental in scrutinizing potential origins of the observed decline in business dynamism within the U.S. economy. For instance, Karahan et al. (2016) posit that demographic changes played a central role in the reduction of entrepreneurial activities in the United States. They specifically contend that the deceleration in the expansion of the U.S. workforce following the conclusion of the "baby-boomer" generation resulted in increased wage levels, subsequently contributing to a decrease in the rate of new firm establishments.

An alternative explanation grounded in structural shifts for the decline in the rate of new firm entries is based on Gordon's (2016) analysis in which he states that the economy has depleted the easily attainable innovations, often referred to as "low-hanging fruit" ideas. These ideas are relatively easier to acquire and have extensive applications. Bloom et al. (2017) endorse this perspective, contending that research endeavors have been on the rise, but their efficiency has been decreasing. This issue is likely aggravated by unproductive efforts, as elucidated by Akcigit and Liu (2016).

In a more precise context, Peters and Walsh (2021) employ a comprehensive SEG framework to investigate the consequences of decelerating population growth on firm dynamics and overall economic growth. Their findings indicate that a decrease in population growth leads to diminished rates of market entry, decreased creative destruction, heightened market concentration, increased markups, and a reduction in productivity growth, observations that align with patterns evident in firm-level data.

Comin and Mulani (2007) have presented empirical support for the notion that both firm exit and entry play a crucial role in the growth dynamics. Utilizing a dataset of U.S. firms, they demonstrate that two measures of leadership turnover in the industry have a positive correlation with earlier research and development (R&D) activities. This discovery underscores the existence of creative-destruction aspect of the innovation process. This aspect wouldn't be expected if the primary mechanism through which innovation impacts economic growth were the expansion of product variety. In fact, the product variety theory provides limited insight into how productivity varies among firms within an industry and does not address changes in the productivity ranking over time.

Moreover, it should be noted that the correlation between economic growth and firm turnover highlighted by Fogel et al. (2008) does not find an equivalent in horizontal-innovation theory. Therefore, to conceptualize product obsolescence (or technical obsolescence) within the concept of product development, one needs to quit the horizontal dimension and instead adopt the quality-improving vertical models introduced by Dixit and Stiglitz (1977).

2.3. THE MODEL ECONOMY

Drawing upon Attar's (2019) model, this chapter delves into the determinants of economic growth in U.S. economy spanning from 1950s to the present. The principal catalysts behind the increase in real GDP per capita are growth in productivity, increase in human capital accumulation, and decline in fertility. This study constructs an Overlapping Generations General Equilibrium (OLG-GE) model, incorporating technological progress, human capital accumulation, and fertility as endogenous variables. The model exhibits an eclectic approach by combining diverse theoretical mechanisms to comprehensively elucidate economic growth within a single framework. It is mainly based on the simple multi-sectoral Schumpeterian model as in Aghion and Howitt (2009) and the model of child quality-quantity (Q-Q) tradeoff as constructed by de la Croix and Gosseries (2012). The Schumpeterian characteristic is important because it not only offers a framework covering key microeconomic factors like incentives, policies, and organizations influencing macroeconomic growth but also provides insight into the overall advantages of innovation. These benefits depend on factors such as the level of competition, openness to trade, education levels, democracy, and other relevant characteristics. These factors may vary among countries and sectors, changing at different stages of development over time.

In addition, it incorporates both the horizontal (product diversification) and vertical (quality-improving product innovation) dimensions of innovation, as in the second-generation Schumpeterian (2GS) models. Incentivized by monopoly rents, firms invest in technology and endogenously choose the optimal level of research intensity. This process increases productivity and the real GDP per capita. In other words, innovations resulting from entrepreneurial investments generate economic growth.

Adult individuals face the child Q-Q trade-off, as in Becker (1960), on the side of preferences. This concept is important because it directly influences the long-term determinants of human capital accumulation through fertility and education investment decisions. As Becker states, quality emerges as a plausible alternative to quantity, whereby families endowed with an abundance of offspring might allocate comparatively fewer resources per child. However, the quality of each child, represented by human capital, and the quantity of children, reflected in fertility rates, both contribute to the increase in adult individual's lifetime utility. Moreover, over the course of economic growth, fertility rate decreases while human capital per child increases.

The model economy has a unique decentralized equilibrium. This equilibrium converges to a growth steady-state where the level of population has a fixed-level that represents the carrying capacity of the economy.

The steady state fulfills two long-term feasibility conditions: first, the growth of population is limited as fertility adjusts endogenously to the cost of reproduction contingent upon the land endowment per worker. In other words, the long-run, population growth rate equals zero, as suggested by Peretto and Valente (2015) in their model of *growth in a finite planet*. Second, the expansion of product variety is also restricted, as thoroughly examined in the Manhattan Metaphor model proposed by Peretto and Connolly (2007), which shows that the number of firms per capita converges to some fixed level as well.

The length of model period is 20 years leading to an aggregate data for the years 1950, 1970, 1990, 2010. In the numerical analysis, one period corresponds to 20 years, and t=1 for instance refers to the 1950-1969 averages. Since the majority of the model’s inputs are determined through analytical or numerical methods, they are carefully calibrated using a multi-stage quantitative algorithm that is similar to the Simulated Method of Moments (SMM) approach. This calibration process ensures that the model aligns with the specific data values.

We conduct the calibration of the model over a span of four periods (equivalent to generations) to analyze the breakdown of growth into the components of productivity growth, human capital accumulation, and demographic change. Subsequently, we simulate the model for the periods covering 2030, 2050, 2070, and 2090, incorporating medium projections until 2100 for population, sourced from the World Population Prospects database.

Next, we outline in detail the model economy's following aspects: the environment, including demographic composition, individual preferences, endowments, and technologies available in (i) the economy, (ii) decision problems of households and firms, (iii) market and ownership structures, and market-clearing conditions leading to the unique static general equilibrium (SGE) of the model; and, finally,(iv) the dynamic general equilibrium (DGE) collected from (SGE)s of the model and the steady state.

2.3.1. The Model Environment

2.3.1.1. Households

The model consists of a sequence of discrete time periods indexed by $t = 0,1,2,\ldots$. At the beginning of each time period, two-period-lived consumers are born, they are children of the adults born in the previous period. To simplify the analysis, we introduce the following assumptions frequently encountered in the literature: fertility is common across the adult population, reproduction is asexual, and the population and fertility variables are real numbers. The evolution of the adult population is endogenous since fertility is endogenous and it progresses as follows

$$N_{t+1} = n_t N_t. \tag{1}$$

The adult population's endowments are a fixed unit of time that can be divided into leisure, child-rearing, and labor supply, as well as a unit of human capital stock obtained from the educational investment decision made by the parent in the previous period.

Households are homogeneous, and the utility function for the representative adult consumer in period t is given by

$$u_t = u(c_t, z_t, n_t h_{t+1}) = \ln(c_t) + \lambda \ln(z_t) + \phi \ln(n_t h_{t+1}) \tag{2}$$

where $c_t \geq 0$ denotes the consumption of the unique all-purpose good, $z_t \in [0,1]$ is the leisure time, $n_t \geq 0$ stands for the number of children and finally h_{t+1} is the children's human capital stock that contributes to adult's utility. λ and ϕ are fixed preference parameters representing the taste of leisure and altruism factors respectively, and are greater than zero. There is no dynastic altruism; therefore, children's utility does not affect the parents' decisions. The use of logarithmic utility ensures that leisure does not exhibit a clear trend despite increasing wages, which can occur only when the elasticity of substitution between leisure and consumption approaches unity, as outlined by Prescott (1986).

The acquisition of future human capital stock, h_{t+1}, consists on education investments e_t, in period t. Hence the production function of human capital is as follows

$$h_{t+1} = \tau_t e_t^{\eta} h_t^{\nu} \tag{3}$$

where $\tau_t > 0$, the productivity of education technology, changes over time but remains large enough to imply that the growth rate of human capital accumulation, *Gh* > 1 and $\eta, \nu \in (0,1)$ are fixed structural parameters for human capital elasticity with respect to education spending, and transmission of ability from one generation to the next, respectively. The last parameter, ν, explains part of the human capital stock formation that does not come through education. Additionally, we impose the condition $\eta + \nu < 1$ to ensure the existence of the BGP.

The adoption of the exponential formulation is driven by empirical observations, notably Mincer et al. (1974), who identified that each additional year of schooling is associated with a proportional increase in wages[1]. Moreover, with the alternative interpretation of η as the elasticity of earnings with respect to schooling and by replacing the expression

[1] Bils and Klenow (2000) propose that this characteristic should be incorporated in models with human capital accumulation.

h_{t+1} from (1.3) into the utility function in (1.2), we will see η affecting the relative weight of child quality.

The remaining input needed to raise children is time and the unit of time required for one child is given by $\kappa_t \equiv (1/\zeta)(N_t/\Lambda)^{\omega}$ (de la Croix and Gosseries, 2012) with $\zeta > 0$ and $\omega \in (0,1)$. Note that the cost associated with child-rearing is time-dependent, meaning that it increases according to population size. This assumption captures the patterns of demographic transition, characterized by a decline in the population growth rate. Moreover, this aligns with the secular increase in the observed costs associated with child rearing, particularly over the past 150 years, which is correlated with the stock of human capital, as elucidated by Desmet and Parente (2012).

The most important feature of child reproduction technology is that it involves land endowment as an input and is decreasing in this term. Thus, when households live in small residences, children's production becomes more expensive, resulting in a decrease in the number of offspring per family. This fact is what ensures the convergence of N_t to a stationary level, and eventually reaches its carrying capacity in the long run.

2.3.1.2. Final Good Producing Firms

The production function in the model is specific, as highlighted by Benassy (1998), and may not always exhibit a positive productivity effect associated with product variety. In other words, the positive impact on productivity of having a more diverse range of products is not guaranteed in this particular case.

The production function is given by

$$Y_t = L_t^{1-\alpha}\left(\frac{1}{M_t^{1-\alpha}}\int_0^{M_t} A_{it}^{1-\alpha} x_{it}^{\alpha}\,\mathrm{di}\right) \tag{4}$$

and it requires L_t units of labor and $\{x_{it}\}_i$ units of intermediate goods that are indexed over the interval [0, M_t]. The measure M_t of intermediate goods depends on the entrepreneurship decisions, and $\alpha \in (0,1)$as usual. The evolution of stock of firms will be discussed below in details.

Here, A_{it} is the productivity parameter corresponding to the use of variety i in period t, and it is affected by R&D activities; therefore, the evolution of A_{it} is determined by R&D technology at $t-1$.

Moreover, each period, the intermediate input is produced by a monopolist, using the all-purpose good as the only input, one for one. Specifically, to produce x_{it} units of intermediate good i, we need to use x_{it} units of Y_t.

We assume full depreciation of intermediate goods from one period to the next, considering $\{x_{it}\}_i$ is a flow variable[2].

As mentioned earlier, the final good Y_t represents the unique input in the production process of intermediate goods x_{it} in each period t. Furthermore, in each period, ψN_t units of new intermediate goods emerge, accompanied by εM_t unit of existing intermediate goods becoming obsolete. This dynamic might be conceptualized as the entrance of new firms and the exit of existing obsolete ones. $\psi \in (0,1)$ is a fixed number denoting the probability of success of inventing a new intermediate good, while $\varepsilon \in (0,1)$ represents the exogenous share of products that disappear in each period, that is, the firm exit rate.

The application of the Law of Large Numbers and the assumption of independence of this Bernoulli event among the adult population establish the law of motion of M_t, in other words, the horizontal innovation equation can simply be written as the following difference equation

[2] This variable can be considered the counterpart of physical capital in the model. Unlike standard models, these machines are reproduced entirely in each generation, meaning that there is 100% depreciation.

$$M_{t+1} - M_t = \psi N_t - \varepsilon M_t \tag{5}$$

Proposition I: The size of the economy does not affect the impact of intermediate goods on the final product. The scale effect coming from an increase in population is counteracted.

The difference equation (1.5) will have a fixed value $(\psi/\varepsilon)N^*$proportional to population at the steady-state. Then, if the population increases, the quantity of products would increase accordingly which rules out the scale effect. Starting at M_0, the unique solution to the difference equation $M_{t+1} - M_t = \psi N_t - \varepsilon M_t$ is $M_t = (\psi/\varepsilon)N_t + (1-\varepsilon)^t[M_0 - (\psi/\varepsilon)N_t]$ and, since $(1-\varepsilon) \in (0,1)$, it converges to $(\psi/\varepsilon)N^*$ as *t* converges to infinity.

The dynamics of vertical innovation, on the other hand, exhibits a heightened level of complexity. In each period, the entrepreneur is granted the opportunity to innovate. If he succeeds, this innovation results in the creation of an upgraded or improved version of the intermediate product, which increases productivity. In other words, the productivity of the current intermediate good increases to A_{it} from last period's value A_{it-1} with $A_{it} = \gamma A_{it-1}$ where γ is a fixed number greater than one. We will call this new level of productivity A^*_{it} since it is the previously targeted level of productivity achieved after a costly R&D activity conducted by the entrepreneur. Hence, $\gamma - 1$ the share of the increase in productivity arising from each innovation, is in fact the step size of vertical innovation. Conversely, if the entrepreneur fails, no innovation will occur, and the intermediate good will remain the same as that used in period $t-1$.

The success probability of an innovation depends on the total amount R_{it} of final goods allocated to R&D, on the targeted productivity level A^*_{it}, and on human capital stock h_t. This implies

$$\sigma_{it} \equiv \xi_t \left(\frac{R_{it}}{A^*_{it} h_t}\right)^{\rho} \tag{6}$$

with $\rho \in (0{,}1)$. An important characteristic of this model comes from the fact that the innovation probability, denoted as σ, remains the same across all sectors in equilibrium, regardless of the initial level of productivity A_{it-1}. This might be unexpected because one could think that the payoff for a successful innovation should logically be greater in more developed sectors. Nevertheless, the expense associated with innovating at a specific rate proportionally escalates with the targeted productivity level, given that research expenditure concurrently amplifies. This characteristic provides a straightforward description of the aggregate growth rate of the economy.

We can see from the equality (1.6) that, the more R_{it} is consumed, the more likely it is that the entrepreneur will succeed. Moreover, the probability of successful innovation decreases in A_{it}^* because as the technology improves it becomes more difficult and complex to achieve a higher level of productivity and higher skilled workers demand more inputs. So, the crucial factor for success is not the total amount of research expenditure R_{it}, but rather the productivity and human capital-adjusted expenditure $\frac{R_{it}}{A_{it}^* h_t}$.

If for the sake of convenience, we note $r_{it} \equiv R_{it}/(A_{it}^* h_t)$ and $\sigma_{it} \equiv f(r_{it})$, we then have $f(r_{it}) \equiv \xi_t r_{it}^{\rho}$ as an alternative equation to (1.6) where $\rho \in (0{,}1)$ represents the elasticity and $\xi_t > 0$ is the parameter scaling the R&D productivity which is small enough to infer $f(r_{it}) < 1$ for all i and for all t.

2.3.2. Decision Problems and Market and Ownership Structures

2.3.2.1. Households' Problem

The household's utility maximization problem is

$$\underset{c_t, n_t, e_t \geq 0, z_t, \ell_t \in [0,1]}{\text{maximize}} \quad \ln(c_t) + \lambda \ln(z_t) + \phi \ln(n_t h_{t+1})$$

subject to:

$$c_t + e_t n_t \leq w_t \ell_t h_t \qquad \ell_t + z_t + \kappa_t n_t \leq 1 \qquad h_{t+1} = \tau_t e_t^{\eta} h_t^{\nu} \tag{7}$$

Here, the budget constraint of the household is represented by the first inequality and the time constraint by the second. There is perfect competition in labor market where each adult household supplies $\ell_t \leq 1$ units of labor to obtain $w_t > 0$ units of real wage and, skill-augmented labor supply is $\ell_t h_t$.

2.3.2.2. Final Good Producing Firms' Problem

The profit maximization problem of identical firms located over the continuum $[0,1]$ and producing the final product Y_t is

$$\underset{L_t \geq 0, \{x_{it}\}_{i \in [0, M_t]} \geq 0}{\text{maximize}} \quad L_t^{1-\alpha} \left(\frac{1}{M_t^{1-\alpha}} \int_0^{M_t} A_{it}^{1-\alpha} x_{it}^{\alpha} \, \text{di} \right) - \int_0^{M_t} p_{it} x_{it} \, \text{di} - w_t L_t \tag{8}$$

The left-hand side of this expression is the total revenue and the right-hand side is the total cost of the intermediate goods, and finally, the last term represents the total cost of labor. Firms are price takers in both product and factor markets. The price of the final good, which is considered as numeraire is normalized and is equal to one for all t. The production of the all purpose good Y_t requires a total of amount of L_t of skill-augmented labor input.

This construction ensures that both households' and firms' problems attain unique closed-form solutions at the equilibrium, which we discuss further in detail.

2.3.2.3. Monopoly's Problem

To formalize the monopolists' problem, let us first express the inverse demand function for intermediate good $i \in [0, M_t]$, by $p_{it} = p(x_{it}; A_{it}, L_t/M_t)$[3]. Note that, it is increasing in its both arguments. The monopoly firm exhibits forward-looking behavior in the sense

[3] L_t/M_t can be considered as labor input per variety of product.

that investment decisions to create new varieties rely on the anticipated long-term profits that maximize monopoly revenues. By construction, we assume that the monopolist can set the price in its product market[4] whereas he is a price taker in the factor market.

Then, the profit maximization problem of monopoly i can be written as

$$\underset{x_{it}\geq 0}{\text{maximize}} \quad p(x_{it}; A_{it}, L_t/M_t)x_{it} - x_{it} \tag{9}$$

here, the first term represents the total revenue and the second is the total cost. The solution of this problem leads to the following optimal profit function, $\pi_{it} = \pi(A_{it}, L_t/M_t)$ and it is also increasing in both A_{it} and L_t/M_t.

The most attention worthy assumption of the model is that, the monopoly rights are only granted for one generation. In the subsequent generation, another firm is responsible for producing any product variety. This ownership structure is what simplifies the decision problems in goods markets. Furthermore, assuming that unsuccessful R&D does not yield any returns, and the R&D problem for the intermediate good i is formulated as an expected payoff maximization problem such as

$$\underset{r_{it}\geq 0}{maximize} \quad \xi_t r_{it}^{\rho} \pi(A_{it}^*, L_t/M_t) - r_{it}A_{it}^* h_t \tag{10}$$

where the success probability is represented by $\xi_t r_{it}^{\rho}$ and the total amount of all-purpose good allocated to R&D for intermediate good i is represented by $R_{it} = r_{it}A_{it}^* h_t$, this problem also has a unique, closed-form solution.

[4] Intermediate monopolists have the liberty to set prices for final goods producers without concerns about potential rivals entering the market. This assumption is referred to as the "drastic innovation case" in industrial organization theory (Tirole, 1988).

2.3.3. Market Clearing Conditions and the SGE

Note that the market clearing condition for any intermediate good i situated in the continuum of $[0, M_t]$ at period t is inherently incorporated since x_{it} represents both the supplied and demanded quantity of the intermediate good.

So, the market clearing condition for the labor market is

$$L_t = \ell_t h_t N_t \tag{11}$$

where L_t stands for total quantity demanded and the right-hand side of the equality stands for total quantity supplied.

For the all-purpose good, we have

$$N_t(c_t + e_t n_t) + \int_0^{M_t} x_{it}\, di + \int_0^{M_t} R_{it}\, di = Y_t \tag{12}$$

as the market clearing condition, and the total quantity demanded by adults is represented by the first term on the left-hand side, the total quantity demanded by monopoly firms is represented by the second term on the left-hand side, and the total quantity demanded by the R&D firms is represented by the last term on the left-hand side.

To define the equilibrium, we need only one of these market clearing conditions to be satisfied because, according to Walras' Law, the other must be cleared at the equilibrium as well.

Before defining the model's SGE, it is necessary to analyze how the average productivity of intermediate goods changes over time. It is important to highlight that the tractability of this 2GS model is primarily attributed to the symmetry of R&D firms in terms of their ex ante success probability. Within this context, two factors counteract each other: on the one hand, targeted productivity γA_{it-1} decreases the success probability for any given level R_{it} of R&D spending; on the other hand, it increases the expected payoffs through profits. In equilibrium, these two factors perfectly offset each other, resulting in symmetric outcomes: $r_{it} = r_t > 0$ and $f(r_{it}) = f(r_t)$ for all i. Under these circumstances, we have probability σ_{it} of having $A_{it} = \gamma A_{it-1}$, and probability (1-σ_{it}) or (1-$f(r_t)$) of having $A_{it} = A_{it-1}$. Since the success probability should be equal to the proportion of intermediate goods with successful R&D at the final stage, then the average productivity can simply be written as

$$A_t \equiv \frac{1}{M_t}\int_0^{M_t} A_{it}\mathrm{di} \tag{13}$$

Let us define $\mathcal{S}_\mathrm{t} \subset [0, \mathrm{M_t}]$ as the set of intermediate goods with successful R&D in the beginning of period *t*, then equation (1.13) can be written as

$$A_t \equiv \frac{1}{M_t}\left[\int_{i\in\mathcal{S}_t}\gamma A_{it-1}di + \int_{i\in[0,M_t]\setminus\mathcal{S}_t}A_{it-1}di\right] = [(\gamma-1)f(r_t)+1]A_{t-1} \tag{14}$$

implying that the percentage growth rate of average productivity between two generations is $(\gamma - 1)f(r_t)$.

The **Static General Equilibrium** of the model is defined as a collection of allocations $\left(c_t, n_t, e_t, z_t, \ell_t, L_t, \{x_{it}, r_{it}\}_{i\in[0,M_t]}\right)$ and of relative prices $\left(w_t, \{p_{it}\}_{i\in[0,M_t]}\right)$ for any $t \in \{0,1,\ldots\}$ and given endogenous state variables (N_t, h_t, M_t, A_{t-1}), such that,

- The decision problem (1.7) is solved for each adult with $c_t, n_t, e_t \geq 0, z_t, \ell_t \in [0,1]$,
- The decision problem (1.8) is solved for each all-purpose good producing firm with $L_t \geq 0,\ \{x_{it}\}_{i\in[0,M_t]} \geq 0$,
- The decision problems in (1.9) and (1.10) are solved for any *i*, with $x_{it} \geq 0$ and $r_{it} \geq 0$, and
- the labor market clearing condition in (1.11) is satisfied.

As previously stated, all decision problems have unique solutions; therefore, the generated SGE exists, and is unique. From the utility maximization problem, we know that both the budget and time constraints are binding at the optimum. Then if we rearrange (1.7) to eliminate c_t and z_t, we obtain the optimal allocations for (n_t, e_t, ℓ_t) as follows:

$$n_t = \frac{\phi(1-\eta)\zeta\Lambda^{\omega}}{(1+\lambda+\phi)N_t^{\omega}} \qquad \ell_t = \ell = \frac{1+\eta\phi}{1+\lambda+\phi} \qquad e_t = \frac{\eta N_t^{\omega} w_t h_t}{(1-\eta)\zeta\Lambda^{\omega}}. \tag{15}$$

On the labor market there is a fixed fraction $\ell \in (0,1)$ of adult household's time endowment devoted as labour supply. Then the level of lifetime earnings of this adult individual becomes equal to $w_t h_t \ell$, given h_t. A fixed $e_t n_t$ fraction of this earning is allocated to children's education and a fixed c_t fraction is to consumption.

Notice that optimal fertility n_t decreases with population N_t, and education spending e_t increases with it. Therefore, the SGE clearly introduces the Q-Q trade-off as the economy progresses with a growing population dynamic, with e_t increasing and n_t decreasing.

Let us revisit the problem of firms' producing all-purpose good Y_t. This is a basic profit maximization problem where the first order necessary conditions provide the following inverse labor demand function

$$w_t = \frac{(1-\alpha)\left(\frac{1}{M_t^{1-\alpha}}\int_0^{M_t} A_{it}^{1-\alpha} x_{it}^{\alpha} di\right)}{L_t^{\alpha}} \tag{16}$$

and the inverse demand function for intermediate good $i \in [0, M_t]$

$$p_{it} = p\left(x_{it}; A_{it}, \frac{L_t}{M_t}\right) = \frac{\alpha\left(\frac{L_t}{M_t}\right)^{1-\alpha} A_{it}^{1-\alpha}}{x_{it}^{1-\alpha}}. \tag{17}$$

As previously articulated, the employment of 2GS models facilitates the mitigation of scale effects through product innovation. In other words, an expanding labor force is accompanied by a larger quantity of intermediate goods.

We then observe Monopoly i's problem having its optimum at

$$x_{it} = \alpha^{\frac{2}{1-\alpha}} \left(\frac{L_t}{M_t}\right) A_{it}. \tag{18}$$

considering the inverse demand function for intermediate good i, $p(x_{it}; A_{it}, L_t/M_t)$.

Clearly this optimum is unique and leads us to the following optimal profit function $\pi_{it} = \pi(A_{it}, L_t/M_t)$ that satisfies

$$\pi_{it} = \tilde{\alpha} \left(\frac{L_t}{M_t}\right) A_{it} \qquad \tilde{\alpha} \equiv \alpha^{\frac{1+\alpha}{1-\alpha}} - \alpha^{\frac{2}{1-\alpha}} = (1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} > 0 \tag{19}$$

From equation (1.19), we see that the primary determinants of R&D incentives for new market entrants rely on two key factors: L_t/M_t and A_{it}. The first term is the market size effect which increases optimal monopoly profits, and the second term is the productivity effect which is related only to intermediate input i.

The last problem is the R&D problem where we need to select the optimal success probability r_{it} for intermediate input $i \in [0, M_t]$, given the optimal profit function $\pi(A_{it}, L_t/M_t)$. This problem has a unique solution and it satisfies the following equality

$$r_{it} = r_t = \left[\tilde{\alpha} \left(\frac{L_t}{M_t}\right) \times \xi_t \rho \times \left(\frac{1}{h_t}\right)\right]^{\frac{1}{1-\rho}} \tag{20}$$

The optimal probability of a successful R&D depends on three factors: first, the market size L_t/M_t has a positive effect on r_{it}; second, the scale and curvature parameters of R&D technology also have positive effects on r_{it}. Finally, the effect of human capital is negative, which makes sense because a greater R&D investment becomes imperative to attain an equivalent probability of success, all other things being equal.

Prior to finalizing the discussion on the unique SGE solutions of the model, we will first state closed form solutions for some of our variables such as w_t and Y_t. To do so, we need to solve for the total flow of intermediate goods $K_t \equiv \int_0^{M_t} x_{it}\, \mathrm{d}i$ and the real GDP expressed in terms of the total output and the total flow of intermediate goods as in $\hat{Y}_t \equiv Y_t - K_t$.

The closed form solution of w_t is generated by (1.3), (1.13), (1.16), and (1.18) is as follows

$$w_t = (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}} A_t, \tag{21}$$

and the closed form solution of Y_t is generated by (1.3), (1.13), (1.18) combined with the market clearing condition (1.11) and is given as

$$Y_t = \alpha^{\frac{2\alpha}{1-\alpha}} \left(\frac{1+\eta\phi}{1+\lambda+\phi}\right) h_t A_t N_t \tag{22}$$

The stated equations also indicate that $K_t \equiv \int_0^{M_t} x_{it}$ di is proportional to $h_t A_t N_t$ as well.

Then we finally obtain the aggregate real GDP $\hat{Y}_t$ as

$$\hat{Y}_t = \hat{\alpha} \left(\frac{1+\eta\phi}{1+\lambda+\phi}\right) h_t A_t N_t \qquad \hat{\alpha} \equiv \alpha^{\frac{2\alpha}{1-\alpha}} - \alpha^{\frac{2}{1-\alpha}} = (1-\alpha^2)\alpha^{\frac{2\alpha}{1-\alpha}} \tag{23}$$

By setting total population equal to $P_t \equiv (1+n_t)N_t$, and rearranging, we are left with the unique SGE solutions of our main variables GDP per worker, y_t^{pw}, and GDP per capita, y_t, as shown below

$$y_t^{pw} = \hat{\alpha}\left(\frac{1+\eta\phi}{1+\lambda+\phi}\right)h_t A_t \qquad y_t = \hat{\alpha}\left(\frac{1+\eta\phi}{1+\lambda+\phi}\right)\left(\frac{h_t A_t}{1+n_t}\right) \tag{24}$$

If we define d_t as the inverse of gross fertility $1 + n_t$ and rewrite the real GDP per capita, we get

$$y_t = \hat{\alpha}\left(\frac{1+\eta\phi}{1+\lambda+\phi}\right)h_t A_t d_t \tag{25}$$

This equation for real GDP per capita illustrates that growth in y_t has three determinants:

1. Innovation: R&D activities result in an increasing average productivity A_t.
2. Human capital accumulation: Educational investments of adult individuals lead to higher quality h_t of their children.
3. Demography: Real GDP per capita increases with decreasing fertility n_t.

Before delving into the dynamic general equilibrium (DGE) of the model, we establish the definitions of the gross and percentage growth rates for a representative variable *j*, between two generations as follows $G_{jt} = 1 + g_{jt}$. This step might facilitate the subsequent examination of growth decomposition of y_t into its components.

$$G_{yt} = G_{ht}G_{At}G_{dt}, \tag{26}$$

2.3.4. The DGE and the Steady-State

Previous studies of growth economists, such as Galor and Weil (2000), Jones (2001), and Desmet and Parente (2012), show that the DGE of such a model can be formulated by simply assembling the unique SGEs at each period *t*, considering the laws of motion of our state variables:

Thus, given the history $\mathcal{H} \equiv \{0,1,...\}$, and given the initial values N_0, M_0, A_{-1}, and h_0 at $t = 0$, the **Dynamic General Equilibrium** of the model is a sequence of SGEs for any $t \in \mathcal{H}$ that satisfies equations (1.1), (1.4), (1.5), and (1.14).

Let us first describe the laws of motion in (1.1), (1.4), (1.5), and (1.14) in terms of only the state variables N_t, M_t, A_t, and h_t, so as to accurately define the dynamical system's parameters and characteristics we refer to.

$$N_{t+1} = \left[\frac{\phi(1-\eta)\zeta\Lambda^{\omega}}{1+\lambda+\phi}\right] N_t^{1-\omega} \tag{27}$$

$$M_{t+1} = M_t + \psi N_t - \varepsilon M_t \tag{28}$$

$$A_t = \left\{1 + (\gamma - 1)\xi_t \left[\tilde{\alpha}\ell\xi_t\rho\left(\frac{N_t}{M_t}\right)\right]^{\frac{\rho}{1-\rho}}\right\} A_{t-1} \tag{29}$$

$$h_{t+1} = \tau_t \left[\frac{\eta(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}}{(1-\eta)\zeta\Lambda^{\omega}}\right]^{\eta} A_t^{\eta} N_t^{\eta\omega} h_t^{\eta+\nu} \tag{30}$$

The recursive configuration of the dynamical system holds noteworthy implications for the convergence of state variables toward their steady-state levels. For instance; $N_t$converges monotonically to its stable nontrivial steady-state N^*. M_t, then, converges to its unique steady-state level M^*given N_t for all t. Given that (N_t/M_t) converges to a positive constant, A_t converges to a balanced growth path (BGP) with strictly positive growth. Ultimately, given (N_t, A_t), h_t converges to a BGP with strictly positive growth as long as $\eta + \nu < 1$. On this singular path, $A_t^{\eta}/h_t^{1-(\eta+\nu)}$ converges to a constant[5].

[5] Remember that $\lim_{t\to\infty} \tau_t = \bar{\tau}$ and $\lim_{t\to\infty} \xi_t = \bar{\xi}$.

Consider now the equations (1.27) - (1.30) of this dynamical system under the conditions that $(A_t, h_t)$are increasing, and $\left(N_t, M_t, A_t^{\eta}/h_t^{1-(\eta+\nu)}\right)$are fixed. Then, steady-state values (N^*, M^*) are given as in

$$N^* = \left[\frac{\phi(1-\eta)\zeta}{1+\lambda+\phi}\right]^{\frac{1}{\omega}} \Lambda \qquad M^* = \left(\frac{\psi}{\varepsilon}\right) N^* \tag{31}$$

accompanied by steady-state gross growth rates (G_A^*, G_h^*) as in

$$G_A^* = 1 + (\gamma - 1)\bar{\xi}\left[\tilde{\alpha}\left(\frac{1+\eta\phi}{1+\lambda+\phi}\right)\bar{\xi}\rho\left(\frac{\varepsilon}{\psi}\right)\right]^{\frac{\rho}{1-\rho}} \qquad G_h^* = (G_A^*)^{\frac{\eta}{1-(\eta+\nu)}}. \tag{32}$$

This is the balanced growth condition of the economy. It is known that n_t converges to its limit of 1 at steady state, and therefore d_t converges to 1/2. This implies that the growth rate of real GDP per capita depends on human capital and productivity growth rates. In other words, long-run endogenous economic growth is exclusively attributed to the accumulation of human capital and innovation.

$$G_y^* = G_A^* G_h^* = (G_A^*)^{\frac{1-\nu}{1-(\eta+\nu)}} = \left\{1 + (\gamma - 1)\bar{\xi}\left[\tilde{\alpha}\left(\frac{1+\eta\phi}{1+\lambda+\phi}\right)\bar{\xi}\rho\left(\frac{\varepsilon}{\psi}\right)\right]^{\frac{\rho}{1-\rho}}\right\}^{\frac{1-\nu}{1-(\eta+\nu)}} \tag{33}$$

Let us closely examine this central equation of the model and briefly cover some of the concepts discussed up to this point.

Recall that the model's state variables are; human capital per worker h_t, adult population N_t, average productivity across firms A_t, and mass of intermediate inputs M_t,whereas, the model's main control (-like) variables are; educational spending e_t which determines the evolution of h_t, fertility n_t which determines the evolution of N_t, research spending r_{it} which determines the evolution of A_t, and finally, entrepreneurship ψN_t which determines the evolution of M_t.

Basically, the equation (1.33) suggests that the long-term economic growth can be deciphered through the implication of the following structural parameters as follows:

- α is the parameter that stimulates innovation: the profit level of firms engaged in the production of intermediate goods increases through $\tilde{\alpha}$.
- ε can be interpreted as the exit rate parameter since it represents the measure at which existing goods become obsolete from one period to the next.
- ψ stands for the entry rate or the successful entrepreneurship measure, as it indicates the extent to which new intermediate goods are introduced to the market in each period.

Considering the law of motion of M_t, in (1.5), it is straightforward to induce that with increasing ε and decreasing ψ, the horizontal innovation equation leads to a greater market size, which in turn results in higher profits.

- λ is the preference parameter for leisure. An increase in λ implies a decrease in labor supply, and therefore a decrease in market size and profits.
- ϕ is the altruism parameter that not only differs the curvature of the utility function, but also affects growth via labor supply. However, its effect cannot be predicted without knowing the relative impacts of other parameters such as λ and the return to education parameter η which we will discuss next.
- η being sufficiently large, that is, when $\eta > (1+\lambda)^{-1}$, it attains significant size which enhances labor supply through ϕ,and boosts growth by expanding the market size. This parameter exerts a direct impact on growth through two distinct mechanisms. Firstly, there is a positive impact on both labor supply and market size as η increases. Secondly, derived from the second equality in (1.32), it is evident that the steady-state gross growth rate of human capital G_h^* is cotingent upon the steady-state gross growth rate of average productivity G_A^*. In the event of an increase in this parameter $\eta \in (0,1)$, G_h^* escalates, increasing the gross growth rate of real GDP per capita, for any given G_A^*.

- ν is the parameter determining speed of convergence, and it acts as the return to education parameter η, meaning that it affects growth through the same mechanism based on the equation (1.32).
- $\bar{\xi}$ and ρ are scaling and curvature parameters related to R&D, and both inherently have positive effects on the growth rate of productivity.
- Finally, the last parameter γ represents the step-size of vertical innovation in the model, and directly increases the growth rate of productivity.

2.4. THE BENCHMARK CALIBRATION

The primary objective of this section is to establish a foundational calibration of the model economy. This calibration aims to ensure that the model mirrors the long-term population, human capital, productivity, and real GDP per capita trends observed in the U.S. economy. To achieve this objective, two key steps must be undertaken: first, we need to discern good starting values in order to position the U.S. economy at the appropriate historical initial point, and second, we need to assign suitable values to structural parameters of the model so that we maximize the model's ability to explain and align with the trajectory leading to the long-term BGP.

We employ a hybrid approach to effectively fulfill these requirements, a technique commonly applied in the context of endogenous growth models. Initially, certain parameters and initial values are assigned values that are arbitrary yet reasonable. Then, the equilibrium relationships within the model economy at specific points in time are utilized to deduce initial values and parameters as expressions of other yet-to-be-identified parameters and provided data points. Finally, a numerical method for fitting the model to data known as the "minimum distance problem (MDP)" is used to determine the values for the unidentified parameters.

As per the construction, MDP tries to minimize the distance between two specified elements; in our case, two specified vectors of elements. It applies a forward recursion in nested loops. The outer loop guesses the initial unidentified parameters and values, and the inner loop traverses the array in the quest of all the identified parameters and initial values, taking the minimum distance between model moments and data moments. Thus, a forward recursion is applied, starting from *t=0*, to the dynamic system defined in (1.27) – (1.30). In simpler terms, the model can be readily solved for any specified group of unidentified parameters, and the MDP utilizes this concept to numerically identify an optimal set of these parameter values.

2.4.1. Initial Values and the Steady-State

In order to allow the model economy to provide a reasonable outlook of the long-term growth tendencies in the US economy, we create a real GDP per worker dataset using the relevant employment numbers that we compute as follows: for the future values of 15-64 age group and total population we rely on World Population Prospects' medium fertility projections for the following years: 1950, 1970, 1990 and 2010. However, for the employment numbers, instead of taking 15-64 age group population values directly, we examine the proportional relationship between employment and the 15-64 population over the period 1950-2021, and assume that this proportionate relationship will remain consistent. The main reason we construct an employment figure consistent with the 15-64 population is that the demographic structure of the model is too simple. Moreover, raw data for GDP, human capital and physical capital is retrieved from the series in Penn World Table (PWT) version 10.01, by Feenstra, Inklaar, and Timmer (2015).

Finally, let $y^{\mathrm{pw}}_{t,\mathrm{obs}}$, $N_{t,\mathrm{obs}}$, $h_{t,\mathrm{obs}}$ stand for the real GDP per worker, the employment, and the average human capital in data respectively.

The length of each period in the model, set at 20 years, designates the period from 1950 to 1970 as the adulthood period for the first generation. The fundamental justification for this framework stems from the recognition that the manifestation of growth slowdown becomes evident only when assessed through 20-year averages.

For corporate data, that is represented by stock of establishments variable *M*, in the model, we employ the US Census for the period spanning from 1978 to 2021. Preceding the year

1978, the data is derived from the annual business surveys of the County Business Patterns (CBP), offering U.S. establishment figures alongside various other datasets. Nevertheless, as data is not accessible before 1968, a simple linear time-series estimation was conducted in Stata to forecast the data for the years 1950 to 1967.

Fertility figures are sourced from the World Population Prospects, specifically utilizing the total fertility rates from medium projections. Concerning the R&D share in GDP, we use the Gross Domestic Expenditure on Research and Development (GERD) data from OECD. In instances of missing data, we calculated this value by referencing the Congressional Budget Office Report, which furnishes information on federal R&D spending and nominal GDP for the period 1950-1970.

Regarding initial values, N_0 is simply set equal to its calculated counterpart of $N_{0,obs}$ =71.734 million in 1950. R&D decisions made at $t = 0$ determine the initial productivity level A_0 in equilibrium since A_t belongs to the end-of-period average productivity. A normalized value of $A_{-1} = 1$ is imposed for sake of convenience. As a result, we obtain $A_0 = 1.0578$. The stock M_t of firms is also equated to its calculated counterpart of $M_{0,obs} = 3.058$ million firms in 1950 of which computation method is explained above. Recall that this figure also stands for the measure of intermediate inputs in the model. Finally, given the observed value of $y_{0,obs}^{pw} = 50{,}713$ in 1950, A_0 and the parameters $(\alpha, \lambda, \phi, \eta)$, equation (1.24) yields an initial level of human capital per adult of 8.0483. We rescale the data to eliminate measurement unit variations for both physical and human capital prior to their use in the model.

Furthermore, we relied on de la Croix and Gosseries (2012) for the calibration of (λ, ϕ, η). Let's recall that $\lambda > 0$ and $\phi > 0$ are preference parameters, and $\eta \in (0,1)$ is the parameter determining the return to education. We need three data moments to calibrate these parameters; the share of household income allocated to education spending (or share in GDP), the share of time dedicated to childcare remaining after leisure activities, and the share of time allocated to non-market activities. The first and second of these data moments are set to $\eta\phi/(1 + \eta\phi)$ and $(\phi - \eta\phi)/(1 + \phi)$ in the steady-state. OECD

Time Use Survey indicates that, around 2015 and 2016, households dedicate 80% of their time to non-market activities and 14% of their time to child rearing. Besides, the WB reports that, the share of education spending in GDP dropped from 6.7% in 2010 to 4.8% in 2016. These figures imply $\phi = 0.2360$ and $\eta = 0.2815$, enabling us to calibrate λ using the following equality $(\lambda + \phi - \eta\phi)/(1 + \lambda + \phi)$, to match the time share allocated to non-market activities and which turns out to be $\lambda = 4.0684$.

Given the annual exit rate average from 1978 to 2020 in the U.S. ε^a =0.1036, we obtain $\varepsilon = 0.8878$ through the computation $\varepsilon = 1 - (1 - \varepsilon^a)^{20}$. Moreover, steady-state equality$M^* = (\psi/\varepsilon)N^*$,with the estimated number of firms per capita being 10 in the steady-state leads us to $\psi = 0.0581$ given ε (note that the steady-state adult population level equals $2N^*$in our model).

From (1.31) it is seen that to identify parameters ζ and Λ, we need to normalize one of them since they are dependently determined. We choose to normalize the land endowment parameter $\Lambda = 1$and $N^* = 152.77$ million. Then, our scaling parameter satisfies $\zeta = 270.1$.

Last but not the least, the step-size of R&D technology parameter γ is directly calibrated and $\gamma = 11.1470$, with the long-term growth rate remaining unidentified and selected by the MDP.

In the following sub-section, we define in details the Minimum Distance Problem related to our model, that is employed to determine the remaining unidentified parameters.

2.4.2. Minimum Distance Algorithm

The applied methodology so far lefts out the following parameters τ_1, τ_2, τ_3, τ_4, ω, ν, ξ_1, ξ_2, ξ_3, ξ_4 and ρ. At this point, previously mentioned MDP comes into play and through its numerical solution, it designates values to these eleven parameters. This is about minimizing a quadratic form deviations (distances) between observed and simulated moments. Here, the mechanism tries to align with the transitional trajectory towards the BGP as closely as possible by using the logarithms of the gross growth rates of N_t, h_t, and y_t^{pw}, as targeted moments over three periods; 1950-1970, 1970-1990, and 1990-2010.

Next, describe the vector of observed gross growth rates

$$G^{obs} \equiv \left(\{G_{vt}^{obs}\}_{vt}\right) \in \mathbb{R}^{3\times 3} \tag{34}$$

where $v \in \{N_t, h_t, y_t^{pw}\}$ and $t \in \{1950{,}1970{,}1990\}$. These periods correspond to average growth rates, with G_t standing for the growth rate from period t to t+1. As can be expected, there is a model counterpart of this vector as follows: $G^{sim}(\pi)$, where $\pi \equiv (\tau_1, \tau_2, \tau_3, \tau_4, \omega, \nu, \xi_1, \xi_2, \xi_3\ \xi_4, \rho, g\ *) \in [0,1]^7$. Finally, define the following quadratic form as in Bar and Leukhina (2011) and Attar (2018)

$$Q(\pi) \equiv \left(G^{obs} - G^{sim}(\pi)\right)' W(\pi) \left(G^{obs} - G^{sim}(\pi)\right) \tag{35}$$

Note that, the jth (diagonal) element of weight matrix $W(\pi)$,is the inverse of the jth coordinate of$(1/2)\left(G^{obs} + G^{sim}(\pi)\right)$. The genetic algorithm guarantees the attainment of the global minimum in this context under two priorly set constraints: the probability of successful innovation $f(r_t)$ satisfying $f(r_t) \in (0,1)$ for all t, and $\eta + \nu < 1$ for the BGP to exist.

2.4.3. Benchmark Paths and the Goodness of Fit

We rigorously calibrate this dynamic general equilibrium model, that integrates multiple sources of growth. Initially, we solve the model using a predefined set of parameters and ratios. Subsequently, we let the MDP to determine the remaining parameters. One notable distinction between this model and Attar's (2019) lies in a significant feature that empowers us to select the long-term growth rates of specific variables. To be more precise, we endogenously establish the long-term growth rate of GDP per capita (g^*) in line with our predefined targets, while still maintaining consistency with the current data.

The model and the specified parameter values generated from the calibration give a benchmark for steady-state growth path of the U.S. economy and Table 6 gathers all the figures corresponding to the baseline calibration.

Table 6. *The Baseline Calibration*

Calibrated model input	Value	Target/source/comment
Initial values		
Adult population N_0	71.7336	PWT 10.01 1950 data in millions
Intermediate goods (or firms) M_0	3.0580	predicted based on Census data
Average productivity A_0	1.0578	normalization: $A_{-1} = 1$
GDP per worker y_0	50,713.25	PWT 10.01
Human capital per adult h_0	8.0483	PWT 10.01 rescaled given 1950 data
Preference parameters		
Utility, altruism $\boldsymbol{\phi}$	0.2360	time use & education exp. (joint w/η)
Utility, leisure $\boldsymbol{\lambda}$	4.0684	data on time use (given φ, η)
Technology parameters		
Capital share, $\boldsymbol{\alpha}$	0.3333	arbitrary
Firm entry (entrepreneurship) $\boldsymbol{\psi}$	0.0581	given M^*, N^* and ε
Firm exit $\boldsymbol{\varepsilon}$	0.8878	1978-2020 establishment exit rate average
Human capital, scaling $\boldsymbol{\tau_1}$	21.863	mdp
Human capital, scaling $\boldsymbol{\tau_2}$	18.648	mdp
Human capital, scaling $\boldsymbol{\tau_3}$	16.759	mdp
Human capital, scaling $\boldsymbol{\tau_4}$	15.982	mdp
Human capital, education $\boldsymbol{\eta}$	0.2815	time use & education exp. (joint w/$\boldsymbol{\varphi}$)
Human capital, persistence $\boldsymbol{\nu}$	0.6324	mdp
Reproduction, scaling $\boldsymbol{\zeta}$	270.1	targeting N^* given other parameters
Reproduction, land endowment $\boldsymbol{\Lambda}$	1	normalization
Reproduction, curvature $\boldsymbol{\omega}$	0.4286	mdp
R&D, step-size $\boldsymbol{\gamma}$	11.147	targeting g^* given other parameters
R&D, scaling $\boldsymbol{\xi_1}$	0.5985	mdp
R&D, scaling $\boldsymbol{\xi_2}$	0.8356	mdp
R&D, scaling $\boldsymbol{\xi_3}$	0.9768	mdp
R&D, scaling $\boldsymbol{\xi_4}$	1.0356	mdp
R&D, curvature $\boldsymbol{\rho}$	0.7092	mdp
Steady-state values		
g^*	1.3409	mdp
M^*	10	arbitrary
N^*	152.77	World Population Prospects

Benchmark paths in level of our variables of interest are given in Figure 1 below where for *y*, *h*, *N*, and *M*, growth rates are targeted:

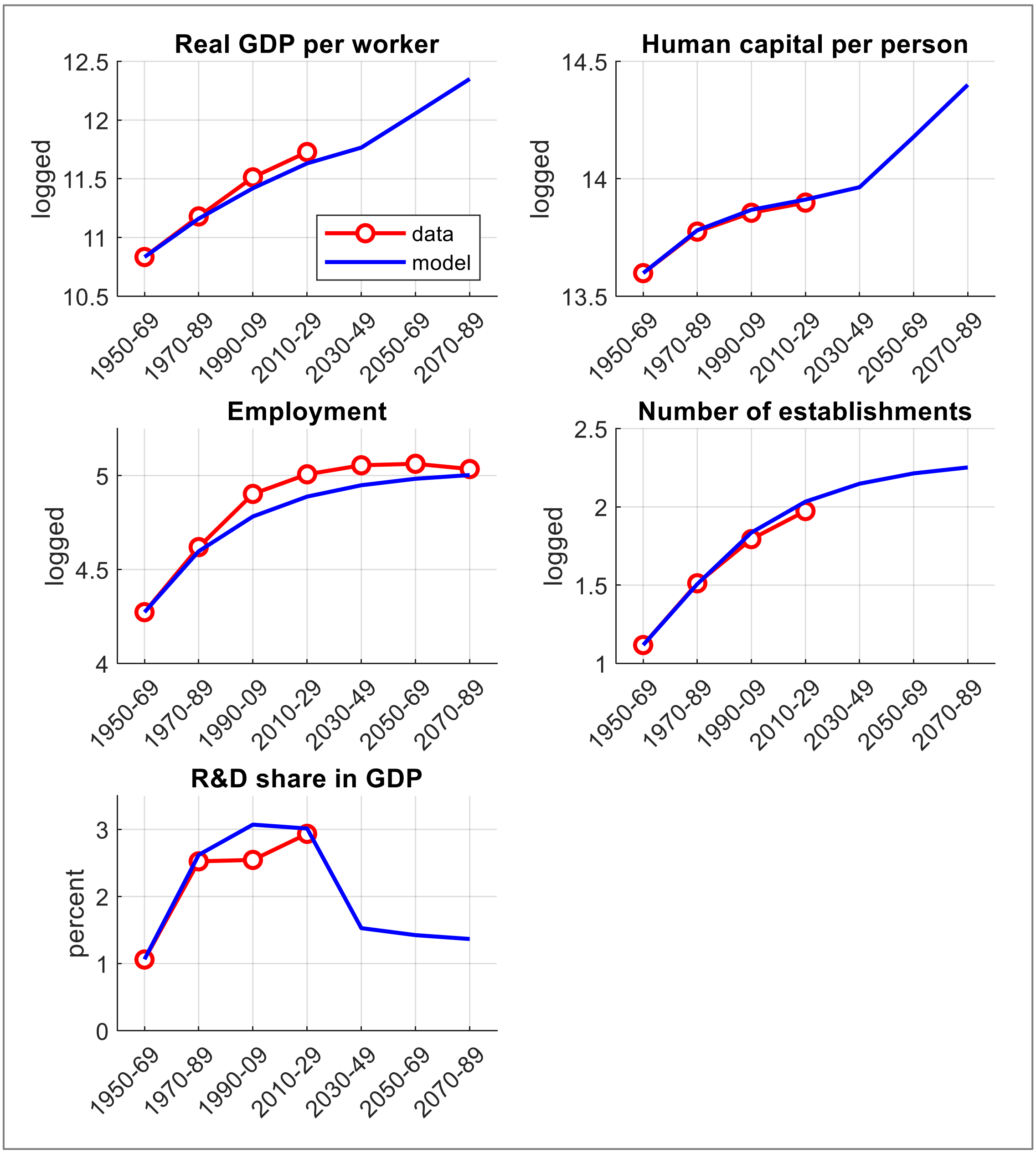

Figure 1. *Benchmark Paths of Targeted Variables From 1950 to 2090*

Note that the initial data point in the graphs presented in Figure 1 corresponds to the average growth rates from 1950-1970 to 1990-2010. Therefore, after the fourth data point at 2010-2029 for instance, which reflects the next period's growth rate, the values can be taken as projections.

When we examine the Figure 1, the immediate striking observation is how well the model fits the data for the following targeted variables, real GDP per worker, human capital per person and number of establishments. Moreover, the transition shapes of human capital per person and real GDP per worker are quite similar, although the growth rate of human capital is slower than that of real GDP per worker for the first three periods. This could be partly explained by slow growth in employment.

The evolution of human capital per person evolves in accordance with Jones (1997). He states that human capital investment has witnessed a substantial rise in the United States. In 1940, fewer than one in four adults had attained a high school diploma, and only 5 percent had acquired a bachelor's degree or higher. By 1993, the percentage of individuals who had successfully graduated from high school exceeded 80 percent, while more than 20 percent had obtained at least a four-year college degree. Furthermore, he provides empirical evidence regarding educational attainment, wherein the mean substantially increases from 9.3 years of schooling in 1950 to 12.0 years in 1967. Following 1967, educational attainment continues to increase, albeit with more modest changes, reaching 12.8 years by 1993. This assertion is corroborated by the findings of the model (figure 1, top panel on the right). Additionally, the model predicts that human capital accumulation growth will accelerate in the future.

Another important variable of interest of the model is the R&D expenditures share in GDP. In the data, 2010 statistics show that the gross domestic spending on R&D in the U.S. stands at 2.71%, according to the OECD. The model economy with 3.01% matches this share in the baseline calibration.

Fernald et al. (2014) illustrates that South Korea and China are experiencing notably swift growth in research expenditure (surpassing their already rapid income per capita growth rates. This reminds Freeman (2009) highlights; in 1978, China's output of PhD’s in science and engineering was notably limited; nevertheless, by 2010, the production had surpassed that of the United States by 25 percent.

Based on Congressional Research Service Reports (2022), Jones (2022) combine the public R&D spending trends with private R&D spending ones in U.S. economy between 1956 and 2020 and shows that the share of public R&D spending in relation to the total U.S. R&D expenditures reaches its highest point in 1964 at 66.8%, coinciding with the private R&D spending reaching its lowest point at 30.8%. Subsequently, between 1964 and 2000, there is a decline in the federal government's share, accompanied by an increase in the share attributed to private sector. In 2000, private sector constitutes 69.4% of the total U.S. R&D expenditures, while the public accounts for 25.1%. This alteration in the distribution of R&D funding was not driven by a decrease in public R&D expenditures but rather by the accelerated growth in business R&D expenditures. Between 2000 and 2010, the share of private R&D spending declined from 69.4% to 61.0%, and it has steadily increased each year thereafter, reaching its peak at 73.1% in 2020. Conversely, during the same period from 2010 to 2020, public share decreased from 31.1% to 19.5%.

Regarding the goodness of fit of the baseline calibration, we must acknowledge some features of the model. First, the genetic algorithm efficiently solved the MDP and, as a result, it did not encounter any convergence problems. Second, we targeted the growth paths of N_t, h_t, M_t, and y_t^{pw}, and it provides us accurate matches for log levels of these variables for the required periods: 1970, 1990, and 2010. However, to fairly assess the goodness of fit of the model, we need to examine non-targeted moments, which are total fertility rate (TFR) and total population P_t (see Figure 2). Evidently, it would not be relevant to directly compare the model with the data for the former variable in level, because the model is quite simple in terms of demography, as we only consider two generations. Moreover, physical capital is omitted since it is not considered as a major factor contributing to GDP growth as it is assumed to fully depreciate.

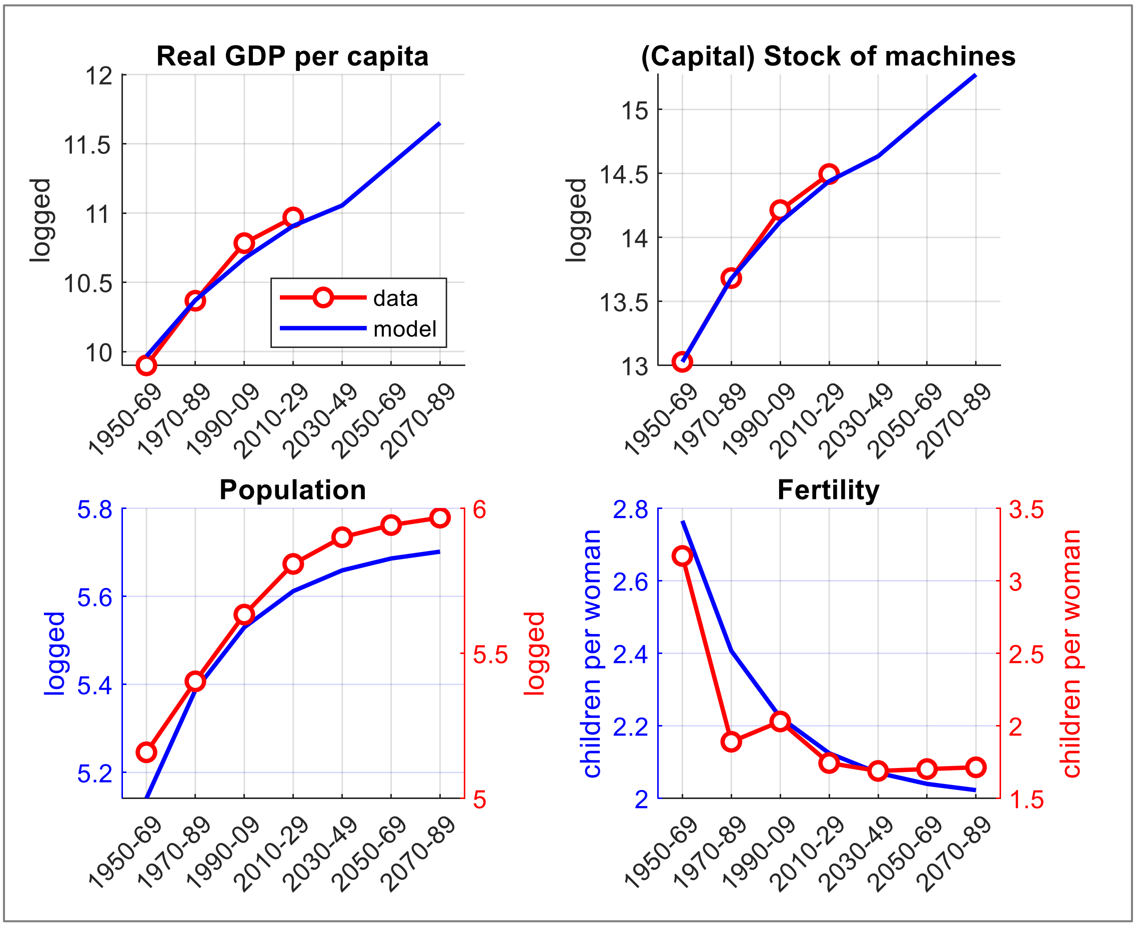

Figure 2. *Benchmark Paths of Non-Targeted Variables From 1950 to 2090*

From Figure 2, we can see that although our analysis is limited to two generations, it is worth noting that the TFR simulated within the model and that observed in the data are close. Given that the U.S. economy was midway through its demographic transition in the 1950s, the subsequent decline in the growth rate of demography until the conclusion of the 21st century is not surprising. The periods of relatively rapid demographic decline appear to be from 1950 to 2010, in which economic growth also diminishes; however, as the pace of decline gradually slows down, growth rate of GDP per capita experiences a subsequent increase. This reminds us of recent empirical work of Siskova et al. (2023) who argue that declining fertility is partially offset by the accumulation of human capital. Their findings show that, countries experiencing population decline face greater challenges in compensating for the human capital consequences associated with declining fertility.

In brief, for population and fertility, the model cannot fit the levels since the demographic part is too simple. But the movement has been captured well. On the contrary, the model catches a better fit regarding the growth rate of capital stock and the real GDP per capita where the growth of stock of machines exhibits a pattern more closely aligned with the growth of real GDP per capita. Moreover, it can be seen from Figure 2 that the periods where the model aligns closely with the data moments and where there is a slight deviation from them are precisely coincident for both variables. This result reflects the basics of Solow's growth theory, the total amount of physical capital (machinery, buildings, infrastructure, etc.) in an economy, contributes to economic output growth.

Combined, Figures 1 and 2 partly provide results that are in accordance with Galor et al.'s (2000) findings, which state that per capita output rises with an increase in population growth rate and the accumulation of human capital, and that the technological change following the increase in human capital leads to a permanent decrease in fertility rates.

This section concludes by underscoring the model's noteworthy accuracy stressed out by the goodness of fit matching the U.S. data, in particular, based on an endogenous growth framework and in the presence of multiple sources of growth, considering the related literature. Despite exhibiting poor matches for a few variables at some specific periods, the overall performance of the model in capturing the convergence to BGP is very good. Consequently, the model holds promise for replicating the long-run economic growth dynamics of the U.S. economy.

2.5. RESULTS

2.5.1. The Benchmark Paths

The benchmark paths of the two crucial determinants impacting GDP per worker encompass human capital and productivity. Consequently, we analyze their individual benchmark trajectories, examine the mechanisms that govern them within the model, and present the outcomes in figures 3 and 4.

Note that the benchmark scenario presented is generated by adopting the medium value of gross growth rate $g*$ at 1.34%, equivalent to an annualized percentage growth rate of 1.48%, as provided by the MDP. We intentionally select this path to maintain a reasonable outlook, although the results exhibit only minor variations when considering the highest and lowest values of the gross growth rate $g*$ at 1.74%, corresponding to an annualized percentage growth rate of 2.81%, and 1.21%, with an annualized percentage growth rate of 0.96%, respectively.

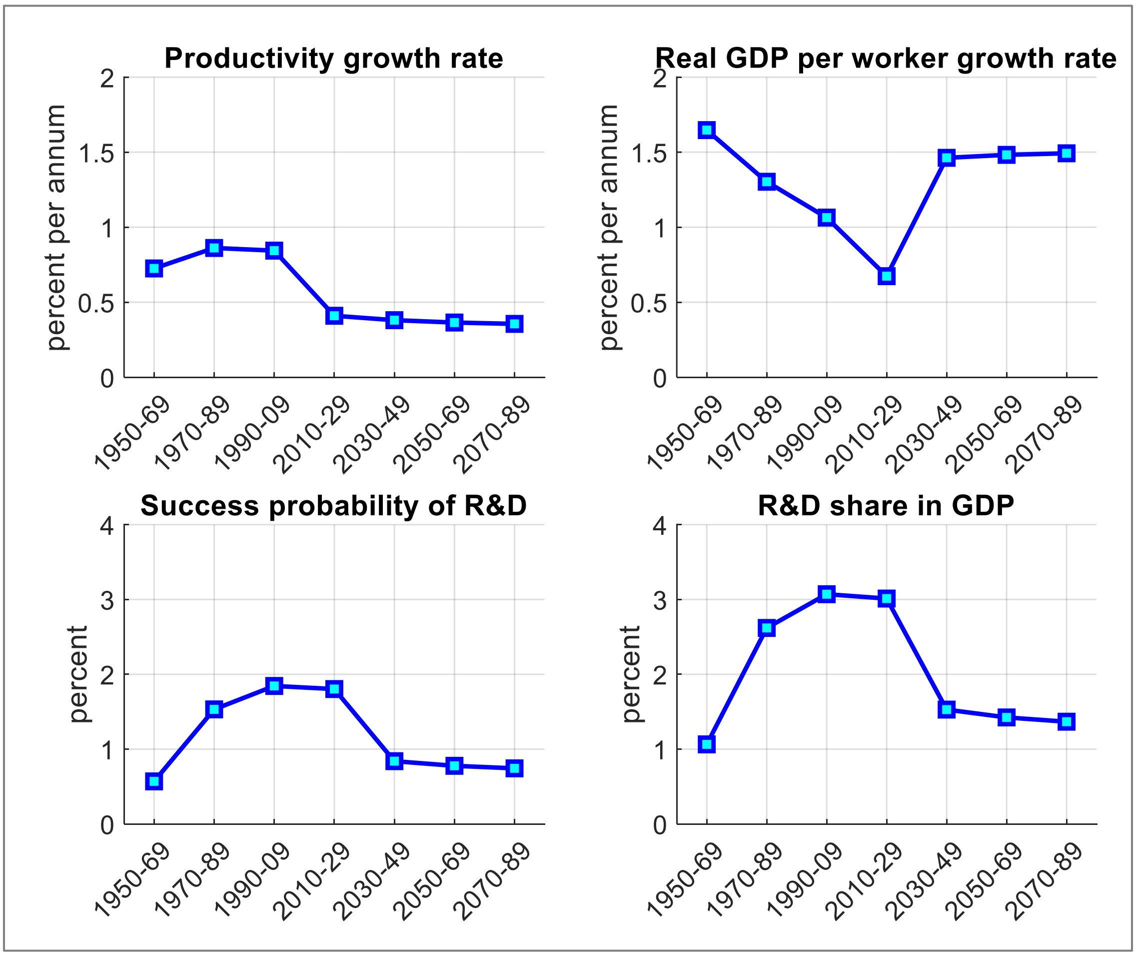

Figure 3. *Benchmark Paths of Productivity Growth Rate and Other Related Variables*

Figure 3 depicts the productivity growth in benchmark path and its primary determinants within the model. When examining Figure 3, the prominent observation that immediately captures attention is the substantial relationship between the R&D share and success probability. Moreover, the R&D share in GDP growing at only 1% from the 1950-69 period to 1970-89 has little productivity growth effect that could not prevent GDP per working from slowing down during the same periods. However, the rapid increase from the first period to the second, followed by a comparatively modest rise from the second to the third, is evident in the consecutive growth rates of productivity. After the fourth period the slowdown in productivity growth rate tends to continue accompanied with a very moderate increase in the growth slowdown of real GDP per worker.

Furthermore, as depicted from Figure 1 and 2; the growth rate of employment declines as the population is ageing. In other words, as explained by the Q-Q tradeoff concept, adult households invest more in their children's quality instead of having more of them. This in turn increases human capital. Note that the growth rate of human capital decreases from one generation to the next, as the growth rate of h_t is decreasing in h_t, but in the model, the adult individual's income does not solely depend on h_t, but also on the growth of average productivity. Furthermore, the growth rate of education spending follows a path similar to that of human capital growth for the same reasons explained by the Q-Q tradeoff.

On the contrary, the growth rate of productivity experiences slight increases for the first three periods, after which it declines and practically stagnates. One explanation for this could be that, at the beginning of the first period, in 1950 per se, the employment level is almost twice the level of establishments, which could be interpreted as a relatively large market size. Then with an increased amount of R_{it} devoted to the process of vertical innovation in order to sustain increased levels of targeted productivity γA_{it-1} coupled with human capital h_t, the sequence of normalized research input r_{it}, which is the success probability of R&D in the model, follows the path of average productivity growth from one period behind.

The shapes of the transition of the R&D expenditures share in GDP and the success probability of R&D are similar since one is the implicit function of the other.

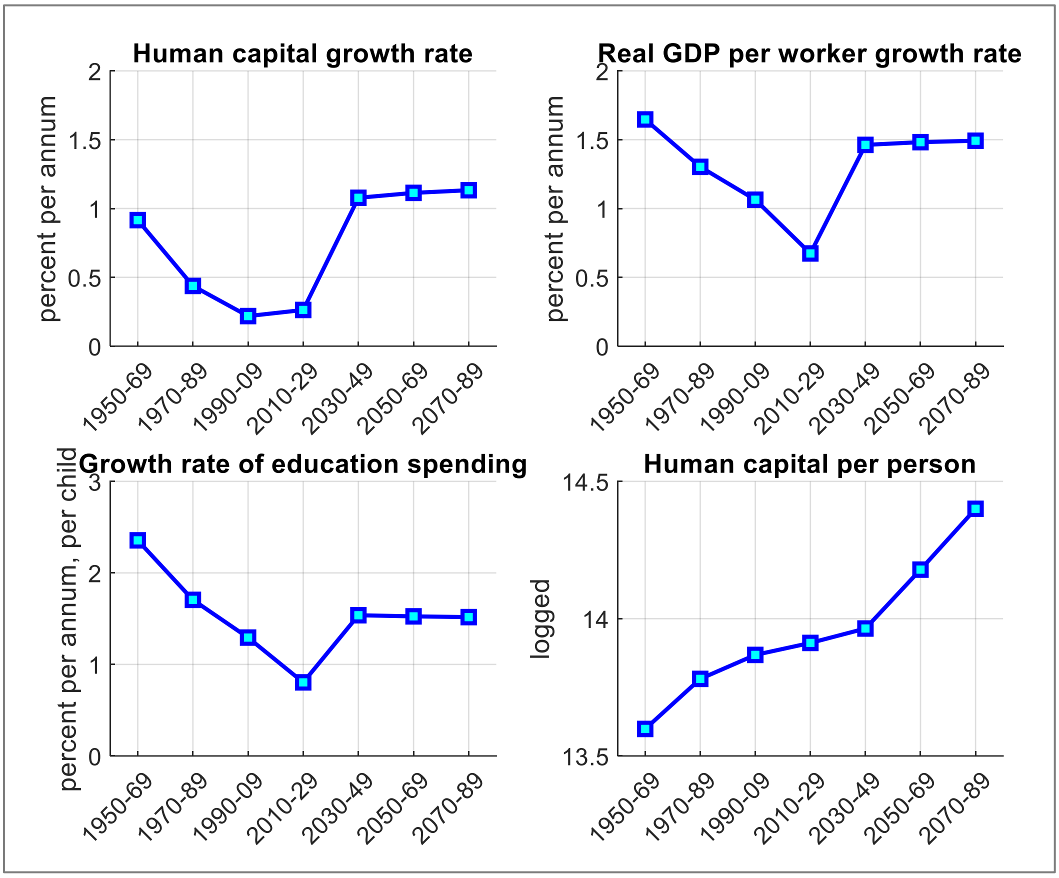

Figure 4. *Benchmark Paths of Human Capital Growth Rate and Other Related Variables*

Figure 4 shows the human capital growth in benchmark path and its primary determinants within the model where the similarity in the trends of the growth rates in real GDP per worker and the growth rate of educational spending is noteworthy. This relationship obviously results from the Q-Q tradeoff decisions defining the growth rate of human capital accumulation as explained above.

2.5.2. Growth Decomposition

Table 7. *Annual Growth Rates and Contributions to Growth From 1955 to 2095*

Period		GDP per capita	Human capital	Productivity	Demography
1950-1970	Growth rate %	2.05	0.92	0.72	0.39
	Contribution %	-	45.01	35.67	19.32
1970-1990	Growth rate %	1.52	0.44	0.86	0.21
	Contribution %	-	28.96	56.92	14.12
1990-2010	Growth rate %	1.18	0.22	0.84	0.12
	Contribution %	-	18.55	71.41	10.04
2010-2030	Growth rate %	0.74	0.26	0.41	0.07
	Contribution %	-	35.60	55.41	8.99
2030-2050	Growth rate %	1.50	1.08	0.38	0.04
	Contribution %	-	72.00	25.49	2.52
2050-2070	Growth rate %	1.50	1.11	0.36	0.02
	Contribution %	-	74.20	24.37	1.43
2070-2090	Growth rate %	1.50	1.13	0.35	0.01
	Contribution %	-	75.43	23.76	0.81

We make use of equation (1.26) to obtain the decomposition analyses shown above in Table 7, which differs from the ones used in the growth literature. It provides very enlightening results not only because it illustrates how the growth rates of (y_t, h_t, A_t, d_t) evolve throughout the 21st century, but also, the contributions of different variables to the growth of GDP per capita in percentages. Physical capital is not considered as a major factor contributing to GDP growth since it is assumed to fully depreciate and the decomposition is driven by the calibration of a general equilibrium OLG model, grounded on important microeconomic principals in the very long run.

The growth rate of GDP per capita exhibits consistent declines during the initial four periods after which it stabilized at approximately 1.50% per annum. During the first generation, the primary driving force behind the growth of GDP per capita is human capital. Subsequently, between 1950 and 1970, human capital grows at 0.92% per annum contributing approximately 45% to the overall increase in GDP per capita. It is followed by productivity exhibiting a slightly lower growth rate than human capital, recording 0.72%. Demography has the least contribution to the growth of GDP per capita over the same period, with only a growth rate of 0.39%. For the ensuing three consecutive periods, until 2030, the contribution of productivity to the growth rate of GDP per capita surpasses that of human capital. Nevertheless, starting from 2030 until the conclusion of the 21st

century, the contribution of human capital nearly triples the contribution of productivity with an increased growth rate soaring from 0.26% to 1.13% per annum.

According to Jones (1997), human capital investment has witnessed a substantial rise in the United States. In 1940, fewer than one in four adults had attained a high school diploma, and only 5 percent had acquired a bachelor's degree or higher. By 1993, the percentage of individuals who had successfully graduated from high school exceeded 80 percent, while more than 20 percent had obtained at least a four-year college degree. Furthermore, he provides empirical evidence regarding educational attainment, wherein the mean substantially increases from 9.3 years of schooling in 1950 to 12.0 years in 1967. Following 1967, educational attainment continues to increase, albeit with more modest changes, reaching 12.8 years by 1993.

The most dramatic change observed throughout the century is the contribution of demography to the growth rate of GDP per capita, registering nearly 19.32% in the initial period and 0.81% in the last.

We can conclude that, since starting from 2010 until the conclusion of the century, the growth rate of productivity and demography slowdown while that of GDP per capita remains constant, human capital emerges as the primary factor sustaining the growth rate of GDP per capita.

2.6. COUNTERFACTUAL EXPERIMENTS

In this section, we aim to provide a quantitative analysis of the long-term economic growth rate within the U.S. economy under diverse scenarios. We wish to find a plausible proposition to alleviate the impact or the pace of the growth slowdown. To achieve this objective, we systematically vary three parameters (ξ_f, ξ_v ρ, ψ) of the model associated with technology preferences and innovation process. These parameters that also shape the market structure will be studied in details shortly.

The impact of research and development on economic growth is expected to differ based on the distinctive characteristics of the national innovation system, influencing the effectiveness of knowledge creation, commercialization, and diffusion (Lundvall, 1985, 1992; Freeman, 1988).

Parameter values used in each scenario are selected to yield a consistent counterfactual value for a specific variable, allowing for direct comparisons among the results within the set. In this context, the variable under consideration is the total R&D share in GDP in 2010. Notably, we set this share equivalent to 5% after considering the highest GERD rates taken from the data. For instance, in 2010, the highest rate among OECD countries stands at 3.86% for Israel and the next highest rate is that of Finland with 3.71%. Therefore, setting the targeted R&D share at 5% for the U.S. economy is reasonable since there exists a considerable difference with its GERD which is only 2.71% in the same period[6]. Finally, the reporting variable of interest is the growth rate of GDP per capita in percentage at t.

2.6.1. Design

In each scenario, only the experimented parameter's value changes, leaving the rest of the model inputs as they are in the benchmark scenario. First two of these parameters are ξ and ρ, and they are productivity and curvature parameters related to R&D in the model. Moreover, they both inherently have positive effects on the growth rate of productivity. The last parameter is ψ, and it represents the entry rate or the successful entrepreneurship which indicates to what extent new intermediate goods are introduced to the market in each period.

As mentioned above, the total R&D expenditure in GDP is the common counterfactual of our experiments and it is set to 5% for the R&D share in GDP for the last period in the

[6] As of 2021, UN GERD statistics show that OECD average stands at 2.718% and US GERD is 3.457.

model, S = (4,1). This value is 2.29% higher than the U.S. GERD in 2010 and 1.99% higher than the benchmark value.

Different values of the three parameters that implies in each experiment a 5% share of R&D spending results in various growth and welfare effects, as explained further.

2.6.1.1. Constant R&D Productivity

This parameter defines how efficiently R&D is transformed into new innovations and growth. A higher ξ, which means a higher productivity of R&D technology is supposed to make a positive effect on the growth rate. In this experiment, we set the parameter ξ_f equal to a constant in all periods to imply the common counterfactual S (4,1) = 5%.

2.6.1.2. Time Varying R&D Productivity

We allow for the R&D productivity parameter ξ_v to be time varying, but for all t, it is larger by some factor to imply S (4,1) = 5%.

2.6.1.3. Weakened Diminishing Returns

The parameter ρ is the curvature parameter that rules the diminishing returns to scale for the R&D production function. If, with the same amount spent on R&D we obtain decreasing research productivity levels, then we might talk about the presence of diminishing returns. This decreasing returns to R&D notion is a widely discussed topic in the literature, Jones (1995, 1997), Diao et al. (1999), Bloom et al. (2020).

In this experiment, we enable a weakening in diminishing returns by setting ρ to be larger (and close to 1) so that the R&D production function f has less curvature (implying weaker diminishing returns). Again, the target is S (4,1) = 5%

As expected, it is seen from figure 5 that this experiment yields a positive growth effect on both GDP per capita and lifetime utility since rendering the R&D production function more linear, i.e. approaching the curvature parameter to unity, weakens the diminishing returns effect and increases productivity of research effort.

2.6.1.4. Larger Market Size

Another important parameter to experiment with is the parameter ψ, which represents the market size effect. Again, there is a large literature debate concerning this parameter after Akcigit et al.'s (2018) on declining business dynamism, particularly in the U.S. economy. As Schumpeterian growth theory suggests, firms engage in innovation to expand their market size. Babina et al. (2023) illustrate that, over the past decade, larger companies increased their investments in Artificial Intelligence and, consequently expanded into additional markets. On the contrary, if firms have acquired a market that is sufficiently large and sustainable, this leads to diminishing innovation incentives.

A lower ψ implies a lower entry of new competitors in the market, which in turn implies larger market sizes for incumbent firms that perform R&D. Thus, S increases. So, limited entrepreneurship, and therefore limited horizontal innovation activity (lower ψ), should trigger a positive growth effect through positive market size effects. The target in this experiment is again S (4,1) = 5%

In figure 5 below, we graphically show the experiments' results where we intended to analyze how the model economy would have evolved under different scenarios by modifying the parameters affecting the R&D activities. Moreover, in table 8, we report and compare the results with the benchmark values.

2.6.2. Main Results

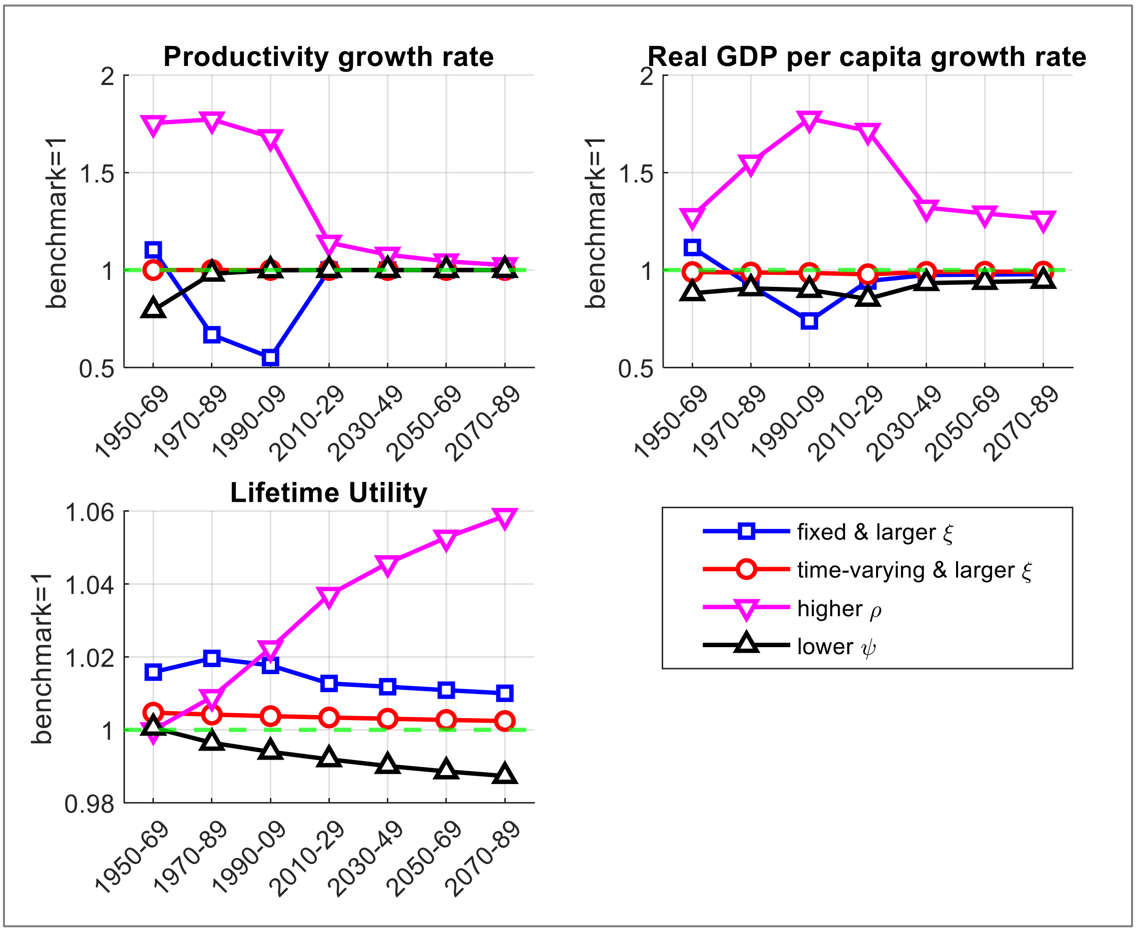

Figure 5. *Experiment Results*

In figure 5, the benchmark value is represented by the green line equating to one. Values above this line indicate that the experiment yielded positive effects. For instance, the GDP per capita growth rate standing at 1.5 translates into a 50% increase in the value of this variable in that period.

From diverse experiments involving a 5% R&D spending share in GDP, it is evident that the curvature parameter ρ plays a pivotal role in determining the efficiency that yields the most favorable outcomes in both welfare and growth. Productivity growth consistently exhibits an upward trajectory from the initial stage, albeit with a deceleration; nonetheless, this deceleration occurs from a higher level. If we consider a decrease from the benchmark's 1 unit level, in this experiment, the decline commences from 1.75 units in terms of growth rate.

Certainly, given the higher trajectory of the productivity growth rate, the GDP per capita growth rate also follows a higher path. The increase in the GDP per capita growth rate, in conjunction with production capabilities, facilitates a greater expansion in consumption possibilities. This, in turn, contributes to welfare through level effects.

With fixed but higher ξ, growth slowdown is more obvious with values with the trajectory descending below the benchmark path. As there is no increase in the periods 50-70 and 70-90, the economy experiences a considerably more pronounced slowdown in growth. Subsequently, it fails to recover. Nevertheless, even in this scenario, life time utility is higher compared to the benchmark, likely due to an increase in human capital. Spending less on R&D also translates into more consumption, and while this exerts a significant short-term level effect, in the long term, it reverts back to the benchmark, i.e., 1. However, owing to the growth impact from previous periods, this parameter change endures as a persistent level effect.

A time-varying higher ξ, on the other hand, turns out to create the least impact in terms of growth and welfare. Here, we allow for level adjustments considering the change over time of the R&D productivity parameter. It has almost no impact on growth, but due to the reduced spending on R&D, there is a slight welfare gain through increased consumption (productivity growth rate seems to be unaffected).

Experiment ψ yields the most unlikely results as it counteracts the expected outcomes. Reducing ψ implies a decrease in market entry, thereby adversely affects entrepreneurship. This process is supposed to generate a positive impact on R&D activities performed by incumbent firms, stemming from the increased profitability. However, GDP per **capita growth realizes** lower values. This indicates that the firm entry, namely the channel referred to as horizontal innovation, is not as inconsequential as previously presumed since GDP growth rate decreases. Besides, there is a welfare loss resulting from the increased monopoly power. If R&D were to have a positive significant impact, the economy would actually have tolerated these outcomes. In other words, if the gains assumed to have generated from R&D were to compensate or even surpass the efficiency loss arising from the monopoly, we would have expected positive effects on growth and utility. It would have also offset the loss resulting from the decline in *M*'s growth. However, even with an increased level of *S* to 5%, the growth rate of *A* does not increase because the negative effects of restricted competition and firm entry level are more pronounced.

Akcigit and Kerr (2018) present evidence indicating that research productivity diminishes with the size of the firm. This phenomenon is attributed to incumbent firms potentially redirecting their R&D efforts toward a "defensive" strategy aimed at safeguarding their market position. Consequently, this shift leads to a decline in research productivity. These findings align to some point with those of Becker (2014) who argues that R&D subsidies demonstrate positive effects particularly on smaller firms. Moreover, Mowery and Rosenberg (1993) emphasize that, in U.S. recently established and smaller enterprises played a significant role in the commercialization of emerging technologies, as opposed to EU and Japan where larger firms held a more dominant position.

Table 8. *Counterfactual Experiments*

Experiment	*Benchmark Value*	*Experiment Value*	*Change*	*Gstar*
5% R&D Expenditure Share in GDP				
Higher Fixed ξ_1 - Higher productivity of R&D	0.5985	2.1213	-1.5228	1.3409
Higher Fixed ξ_2 - Higher productivity of R&D	0.8356	2.1213	-1.1445	
Higher Fixed ξ_3 - Higher productivity of R&D	0.9768	2.1213	-1.0857	
Higher Fixed ξ_4 - Higher productivity of R&D	1.0356	2.1213	-1.2555	
Higher Time Varying ξ_1 - Higher productivity of R&D	0.5985	1.8540		
Higher Time Varying ξ_2 - Higher productivity of R&D	0.8356			
Higher Time Varying ξ_3 - Higher productivity of R&D	0.9768			
Higher Time Varying ξ_4- Higher productivity of R&D	1.0356			
Lower ψ - Larger Market Size	0.0581	0.0243	0.0338	
Higher ρ - Weaker Diminishing Returns	0.7092	0.8108	-0.1016	

2.7. CONCLUDING REMARKS

In the context of this complex model, consideration of only three arbitrarily chosen parameters yielded a notable goodness of fit. This signifies that the model adeptly mimics the dynamics of the U.S. economy, demonstrating its efficacy in forecasting the future values of fundamental variables in designing the economic outlook.

Perhaps, a broader approach is necessary to evaluate overall findings provided by the experiments stated above. For instance, according to Atkinson (2014), the United States is frequently cited as an exemplary model, implying that its role as a worldwide technology leader is primarily attributed to the effectiveness of its innovation system rather than being solely contingent on the magnitude of its R&D expenditures. Moreover, Guellec and van Pottelsberghe de la Potterie (2004) underscore the necessity for a comprehensive and cohesive innovation policy approach by governments in order for the publicly funded R&D yields positive growth implications. This is emphasized in light of the strong interconnections among diverse diffusion channels and technological sources.

Thus, instead of focusing on increasing the part of the research expenditures in GDP, we might elaborate on how to make the national innovation systems more effective.

CONCLUSION

The present study was designed to comprehensively examine the phenomenon of growth slowdown across diverse dimensions. In the first part, we investigate long-run economic growth dynamics where we provide an empirical analysis of different types of countries under different estimation methods to check whether there exists a slowdown in growth rates of GDP per capita, GDP per worker and TFP in advanced economies. We conduct estimations of the regression model described earlier under different specifications and examine the growth slowdown effects on multiple outcome variables. Additionally, we alter the country classifications across different estimations and then discuss the robustness of the framework. Finally, we report both fixed effects and random effects estimates of the model. The main results indicate a slowdown in the long-run growth rates of relevant variables in high-income countries. The slight discrepancy in the slowdown effects between GDP per worker and GDP per capita originates from the dependent population, such as the children and the retired; therefore, the pace of demographic transition should be considered more accurately in analyzing the slowdown effects, particularly that of GDP per capita, which encounters a more pronounced slowdown.

The primary limitations encountered in the first part basically comprehend the lack of microeconomic foundations that are sine qua non in explaining the growth mechanisms behind the "secular stagnation" occurring over the last decades. Achieving a thorough comprehension of these structural mechanisms in a genuinely satisfactory manner necessitates the formulation of endogenous growth models and their empirical validation using real-time data. Consequently, in the second part of the study, we embark on the construction of an endogenous growth model to meticulously examine the dynamics of slowdown, selecting the U.S. economy as a pivotal case study.

In the second part of this research, following the framework proposed by Attar (2019), we examine the determinants of economic growth in the U.S. economy spanning from 1950s to present. We develop an OLG-GE model that takes human capital, technology and fertility as endogenous variables and that holds 2GS features meaning that both horizontal and vertical innovation dimensions shape the market structure. Additionally, we make use of the child Q-Q tradeoff in determining human capital stock and fertility decisions based on household preferences.

After solving the model in light of the static and dynamic equilibrium requirements of the endogenous growth general equilibrium framework, we run the model using the genetic algorithm feature of MATLAB to provide a baseline calibration of the U.S. economy that replicates the real-time data. Our main aim is to capture the movement through the BGP and reach the highest explanatory power during the process. This is obtained using a mixed approach made possible by the MDP, allowing for the forward recursion of the dynamical system constructed as shown previously in detail.

We find that the model works well, considering both targeted and non-targeted moments, and leads to accurate paths throughout the transitions of different variables of interest. Thus, the model is within acceptable dimensions to analyze the U.S. economy's dynamics of growth slowdown, including forecasts for the long run.

The analysis of GDP per worker considers two fundamental determinants of growth: productivity and human capital. Our main findings indicate a direct proportional relationship between productivity and GDP per worker, as posited in the economic growth literature. However, this relationship is discerned with a one-period lag, indicating that the impact of an increase in productivity growth rate becomes apparent in the subsequent period's GDP per worker growth rate. In contrast, the relationship between human capital and GDP per worker is more substantial, exhibiting reciprocal evolution.

With confidence derived from the accuracy of our results, we aimed to enrich our study by conducting experiments in which we altered certain parameters of the model. These diverse experiments involved the same target, with a 5% share of R&D spending in the GDP. The most favorable outcome occurs through the curvature parameter, which affects diminishing returns. The most unlikely outcome, on the other hand, results from the experiment altering the market size effect. A lower entry rate to the market was supposed to increase the market size for incumbent firms, which would be more incentivized to increase their R&D investments that yield higher returns. However, the experiment shows that the welfare loss resulting from increased monopoly power has negative effects on growth and does not compensate for the efficiency loss caused by the decreasing stock of firms. This new understanding emphasizes the underestimated impact of horizontal innovation on economic growth, which is affected by microeconomic foundations.

The insights gained from this research underscore the significance of investments aimed at fostering growth in two primary determinants of GDP per worker: human capital and productivity. The question of whether such investments yield low and precarious returns or otherwise is a matter to be explored in a separate investigation.

The primary limitation of the model is that it does not incorporate international trade dynamics or the potential influence of economic policy considerations, making room for aspects such as R&D subsidies, taxes, social security, skill accumulation incentives, and effective knowledge diffusion. Additionally, the model lacks fundamental factors that mold long- run economic growth, including but not limited to geography, culture and institutions. Moreover, the preference for leisure represented by the parameter λ should be considered from scratch since the households' leisure preferences are undergoing a transformation which will affect directly the budget constraint and the market structure. Future research endeavors should delve into these unexplored dimensions to provide a more holistic understanding of long-run economic growth.

BIBLIOGRAPHY

Abiad, M. A., Leigh, M. D., Tytell, M. I., Balakrishnan, M. R., & Brooks, M. P. K. (2009). What's the damage? Medium-term output dynamics after banking crises. International Monetary Fund.

Acemoglu, D., Aghion, P., Lelarge, C., Van Reenen, J., & Zilibotti, F. (2007). Technology, Information, and the Decentralization of the Firm. The Quarterly Journal of Economics, 122(4), 1759-1799.

Acemoglu, D., Autor, D., & Patterson, C. (2023). Bottlenecks: Sectoral Imbalances and the US Productivity Slowdown. NBER Chapters.

Acemoglu, D., Johnson, S., Robinson, J. A., & Yared, P. (2008). Income and democracy. American economic review, 98(3), 808-842.

Acemoglu, D., Johnson, S., Robinson, J. A., & Yared, P. (2014). From education to democracy?. From Education to Democracy?, 103-113.

Acemoglu, D., Naidu, S., Restrepo, P., & Robinson, J. A. (2019). Democracy does cause growth. Journal of political economy, 127(1), 47-100.

Aeppel, T. (2014). Economists debate: Has all the important stuff already been invented?. The Wall Street Journal, 15.

Aghion, P., & Bircan, C. (2017). The middle-income trap from a Schumpeterian perspective. ADB Working Paper Series, 521.

Aghion, P., & Howitt, P. W. (2008). The economics of growth. MIT press.

Aghion, P., Akcigit, U., & Howitt, P. (2015). Lessons from Schumpeterian growth theory. American Economic Review, 105(5), 94-99.

Aghion, P., Bloom, N., & Blundell, R. (2005). Griffith, R., & Howitt. Competition and Innovation: An Inverted% U Relationship. The Quarterly Journal of Economics, 120(2).

Aghion, P., Harris, C., & Vickers, J. (1997). Competition and growth with step-by-step innovation: An example. European Economic Review, 41(3-5), 771-782.

Aghion, P., Harris, C., Howitt, P., & Vickers, J. (2001). Competition, imitation and growth with step-by-step innovation. The Review of Economic Studies, 68(3), 467-492.

Aghion, P., R. Blundell, R. Griffith, P. Howitt, and S. Prantl. (2006). "The Effects of Entry on Incumbent Innovation and Productivity." CEPR Discussion Paper No. 5323.

Aghion, Philippe, and Peter Howitt. 1992. "A Model of Growth Through Creative Destruction." Econometrica: Journal of the Econometric Society:323-351.

Akcigit, U., & Ates, S. (2018). Declining business dynamism and the diagnostics of its causes through growth theory.

Akcigit, U., & Ates, S. T. (2021). Ten facts on declining business dynamism and lessons from endogenous growth theory. American Economic Journal: Macroeconomics, 13(1), 257-298.

Akcigit, U., & Kerr, W. R. (2018). Growth through heterogeneous innovations. Journal of Political Economy, 126(4), 1374-1443.

Akcigit, Ufuk and Qingmin Liu, "The Role of Information in Innovation and Competition," Journal of the European Economic Association, 2016, 14 (4), 828–870.

Antolin-Diaz, J., Drechsel, T., & Petrella, I. (2017). Tracking the slowdown in long-run GDP growth. Review of Economics and Statistics, 99(2), 343-356.

Arrow, K. J. (1962). The economic implications of learning by doing. The review of economic studies, 29(3), 155-173.

Atkinson, R.D. (2014), "Understanding the U.S. National Innovation System", The Information Technology & Innovation Foundation, June, 2014.

Attar, M. U. S. T. A. F. A. (2019). Long-Run Economic Growth in Turkey: Sources, Pitfalls, and Prospects.

Avila, R., Faria, H. J., Montesinos-Yufa, H., & Morales, D. (2006). Time Series Stochastic Properties Of Growth Miracles And Growth Disasters. International Business & Economics Research Journal (IBER), 5(11).

BABINA, T., FEDYK, A., HE, A. X. and HODSON, J. (2023), "Artificial Intelligence, Firm Growth, and Industry Concentration", Journal of Financial Economics, forthcoming.

Baier, S. L., Dwyer Jr, G. P., & Tamura, R. (2006). How important are capital and total factor productivity for economic growth?. Economic Inquiry, 44(1), 23-49.

Baily, M. N., & Lawrence, R. Z. (2001). Do we have a new e-conomy?. American Economic Review, 91(2), 308-312.

Ball, L. (2014). Long-term damage from the Great Recession in OECD countries. European Journal of Economics and Economic Policies: Intervention, 11(2), 149-160.

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

Bar, M., & Leukhina, O. (2011). On the time allocation of married couples since 1960. Journal of Macroeconomics, 33, 491–510.

Becker, B. (2014), “Public R&D Policies and Private R&D Investment: A Survey of the Empirical Evidence”, Journal of Economic Surveys, 29(5), 917–942.

Becker, G. S. (1960). An Economic Analysis of Fertility. In Becker, G. S., Demographic and Economic Change in Developed Countries (pp. 209–231), Princeton: National Bureau of Economic Research.

Becker, G. S., Murphy, K. M., & Tamura, R. (1990). Human capital, fertility, and economic growth. Journal of political economy, 98(5, Part 2), S12-S37.

Bergeaud, A., Cette, G., & Lecat, R. (2016). Productivity trends in advanced countries between 1890 and 2012. Review of Income and Wealth, 62(3), 420-444.

Bils, M., & Klenow, P. J. (2000). Does schooling cause growth?. American economic review, 90(5), 1160-1183.

Blanchard, O. (2019). Public debt and low interest rates. American Economic Review, 109(4), 1197-1229.

Blanchard, O. J., & Summers, L. H. (1986). Hysteresis and the European unemployment problem. NBER macroeconomics annual, 1, 15-78.

Bloom, N., Jones, C. I., Van Reenen, J., & Webb, M. (2020). Are ideas getting harder to find?. American Economic Review, 110(4), 1104-1144.

Blundell, R., Griffith, R., & Reenen, J. V. (1995). Dynamic count data models of technological innovation. The economic journal, 105(429), 333-344.

Blundell, R., Griffith, R., & Van Reenen, J. (1999). Market share, market value and innovation in a panel of British manufacturing firms. The review of economic studies, 66(3), 529-554.

Brynjolfsson, E., & McAfee, A. (2014). The second machine age: Work, progress, and prosperity in a time of brilliant technologies. WW Norton & Company.

Byrne, D. M., Fernald, J. G., & Reinsdorf, M. B. (2016). Does the United States have a productivity slowdown or a measurement problem?. Brookings Papers on Economic Activity, 2016(1), 109-182.

Comin, D., and S. Mulani. (2007). “A Theory of Growth and Volatility at the Aggregate and Firm Level.” Proceedings, Federal Reserve Bank of San Francisco.

Congressional Research Service Reports, September 2022. R44307.pdf (fas.org).

De la Croix, D., & Gosseries, A. (2012). The natalist bias of pollution control. Journal of environmental economics and management, 63(2), 271-287.

Desmet, K., & Parente, S. L. (2012). The evolution of markets and the revolution of industry: a unified theory of growth. Journal of economic growth, 17, 205-234.

Diao, X., Roe, T., & Yeldan, E. (1999). Strategic policies and growth: an applied model of R&D-driven endogenous growth. Journal of Development Economics, 60(2), 343-380.

Dinopoulos, E., & Sener, F. (2007). New directions in Schumpeterian growth theory. Elgar Companion to Neo-Schumpeterian Economics, Edward Elgar, 1-16.

Dinopoulos, E., & Thompson, P. (1998). Schumpeterian growth without scale effects. Journal of Economic Growth, 3(4), 313–335.

Easterly, W., & Levine, R. (2001). It's Not Factor Accumulation: Stylized Facts and Growth Models. The World Bank Economic Review, 15(2), 177–219. http://www.jstor.org/stable/3990260

Fernald, J. G. (2015). Productivity and Potential Output before, during, and after the Great Recession. NBER Macroeconomics Annual, 29(1), 1-51.

Fernald, J. G., & Jones, C. I. (2014). The future of US economic growth. American Economic Review, 104(5), 44-49.

Fogel, K., R. Morck, and B. Yeung. (2008). "Big Business Stability and Economic Growth: Is What's Good for General Motors Good for America?" Journal of Financial Economics, forthcoming.

Freeman, C. (1988), 'Japan: A New National Innovation System?', in G. Dosi, C. Freeman, R. R. Nelson, G. Silverberg and L. Soete (eds.), Technology and Economy Theory, London: Pinter.

Friedman, B. M. (2016). A century of growth and improvement. American Economic Review, 106(5), 52-56.

Fritz, M., Gries, T., & Feng, Y. (2019). Secular stagnation? Is there statistical evidence of an unprecedented, systematic decline in growth?. Economics Letters, 181, 47-50.

Galor, O. (2012). The demographic transition: causes and consequences. Cliometrica, 6(1), 1-28.

Galor, O., & Weil, D. N. (2000). Population, technology, and growth: From Malthusian stagnation to the demographic transition and beyond. American economic review, 90(4), 806-828.

Gordon, R. J. (2012). Is US economic growth over? Faltering innovation confronts the six headwinds (No. w18315). National Bureau of Economic Research.

Gordon, R. J. (2015). Secular stagnation: A supply-side view. American Economic Review, vol. 105(5), 54-59, May.

Gordon, R. J. (2016). Perspectives on the rise and fall of American growth. American Economic Review, 106(5), 72-76.

Gordon, R. J. (2018). Declining American economic growth despite ongoing innovation. Explorations in Economic History, 69(C), 1-12.

Gordon, R. J., & Sayed, H. (2019). The industry anatomy of the transatlantic productivity growth slowdown (No. w25703). National Bureau of Economic Research.

Gordon, Robert J.,The Rise and Fall of American Growth: The U.S. Standard of Living since the Civil War, Princeton University Press, 2016.

Grossman, G. M., & Helpman, E. (2015). Globalization and growth. American Economic Review, 105(5), 100-104.

Grossman, Gene M, and Elhanan Helpman. 1991. "Quality ladders in the theory of growth." The Review of Economic Studies 58 (1):43-61.

Guellec, D. and Van Pottelsberghe de la Potterie, B. (2003), “The Impact of Public R&D Expenditure on Business R&D”, Economics of Innovation and New Technology, 12(3), 225–243.

Ha, J., & Howitt, P. (2007). Accounting for trends in productivity and R&D: A Schumpeterian critique of semi-endogenous growth theory. Journal of Money, Credit and Banking, 39(4), 733-774.

Hall, R. E. (2015). Quantifying the lasting harm to the US economy from the financial crisis. NBER Macroeconomics Annual, 29(1), 71-128.

Hall, R. E., & Jones, C. I. (1999). Why do some countries produce so much more output per worker than others?. The quarterly journal of economics, 114(1), 83-116.

Haltmaier, J. (2013). Do recessions affect potential output?. FRB International Finance Discussion Paper, (1066).

Hansen, A. H. (1939). Economic progress and declining population growth. The American Economic Review, 29(1), 1-15.

https://www.oecd.org/about/members-and-partners.

Huang, K. A. I. X. I. N. G. (2016). The Role of Population and Human Capital in Determining the Economic Growth Rate. Tech. rept. School of Economics, the University of Adelaide, 10 Pulteney Street, Adelaide, SA, 5000.

İlay, K. U. R. T. (2023). On the Growth Slowdown in Developed Economies. Fiscaoeconomia, 7(1), 755-770.

IMF World Economic Outlook October 2023.

Jones, C. I. (1995). “R&D-Based Models of Economic Growth.” Journal of Political Economy, 103, 759–784.

Jones, C. I. (1997). The upcoming slowdown in US economic growth.

Jones, C. I. (2001). Was an industrial revolution inevitable? Economic growth over the very long run. The BE Journal of Macroeconomics, 1(2), 153460131028.

Jones, C. I. (2002). Sources of US economic growth in a world of ideas. American economic review, 92(1), 220-239.

Jones, C. I. (2017). The productivity growth slowdown in advanced economies. In Investment and growth in advanced economies, conference proceedings (pp. 313-323). Sintra: ECB Forum on Central Banking.

Jones, C. I. (2022). The end of economic growth? Unintended consequences of a declining population. American Economic Review, 112(11), 3489-3527.

Jones, C. I., & Romer, P. (2010). The New kaldor facts: Ideas, institutions, population, and human capital. American Economic Journal: Macroeconomics, 2(1), 224–245

Kahn, J., & Rich, R. (2013). Productivity Model Update. December. http://newyorkfed. org/research/national_economy/richkahn_prodmod. pdf.

Karahan, Fatih, Benjamin Pugsley, and Aysegul Sahin, “Demographic Origins of the Startup Deficit,” 2016. New York Fed, mimeo.

Klenow, P. J., & Rodriguez-Clare, A. (1997). The neoclassical revival in growth economics: Has it gone too far?. NBER Macroeconomics Annual, 12, 73-103.

Lundvall, B-Å. (1985), Product Innovation and User-Producer Interaction, Aalborg: Aalborg University Press.

Lundvall, B-Å. (ed.) (1992, 2010), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter Publishers. (2010), London: Anthem Press.

Lusinyan, M. L., & Cardarelli, M. R. (2015). US Total Factor Productivity Slowdown: Evidence from the US States (No. 2015/116). International Monetary Fund.

Malthus, T. R. (1798). An Essay on the Principle of Population. Printed for J. Johnson, in St. Paul’s Church-Yard, London.

Mincer, J. A. (1974). The human capital earnings function. In Schooling, experience, and earnings (pp. 83-96). NBER.

Mokyr, J. (2018). The past and the future of innovation: Some lessons from economic history. Explorations in Economic History, 69, 13-26.

Mowery. D.C. and Rosenberg, N. (1993), 'The U.S. National Innovation System', In: R.R. Nelson (ed.), National Innovation Systems: A Comparative Analysis, New York: Oxford University Press.

Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt, "Competition and Innovation: An Inverted-U Relationship," Quarterly Journal of Economics, 2005, 120 (2), 701–728.

Organisation for Economic Co-operation and Development- Our global reach - OECD

Peretto, P. F., & Valente, S. (2015). Growth on a finite planet: resources, technology and population in the long run. Journal of Economic Growth, 20, 305-331.

Peretto, P., & Connolly, M. (2007). The Manhattan Metaphor. Journal of Economic Growth, 12(4), 329–350.

Peters, M., & Walsh, C. (2021). Population growth and firm dynamics (No. w29424). National Bureau of Economic Research.

Plosser, C. I. (2014). Economic Growth and Monetary Policy: Is There a New Normal?. The George Washington University and Princeton University's Griswold Center for Economic Policy Studies, Philadelphia, 5-7.

Prescott, E. C. (1986, September). Theory ahead of business-cycle measurement. In Carnegie-Rochester conference series on public policy (Vol. 25, pp. 11-44). North-Holland.

PWT 10.0 | Penn World Table | Groningen Growth and Development Centre | University of Groningen (rug.nl)

Ramey, V. A. (2020). Secular stagnation or technological lull?. Journal of Policy Modeling, 42(4).

Ramsey, F. P. (1928). A mathematical theory of saving. Economic Journal, 38(152),

Reifschneider, D., Wascher, W., & Wilcox, D. (2015). Aggregate supply in the United States: recent developments and implications for the conduct of monetary policy. IMF Economic Review, 63(1), 71-109.

Romer, P. M. (1986). Increasing returns and long-run growth. Journal of Political.

Romer, Paul M. 1990. "Endogenous technological change." Journal of political Economy:S71-S102.

Schumpeter, J. A. (1942). Socialism, capitalism and democracy. Harper and Brothers.

Siskova, M., Kuhn, M., Prettner, K., & Prskawetz, A. (2023). Does human capital compensate for population decline? The Journal of the Economics of Ageing, 26, 100469.

Solow, R. M. (1956). A contribution to the theory of economic growth. Quarterly Journal of Economics, 70(1), 65–94. doi: 10.2307/1884513

Storm, S. (2017). The new normal: Demand, secular stagnation, and the vanishing middle class. International Journal of Political Economy, 46(4), 169-210.

Summers, L. H. (2014). US economic prospects: Secular stagnation, hysteresis, and the zero lower bound. Business economics, 49(2), 65-73.

Summers, L. H. (2015) My views and the Fed's views on secular stagnation | Larry Summers

Summers, L. H. (2015). Demand side secular stagnation. American economic review, 105(5), 60-65.

Swan, T. W. (1956). Economic growth and capital accumulation. Economic Record,

Syverson, C. (2017), Challenges to mismeasurement explanations for the US productivity slowdown, Journal of Economics Perspectives, Vol. 31, No. 2, pp. 165–186.

The World Bank- High Income https://data.worldbank.org/country/high-income.

Tirole, J. (1988). The theory of industrial organization. MIT press.

Vollrath, D. (2020). Fully grown: Why a stagnant economy is a sign of success. University of Chicago Press.

World Economic Situation and Prospects 2020 (un.org).

World Populations Prospects 2022 (un.org).

APPENDIX 1. LIST OF HIGH INCOME COUNTRIES

List of High Income Countries

World Bank Group (D1)		United Nations Group (D2)		OECD Group (D3)	
Australia	Italy	Australia	Iceland	Australia	Iceland
Austria	Japan	Austria	Ireland	Austria	Ireland
Belgium	Luxembourg	Belgium	Italy	Belgium	Israel
Canada	Malta	Canada	Japan	Canada	Italy
Chile	Mauritius	Cyprus	Luxembourg	Chile	Japan
China, Hong Kong SAR	Netherlands	Denmark	Malta	Colombia	Luxembourg
Cyprus	New Zealand	Finland	Netherlands	Denmark	Netherlands
Denmark	Norway	France	New Zealand	Finland	New Zealand
Finland	Panama	Germany	Norway	France	Norway
France	Portugal	Greece	Portugal	Germany	Portugal
Germany	Republic of Korea	Spain	Romania	Greece	Republic of Korea
Greece	Romania	Switzerland	Sweden	Spain	Sweden
Iceland	Singapore	United Kingdom	United States	Switzerland	Turkey
Ireland	Sweden			United Kingdom	United States
Israel	Taiwan				
Spain	Trinidad and Tobago				
Switzerland	United States				
United Kingdom	Uruguay				

APPENDIX 2. WHAT IS A GENETIC ALGORTIHM AND HOW DOES IT WORK?

The genetic algorithm, grounded in the principles of natural selection governing biological evolution, serves as an approach to address both constrained and unconstrained optimization problems. It iteratively adjusts a population of individual solutions to achieve its objectives.

In each iteration, the genetic algorithm chooses individuals from the existing population to act as parents, employing them to generate the children for the subsequent generation. Through successive generations, the population gradually progresses towards an optimal solution.

The genetic algorithm can be used to address a range of optimization problems that are not particularly suitable for conventional optimization algorithms. These include problems with discontinuous, nondifferentiable, stochastic, or highly nonlinear objective functions.

The genetic algorithm is also capable of tackling mixed-integer programming problems, where certain components are constrained to have integer values.

The functioning of the genetic algorithm:

1. The process initiates by generating an initial population at random.
2. 143eSubsequently, the algorithm generates a series of new populations. In each iteration, the individuals from the current generation are utilized to form the succeeding population. The following steps outline the process of creating the new population:

   a) Evaluates the fitness of each member in the current population by calculating its fitness value, referred to as raw fitness scores.
   b) Adjusts the raw fitness scores through scaling to transform them into a more practical range of values, known as expectation values.
   c) Chooses individuals, referred to as parents, according to their expectation values.

d) A subset of individuals in the existing population with lower fitness is selected as elite. These elite individuals are carried over to the subsequent population.

e) Generates offspring from the parents, where children are created through either introducing random alterations to a single parent (mutation) or by merging the vector entries of a pair of parents (crossover).

f) Substitutes the current population with the offspring to establish the succeeding generation.

3. The algorithm concludes when it satisfies any of the specified stopping criteria.
4. The algorithm follows adjusted procedures when dealing with linear and integer constraints.

The distinctions between genetic algorithms and classical algorithms lie in:

1. The genetic algorithm produces a population of points in each iteration rather than a single point. The optimal solution is approached by the best point in the population rather than a sequence of points.
2. Chooses the subsequent population through a computation involving random number generators, as opposed to selecting the next point in the sequence through deterministic computation.
3. Usually requires a substantial number of function evaluations to converge. It may or may not converge to a local or global minimum. In contrast, classical algorithms typically converge rapidly to a local solution.

APPENDIX 4. ORIGINALITY REPORT

	HACETTEPE ÜNİVERSİTESİ SOSYAL BİLİMLER ENSTİTÜSÜ	Doküman Kodu *Form No.*	FRM-DR-21
		Yayım Tarihi *Date of Pub.*	04.01.2023
	FRM-DR-21 Doktora Tezi Orijinallik Raporu *PhD Thesis Dissertation Originality Report*	Revizyon No *Rev. No.*	02
		Revizyon Tarihi *Rev.Date*	25.01.2024

TO HACETTEPE UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF ECONOMICS

Date: 17/02/2024

Thesis Title (In English):The Dynamics of Growth Slowdown in Developed Economies

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İlay KURT

Student Information				
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	Programme	İngilizce İktisat		
	Status	**PhD** ☒		**Combined MA/MSc-PhD** ☐

SUPERVISOR'S APPROVAL

APPROVED
Doç. Dr. M. Aykut ATTAR

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		Yayım Tarihi *Date of Pub.*	04.01.2023
	FRM-DR-21 **Doktora Tezi Orijinallik Raporu** *PhD Thesis Dissertation Originality Report*	Revizyon No *Rev. No.*	02
		Revizyon Tarihi *Rev.Date*	25.01.2024

HACETTEPE ÜNİVERSİTESİ
SOSYAL BİLİMLER ENSTİTÜSÜ
İKTİSAT ANABİLİM DALI BAŞKANLIĞINA

Tarih: 17/02/2024

Tez Başlığı The Dynamics of Growth Slowdown in Developed Economies

Yukarıda başlığı verilen tezimin a) Kapak sayfası, b) Giriş, c) Ana bölümler ve d) Sonuç kısımlarından oluşan toplam 81 sayfalık kısmına ilişkin, 17/02/2024 tarihinde şahsım/tez danışmanım tarafından Turnitin adlı intihal tespit programından aşağıda işaretlenmiş filtrelemeler uygulanarak alınmış olan orijinallik raporuna göre, tezimin benzerlik oranı % 14'tür.

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3. ☐ Alıntılar hariç
4. ☒ Alıntılar dâhil
5. ☒ 5 kelimeden daha az örtüşme içeren metin kısımları hariç

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