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THE WEALTH OF WORKING NATIONS

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ABSTRACT

GDP growth per capita and GDP growth per working-age adult have become quite different in advanced economies. Countries with lackluster GDP growth per capita, such as Japan, have performed well in working-age adult terms. Furthermore, many advanced economies are on parallel growth trajectories in working-age adult terms despite differences in levels. We calibrate a standard growth model in which the growth of the working-age adult population varies in line with the data. The calibrated model tracks output per working-age adult in most cases. We conclude that the growth of mature, aging economies is not puzzling from a theoretical perspective.

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1 Introduction

As the populations of advanced economies age, output growth per capita is becoming a misleading indicator for growth theory. Changes in the working-age population have become so large that output growth per capita can hide important movements in output per working-age adult, a more natural object to focus on for many (but not all) purposes.[1]

The paradigmatic case for this argument is Japan. Between 1991 and 2019, GDP in Japan grew at an annual rate of 0.83%, much lower than the 2.58% of the U.S. This seemingly disappointing performance motivated a myriad of books and papers analyzing Japan's lackluster growth and presenting multiple remedies. Pesek (2014), who popularized the term "Japanization," writes:

> ...few lessons are more timely or critical than those offered by Japan, a once-vibrant model for developing economies that joined the world's richest nations, lost its way, and has been struggling to relocate it ever since.
>
> In this book I explore what the world can learn from a Japanese economic funk that began more than 20 years ago and has never really ended. That means exploring where Japan went wrong, how it sank under the weight of hubris and political atrophy, and missed opportunity after opportunity to scrap an insular model based on overinvestment, export-led growth, and excessive debt.

However, the outlook is dramatically different if we look at GDP per working-age adult. Japan has grown at an annual rate of 1.39%, while the U.S. has grown at 1.65%, only 26 basis points (bps) more. Indeed, from 1998 to 2019, Japan has grown *slightly faster* than the U.S. in terms of per working-age adult: an accumulated 31.9% vs. 29.5%. Even more strikingly, if we focus on the period 2008-2019 (i.e., after the outbreak of the financial crisis), Japan has the highest growth rate per working-age adult among our sample of G7 countries plus Spain. There is nothing mysterious about Japan's low total GDP growth: it is merely a consequence of an annual *fall* in the working-age population of about 0.5%.[2]

[1] As is common in the literature and statistical surveys, we define the working-age population as adults between 15 and 64 years old. Child labor is minimal in the advanced economies we consider (the G7 plus Spain). On the other hand, participation rates for adults 65 and older are low but, in some cases, significant. In 2019 (the last year of our dataset), participation rates of adults 65 and older ranged from 2.5% in Spain to 25.3% in Japan (OECD, 2024). We will revisit this point later.

[2] The participation rate of Japanese adults aged 65 and over remained stable, at 25.3% in 1991 and 25.3% in 2019. In contrast, the U.S. rate increased from 11.5% to 20.2% during the same period. Later, we will present an

To document the previous observation systematically, we report basic facts on GDP growth and population for the G-7 countries plus Spain from 1991 to 2019 (in an extension, we also add China and India). In doing so, we provide a big picture of the growth process accompanying changing demographics.

We find that while the working-age population of Canada and the United States grew by about 29-31% between 1991 and 2019, the working-age adult population of Italy and Germany marginally declined by about 2%. Meanwhile, the working-age adult population of Japan fell by about 14%. These differences among countries are large. Yet, output per working-age adult behaved similarly for all economies except Italy. All these economies except Italy are on parallel trends, resembling the balanced growth paths of textbook growth models. Moreover, these trajectories are independent of diverging trajectories in the size of the working-age adult population.

To understand these observations, we develop and calibrate a standard one-sector growth model with exogenous technological growth. The size of the working-age population varies according to the data for each economy. In this context, we ask the extent to which the observed growth patterns of developed economies are consistent with the predictions of basic theory.

The logic of the model is straightforward. The economy travels along a growth path determined by the exogenous growth of technology, the discount factor, and total population growth. Since the production function depends on labor, variations in the labor/population ratio induce transitional dynamics. Thus, a lower labor/population ratio is equivalent to a negative technological shock in a standard real business cycle model (and with the same persistent and propagation effects).

This intuition illustrates that our key insight is that aging changes the ratio of working-age adults to the total population. In the very long run, as the consequences of lower fertility rates and longer life expectancy are worked out through the population pyramid, we might return to a situation where the labor/population ratio stabilizes. At that moment, output growth per capita and output per working-age adult will again become roughly the same.

Our model does a very good job of tracking the observed output per working-age adult in terms of the mean squared errors (MSE) between the model and the data in all cases except Italy. Also, the model calibrated to match output growth per working-age adult tracks much better *both* output per working-age adult and output per capita than the same model calibrated to

output growth decomposition where we employ the total hours worked in the economy to account for changes in demographic composition and participation rate by age. Our main result is robust: in terms of total hours worked, Japan grew 1.26% a year from 1991 to 2019, and the U.S. 1.53%, only 27 bps more.

match output growth per capita, the "canonical" practice in the literature as prescribed by Barro and Sala-i-Martin (2003) and Cooley and Prescott (1995). Our interpretation of the quantitative results is not that our model is the best possible one, but rather that our results support the argument that growth theory must pay sharp attention to output growth per working-age adult, even when working with the simplest models and having an interest in income per capita.

The Appendix extends our analysis in different ways. Our conclusion from the analysis and its extensions is straightforward: the observed behavior of mature, aging economies is not puzzling. Rather, the observed growth paths agree with the simple prediction of basic theory under a slow-moving change in the size of its labor force.

Implications. A central implication of our analysis is that understanding the impact of fiscal and monetary policies, for instance, requires considering demographic trends. This perspective problematizes the traditional assessments of policy effectiveness, such as Japan's monetary policy. Judging Japanese monetary policy from 1991 to 2019 as a failure because it could not deliver faster output growth per capita faces the challenge that monetary policy can do next to nothing about long-run demographic forces. Given that Japan's and U.S. output growth per working-age adult was roughly the same between 1991 and 2019, it is hard to see what else the Bank of Japan could have achieved.

At the same time, we are cautious regarding how to apply our study to assess migration and fertility policies. Immigration, for example, significantly impacts population growth in countries like Canada and the U.S. Yet, its direct association with economic output per working-age adult in our dataset is less evident. We are less concerned with endogenous fertility. Long-term demographic shifts, such as those seen in Japan, are rooted in fertility decisions decades ago.

While we focus on output growth per working-age adult as *one* key object for growth theory, this does not diminish the relevance of other objects like total output growth or per capita growth, which have implications for public debt and social security; see Faruqee and Mühleisen (2003) and Kitao (2015). Similarly, Klenow et al. (2017) argue for the importance of considering total population to evaluate social welfare growth. We are deliberately silent about social welfare.

We also prefer measuring growth via output per working-age adult rather than output per worker or hour worked. Our measure provides us with a comprehensive view of an economy's production possibilities, a central indicator for growth theory. In contrast, the alternative two measures depend on tax/transfer policies and the labor-market regulations in place. Furthermore, data on hours are often of low quality. Nonetheless, we also report growth in terms of output per worker and per hour worked. The results are nearly identical to the findings using output growth in terms of per working-age adult (except for Spain). This complementary analysis reinforces our main point: looking at total GDP growth in times of demographic changes can be misleading.

Related literature. We are not the first to report data or calibrate models in terms of per working-age adult. While this practice is less common than using per capita terms, many papers have followed it, e.g., Klein and Ventura (2021), or several of the chapters in Kehoe and Nicolini (2022).

A large literature explores economic growth and population aging links, starting with Auerbach and Kotlikoff (1990), Cutler et al. (1990), and Weil (1997). Recent related works include Kotschy and Bloom (2023), who focus on the population aging-growth link. However, we differ by emphasizing GDP growth measurement from a growth theory perspective using a standard model instead of empirical regressions. Jones (2022) used endogenous growth models with idea discoveries to study a possible stagnation of living standards from shrinking populations. In contrast, we take technological progress as given and focus on measuring the object of interest in growth theory when working-age populations decline. See also Sasaki and Hoshida (2017) and Sasaki (2019).

Jaimovich and Siu (2009) attribute one-fifth to one-third of the volatility decline of U.S. output to demographic change. Ferraro and Fiori (2020) note that the aging of the baby boomers reduces tax cut effects on aggregate unemployment. Cravino et al. (2022) quantify how aging increases the service consumption share. Acemoglu and Restrepo (2021) link automation and aging. Maestas et al. (2023) find U.S. per capita GDP growth declined by 0.3 percentage point yearly from 1980-2010 due to aging. Hopenhayn et al. (2022) and Karahan et al. (2019) use aging to explain recent declines in firm concentration, entrepreneurship, labor share, and start-up rates. Aksoy et al. (2019) estimate a panel VAR showing how demographics affect OECD data.

The paper is organized as follows. In Section 2, we document the facts of interest. In Section 3, we present, calibrate, and solve the standard growth model we use. Our quantitative results are in Section 4. Section 5 concludes. An Appendix reports further details that provide perspective on our results.

2 Data

Our main data source is the World Bank's World Development Indicators (WDI) database, which compiles comparable statistics for a large number of countries and territories.[3] Real GDP is the GDP in national constant prices. The working-age population is the population between 15 and 64 years old. For our set of mature economies, we consider the G7 countries (U.S., Canada, U.K., Germany, France, Italy and Japan). We also include Spain, the largest Western European economy that is not a member of the G7 and one that has undergone a swift demographic transformation.

2.1 Growth Facts I: 1981-2019

We compute growth facts for the countries in our sample from 1981 to 2019. The WDI does not include all the relevant data before 1981 (GDP data in the WDI start from 1981 for Canada, 1970 for Germany, and 1960 for the other six countries). In any case, this paper's main point is that relating population aging to GDP growth only became relevant in the 1980s.

Table 1 reports output and population facts for 1981-2019. All the variables are annual growth rates and expressed in percentage points. As in all the tables in the paper, we highlight a few numbers in red because they are salient to our argument.

In the first row of Table 1, we see large differences in yearly GDP growth. While Italy (the worst performer in terms of GDP growth) has only grown 1.17% a year for four decades, the U.S. (the best performer) has grown 2.71%. This is a huge difference. In accumulated terms, the Italian economy has grown 155% since 1981, while the U.S. economy has grown 275%.

The second row of Table 1 starts showing our main argument. In per capita terms, the differences in GDP growth become much smaller. Now Italy, still the worst performer, has grown at a rate of 1.03%, while the U.S. has only grown at a rate of 1.74%. A difference in total GDP growth of 1.54% is only a difference of 0.71% in per capita terms. The third row, population growth, explains these differences: while Italy's population has grown at 0.15% a year, the U.S. population has been growing at 0.95%.

Even more interesting is the fourth row of Table 1, where we report GDP growth per working-age adult. The relative performance of Italy vs. the U.S. does not change much, but this is not the case for other countries. For example, compare Japan and the U.S. (our numbers in red). Japan's

[3] For the strength of the WDI vs. alternative databases such as the Penn World Tables (PWT), see Pinkovskiy and Sala-i-Martin (2016).

GDP growth is nearly 1% a year lower than the U.S. (1.78% vs. 2.71%). However, in terms of per working-age adult, Japan outperforms the U.S. (1.96% vs. 1.78%). In fact, Japan becomes the top performer in terms of GDP growth per working-age adult. The mechanism behind this difference is the fifth row of Table 1: while the working-age population has fallen in Japan (-0.18% vs. a total annual population growth of 0.19%) due to population aging, it has grown in the U.S. at 0.91% (roughly the same speed as the total population).

Figure 1 plots the underlying time series. Look at the evolution of the population between ages 15 and 64 in each of the eight countries (bottom right panel). Compare the evolution of the working-age population in the U.S. (dashed blue line at the top of the panel) with the evolution in Japan (dashed green line at the bottom).

2.2 Growth Facts II: 1991-2019

The effects of population aging became more acute in the 1990s. For instance, the working-age population peaked in Japan in 1994 and fell afterward. Consequently, if we drop the 1980s and focus on the more recent period 1991-2019, our results become more striking.[4] The bottom panel of Table 1 presents the facts for the shorter period 1991-2019, while Figure 2 replicates Figure 1 also for 1991-2019.

Let us return to the comparison between Japan and the U.S. Japan's GDP growth has been a lackluster 0.83% (the second worst performance ahead only of Italy). One could fill a library with the books and papers diagnosing the forces behind this performance. But when considering GDP per working-age adult, Japan's growth rate of 1.39% is only slightly behind the U.S. (1.65%). Excluding the early 1990s asset price collapse, Japan grew faster than the U.S. in terms of per working-age adult from 1998 to 2019, with an accumulated growth of 31.9% vs. 29.5% in the U.S. While Japan's working-age population declined by about 0.54% annually from 1991 to 2019, the U.S. experienced 0.91% growth, a difference of 1.45% per year. Suddenly, there is nothing much to explain about Japan's performance: there are fewer Japanese of working age, and a smaller labor input leads to lower total GDP growth. Put differently, for Japan to match the GDP growth of the U.S., its GDP growth per working-age adult would need to have grown at nearly 3% a year, an outstanding feat once Japan had completed its neoclassical growth transition by the late 1980s.

[4] Also, below, we will report an output growth decomposition, and the employment data required for this decomposition start in 1991.

In fact, as we show in Figure 2, seven out of our eight economies (the exception being Italy) moved roughly the same from 1991 to 2019. This is just the time series behind the fourth row of the second panel of Table 1, where GDP growth per working-age adult except in Italy ranges from 1.33 (France) to 1.62 (UK), a narrow range and with much less dispersion in growth rates than in 1981-2019.

2.3 Levels vs. Growth Rates

The countries in our sample started in 1981 with important differences in output *levels*. For example, Spain's output per working-age adult in 1981 was around one-third lower than that of the U.S. Thus, the low dispersion in growth rates shows a lack of convergence toward the U.S. output level. The most striking case is Italy, which is diverging. This is intriguing since Italy did not have a financial collapse (like Ireland), nor was it under a memorandum of understanding with the European Union (like Spain in July 2012). Italy's problems seem deeper than digesting the aftermath of a financial meltdown.

2.4 A Growth Decomposition

Before, we argued that we find the growth of output per working-age adult more informative than the growth of output per worker or per hours worked because of the endogeneity of employment and hours choices. Nonetheless, our results are robust to using these alternative measures.

To show this, define the identity $Y_t \equiv N_t a_t e_t h_t y_t$ where:

1. N_t is total population at t.
2. a_t is the working-age adults $(WA)_t$, per person $((WA)_t/N_t)$.
3. e_t is total employment (regardless of the age of the worker), E_t, as a fraction of working-age adults, $E_t/(WA)_t$. That is, e_t measures the fraction of employed people in terms of working-age adults.
4. h_t is hours worked (regardless of the age of the worker), H_t, divided by total employment H_t/E_t.
5. y_t is output per hour worked Y_t/H_t.

Since the WDI does not have hours data, we use the hours measure from the Conference Board reported by PWT 10.0 – "average annual hours worked by persons engaged."

Table 2 reports the results of this decomposition plus GDP growth per worker, the growth rate of hours, and the growth rate of the working-age population. The key finding is very similar to the main result in our benchmark analysis.[5] For instance, Japan's performance in terms of GDP per hour worked, 1.26% annual growth, compares more favorably with the U.S.' performance (1.53% growth) than in terms of total output (0.83% vs. 2.58%). Indeed, the difference in growth rates of GDP per hour worked (1.53% - 1.26% = 0.27%) is nearly the same as the difference in growth rates of GDP per working-age population (1.65% - 1.39% = 0.26%). GDP per hour worked evolved very similarly to GDP per working-age adult in all the other countries of our sample, with the exception of Spain, probably due to the large immigration inflow into the country in the period.

The key driver of the decomposition in Table 2 is the evolution of total hours worked, which fell -0.43% a year in Japan and increased by 1.04% in the U.S. The evolution of total hours in Japan, -0.43%, is very close to the evolution of the working-age population, -0.54%. A similar result holds for the U.S.: 1.04% growth of hours and 0.91% growth of the working-age population.

We can explore each term of the decomposition further, focusing on the case of Japan. While the working-age population as a fraction of the total population has slightly fallen in the U.S. (-0.03% per year), it has fallen strongly in Japan (-0.62%). Interestingly, increases in the employment rate in terms of the working-age population in Japan (0.74%) have been nearly exactly compensated by a fall in hours worked per worker (-0.6%). The former increase is due to more older people working (even if the participation rate is constant, the total number of people over 65 has grown). Also, female labor force participation has slightly increased. The latter fall is mainly driven by the fact that hours per worker have fallen from an average of around 2,000 hours for full-time workers to around 1,800 hours, closer to the standard in the U.S. and other advanced economies. In the U.S., in comparison, the employment rate per working-age adult and hours worked per worker have been flat. The main factor behind the differences in the U.S. total GDP growth and GDP per hour worked is the growth rate of its population, a vigorous 0.94% per year.

[5] In the case of output per worker, the level of the growth rates is lower (reflecting fewer hours worked per worker across our sample), but the relative performance of countries is roughly the same as when we look at output per working-age adult or output per hour worked.

3 A Standard Growth Model

To understand our observations and highlight the importance of demographics, we formulate a standard one-sector growth model with exogenous technological change and demographics. Each country is modeled as a different economy, without any other interaction except a possible common technology trend. For simplicity, we will work with the social planner's problem formulation in the model, as both welfare theorems hold in our model. We abstract from endogenous labor choices because we want to focus on our economy's growth properties, not its business cycle features.

3.1 Preferences and Technology

The economy is populated by an infinitely lived representative household of varying size N_t. Later, when we take the model to the data, we will equate N_t with the total population.

The preferences of the representative household over per capita consumption are represented by:

$$\max_{C_t/N_t} \sum_{t=0}^{\infty} \beta^t N_t \log\left(\frac{C_t}{N_t}\right),$$

where β is the discount factor and C_t is aggregate consumption.

Output is given by $Y_t = K_t^{\theta}(A_t L_t)^{1-\theta}$ where K_t is capital, and L_t is the working-age population. $A_t = A_0(1+g)^t$ is the level of labor-augmenting technology, which grows at a constant rate g. Output is used for consumption or investment I_t. Given a depreciation rate δ, the law of motion for capital is $K_{t+1} = I_t + (1-\delta)K_t$. The resource constraint is given by $C_t + I_t = Y_t$. Finally, N_t grows at an exogenously given time-varying rate n_t, so that $N_t = \prod_{i=1}^{t}(1+n_i)$, given $N_0 = 1$.

Given the growth of technology and population, we must normalize the variables. We use $A_t N_t$ to make the problem stationary. Specifically, let $c_t = \frac{C_t}{A_t N_t}$, $k_t = \frac{K_t}{A_t N_t}$, $i_t = \frac{I_t}{A_t N_t}$, and $y_t = \frac{Y_t}{A_t N_t} = k_t^{\theta} l_t^{1-\theta}$, where l_t denotes the working-age population rate L_t/N_t.

A standard Euler equation characterizes the solution to the planner's problem:

$$c_t^{-1}(1+g) = \beta c_{t+1}^{-1}\left(\theta(k_{t+1})^{\theta-1}(l_{t+1})^{1-\theta} + 1 - \delta\right).$$

This Euler equation looks like the optimality condition of the textbook neoclassical growth model with population and technological growth except for the presence of a time-varying term l_{t+1}. As such, shocks to N_t and A_t have the usual effects on output and investment.

Imagine, for a second, that $l_{t+1} = \widehat{l}$ is constant, i.e., the working-age population is a constant fraction of the total population. This is equivalent to a constant in front of the (normalized) production function and, hence, irrelevant to the dynamics of the model.

Conversely, consider the case where, as in our calibration below, l_{t+1} changes (i.e., the labor force as a fraction of the total population varies). This is equivalent to a shift in the level of the (normalized) production function as if we had a technological shock: a rise in l_{t+1} increases total production and hence investment and output; a drop in l_{t+1} lowers total production and thus investment and output. In other words, changes in l_{t+1} have the same effect as technological shocks in a real business cycle model without labor choice (and with the same persistence and propagation).

3.2 Calibration and Solution

Our model is indexed by the parameters β, θ, and δ plus the exogenous values for g, N_t, L_t, and the scaling parameter A_0. We also assume that each economy is on its balanced growth path in terms of per working-age adult at the start of the simulation.

We pick common values of β, θ, and δ for all countries to match annual data for 1981-2019 and follow commonly used targets. We select a discount factor β of 0.946 to replicate a 7.6% annual rate of return to capital reported by the PWT 10.0 for the U.S. between 1981 and 2019 (given our model, we want to match the return on all capital goods, not on bonds or other financial assets). We pick the capital share $\theta = 0.39$ to match the average shares between 1981 and 2019 from PWT 10.0. The depreciation rate is the average depreciation rate from PWT 10.0 for the U.S.: $\delta = 0.04$. These values imply a capital/output ratio of about 3.36.

We show next how to calibrate g, N_t, L_t, and A_0 for the U.S. case. Analogous steps are used for all other countries, and we skip their explanation in the interest of space. First, we select A_0 to match the level of U.S. GDP per capita in 1981. This is just a normalization. The L_t and N_t match the observed data year by year in the U.S. Finally, we calibrate $g = 0.0178$ to match GDP growth per working-age population from 1981 to 2019 in the U.S. The corresponding values for the rate g for Canada, France, Germany, Italy, Japan, Spain, and the U.K. are 0.0133, 0.0142, 0.0169, 0.0107, 0.0196, 0.0165, and 0.0188, respectively.[6]

[6] We explored using TFP data to calibrate the model. Unfortunately, the WDI does not include TFP data, and the data from the PWT are not compatible with WDI because of several assumptions the PWT makes.

To find the planner's solution, we take the initial steady state of the normalized model in 1981 and its final steady state in 2019 and compute the transition path between the two using the Euler equation and the investment and resource constraint equations using a nonlinear equation solver. We repeat this process for all countries, where we only change g, N, and A_0.

4 Quantitative Results

In this section, we present our model's quantitative results.

4.1 1981-2019

Figure 3 plots the evolution of output per working-age adult in each of the countries from 1981 to 2019. In each panel, the dashed blue line represents the model, and the solid red line represents the data (normalized to 1 in 1981). While the dashed blue line might appear to be straight, it presents small fluctuations due to varying L_t/N_t ratios. However, since those variations occur at low frequency, they do not change much the slope of the dashed blue line.

The left panel in the top row is the U.S. The model captures well the main evolution of the U.S. economy during the sample. The MSE between the model and data (with output per working-age adult normalized to 1 in 1981) is just 57 bps. The most salient divergence is the drop in income per worker after the financial crisis of 2007-2009, with a permanent change in the trend level of 4.1%. A similar picture of a permanent drop in the output level of around one log point holds for Spain (the left panel in the bottom row) and the U.K. (the right panel in the bottom row). The U.S., Spain, and the U.K. were three economies where many researchers identified a real estate boom in the early 2000s, which has left long-lasting scars. Later, we explore further the idea that g has changed.

The model performs well for Canada, France, and Germany, with minor data-model deviations. However, it clearly misses Italy's growth dynamics, which stagnated in the early 2000s. Capturing this requires calibrating low growth over 1981-2019, causing a large persistent undershooting pre-2000. The MSE between the model and data for Italy is a much higher 126 bps. As in the case of the U.S., introducing different trend growth rates pre-/post-2007 helps resolve this issue. See the Appendix and Fernández-Villaverde et al. (2023a) for more details on Italy's performance.

Japan displays a similar but less severe pattern. Japan grew at extremely fast rates during the 1980s, driven by neoclassical growth convergence. But it then suffered a deep crisis after the drop in asset prices after 1992. The model only captures Japan's average four-decade growth by deviating from the data in the 1980s before slowly returning to the data post-1992. See Fernández-Villaverde et al. (2023b) for an exercise related to Japanese convergence since 1950.

4.2 1991-2019

We repeat the exercise in Figure 1 except now with the shorter sample 1991-2019. We present the corresponding figure in the Appendix. By eliminating the 1980s, all the discussions in the previous subsection become even sharper. The model accounts very well for the experiences of Canada, France, and Germany, quite well for the experiences of the U.S., Japan, Spain, and the U.K. (except for not capturing the boom of the mid-2000s), and misses aspects of Italy unless we introduce a change in the trend of technology.

4.3 The Importance of Demographics

To show the importance of integrating the right demographic measurements in growth models, we recalibrate the model to match GDP growth per capita in each country instead of GDP per working-age adult. Calibrating the model to GDP growth per capita is the practice recommended, for example, in the textbook expositions of Barro and Sala-i-Martin (2003, p. 58) and Cooley and Prescott (1995, p. 20). We call this alternative procedure the "canonical" calibration.

Then, we compare the match of our baseline calibration and the "canonical" calibration to the data using the MSE between the data and the path generated by the model. We look at output per capita and output per working-age adult. In both cases, the "canonical" calibration performs worse than our baseline calibration. For some countries, such as the U.S., the deterioration of fit is not large because L_t/N_t does not change much in our sample. But for other countries, such as Germany and Japan, the deterioration of fit is considerable: the MSE for both output per capita and output per working-age adult nearly triples. In other words, a researcher following the "canonical" calibration will underestimate the standard theory's ability to account for the data, paradoxically even for GDP growth per capita, the target of her "canonical" calibration.

The lesson from our results is *not* that our simple growth model accounts for all features of the data (or that the model is superior to other theoretical frameworks, such as an overlapping generations model) but how, once we look at the data in terms of per working-age adult, there is much more agreement between theory and data.

4.4 Further Exercises

In the Appendix, we present a set of additional exercises. We summarize them here.

First, we use a common g for all countries. Above, we calibrated a country-specific g. The motivation was that technological progress in each country might be mediated by local institutions and social norms that imply that not all scientific and engineering discoveries and business practice developments are implemented equally across the economies (Bloom and Van Reenen, 2010).

Here, we pick the g of the U.S. as a proxy for the growth of the world's technological frontier. In particular, we eliminate the possibility that different aging speeds in each country might lead to different g's (for example, slower adoption of new technologies by an aged workforce). The time-varying population growth rate and working-age population ratio remain country-specific.

A common g makes little difference for Germany, Spain, Japan, and the U.K., since their calibrated country-specific g's are close to the g for the U.S. However, it accentuates how Canada, France, and Italy seem to be falling behind the U.S.

Second, we change the trends of g, both in terms of slope and in levels (i.e., a permanent drop in A), after 2007, to capture the lower growth rate observed in the data after the financial crisis. For example, in the U.S., output growth per adult worker falls from 2.06% to 1.34%. In the case of Italy, it even goes negative, from 1.67% to -0.11%. Interestingly, the country with the highest growth rate of output per working-age adult in this later period is Japan, with 1.49%.

With this change in trends, the model fits the data even better. The improvement is particularly salient when we let A fall in 2008 and continue at its old growth rate. This suggests that the financial crisis permanently reduced the level of technology in our economies.

Third, we extend our analysis to China and India, the two most populated economies in the world. This exercise illustrates when it is relevant to distinguish between total, per capita, and per working-age adult output growth rates in emerging economies.

Both countries have experienced very fast growth since 1980: 9.60% and 6.08%, respectively. The different growth rates for China do not change much whether we look at them in total, per capita, or per working-age adult terms: 9.60%, 8.60%, and 8.18%. This similarity reflects the underlying strong growth of the economy after the start of the economic reforms in 1979 and the relatively moderate growth of the population and working-age population. By 1980, China's fertility rate was already as low as 2.32. Thus, China is a modern incarnation of the behavior common in advanced economies in the 1960s or 1970s, when modern growth theory was developed. In the case of India, however, we have a mirror image of Japan: the GDP growth rate per working-age adult of 3.79% looks much less impressive than the high rate of total GDP growth, 6.08%, due to the fast growth rate of the working-age population (2.21%).

The populations of China and India have not aged enough to make the use of GDP per capita misleading from the perspective of growth theory. However, as China (over the next two decades) and India (starting around 2040) start feeling the effects of an acute aging, we will see the same mechanisms at work as for the G7 and Spain.[7]

5 Conclusion

As Lucas (1988) famously put it, "Once one starts to think about them [the questions involving economic growth], it is hard to think about anything else." But to do so, we need the right measurements. Historically, economists have looked at total and per capita output growth rates to evaluate an economy's performance and test their theories of growth (and the business cycle). We have argued that, as the population ages, total and per capita output growth rates have become increasingly misleading since the early 1990s. The sharpest example is Japan: once we correct for population aging by focusing on output growth rates per working-age adult, Japan appears as a surprisingly robust economy over the last 25 years, outperforming the other G7 countries and Spain.

Admittedly, looking at output growth rates per working-age adult is not without problems: more older individuals are remaining in the labor force, and the trend will continue over the coming decades. However, this fact is not of first-order importance for this paper, as discussed in our growth decomposition in Table 2. But the question remains: how do we define (potential) labor inputs in the most fruitful way for theory? While still a good proxy for individual welfare, output growth per capita is fast becoming a source of confusion more than a help. Let us look for something better.

[7] According to China's National Bureau of Statistics, China's total population started falling in 2022.

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Table 1: G7 plus Spain: Basic Growth and Population Facts

1981-2019	Canada	France	Germany	Italy	Japan	Spain	UK	U.S.
GDP	2.37	1.84	1.75	1.17	1.78	2.35	2.30	2.71
GDP per capita	1.26	1.31	1.60	1.03	1.58	1.76	1.84	1.74
Population	1.10	0.52	0.15	0.15	0.19	0.59	0.45	0.95
GDP per working-age adult	1.33	1.42	1.69	1.07	1.96	1.65	1.88	1.78
Working-age population	1.03	0.41	0.07	0.10	-0.18	0.70	0.42	0.91
1991-2019	Canada	France	Germany	Italy	Japan	Spain	UK	U.S.
GDP	2.47	1.61	1.38	0.70	0.83	2.05	2.08	2.58
GDP per capita	1.40	1.10	1.25	0.52	0.76	1.35	1.53	1.63
Population	1.05	0.50	0.14	0.18	0.08	0.68	0.54	0.94
GDP per working-age adult	1.48	1.33	1.47	0.79	1.39	1.41	1.62	1.65
Working-age population	0.98	0.27	-0.09	-0.08	-0.54	0.63	0.46	0.91

Table 2: Output Growth Decomposition

1991-2019		Canada	France	Germany	Italy	Japan	Spain	UK	U.S.
GDP	Y_t	2.47	1.61	1.38	0.70	0.83	2.05	2.08	2.58
Population	N_t	1.05	0.50	0.14	0.18	0.08	0.68	0.54	0.94
Working-age per person	a_t	-0.08	-0.23	-0.22	-0.27	-0.62	-0.05	-0.08	-0.03
Emp. rate per working-age	e_t	0.42	0.35	0.57	0.34	0.74	0.90	0.36	0.17
Hours worked per worker	h_t	-0.17	-0.30	-0.40	-0.26	-0.61	-0.14	-0.11	-0.04
GDP per hour worked	y_t	1.23	1.28	1.31	0.71	1.26	0.67	1.37	1.53
GDP per worker	Y_t/E_t	1.05	0.98	0.90	0.45	0.65	0.53	1.25	1.49
GDP per working-age adult	Y_t/L_t	1.48	1.33	1.47	0.79	1.39	1.41	1.62	1.65
Total hours worked	H_t	1.23	0.33	0.08	0.00	-0.43	1.40	0.71	1.04
Working-age population	L_t	0.98	0.27	-0.09	-0.08	-0.54	0.63	0.46	0.91

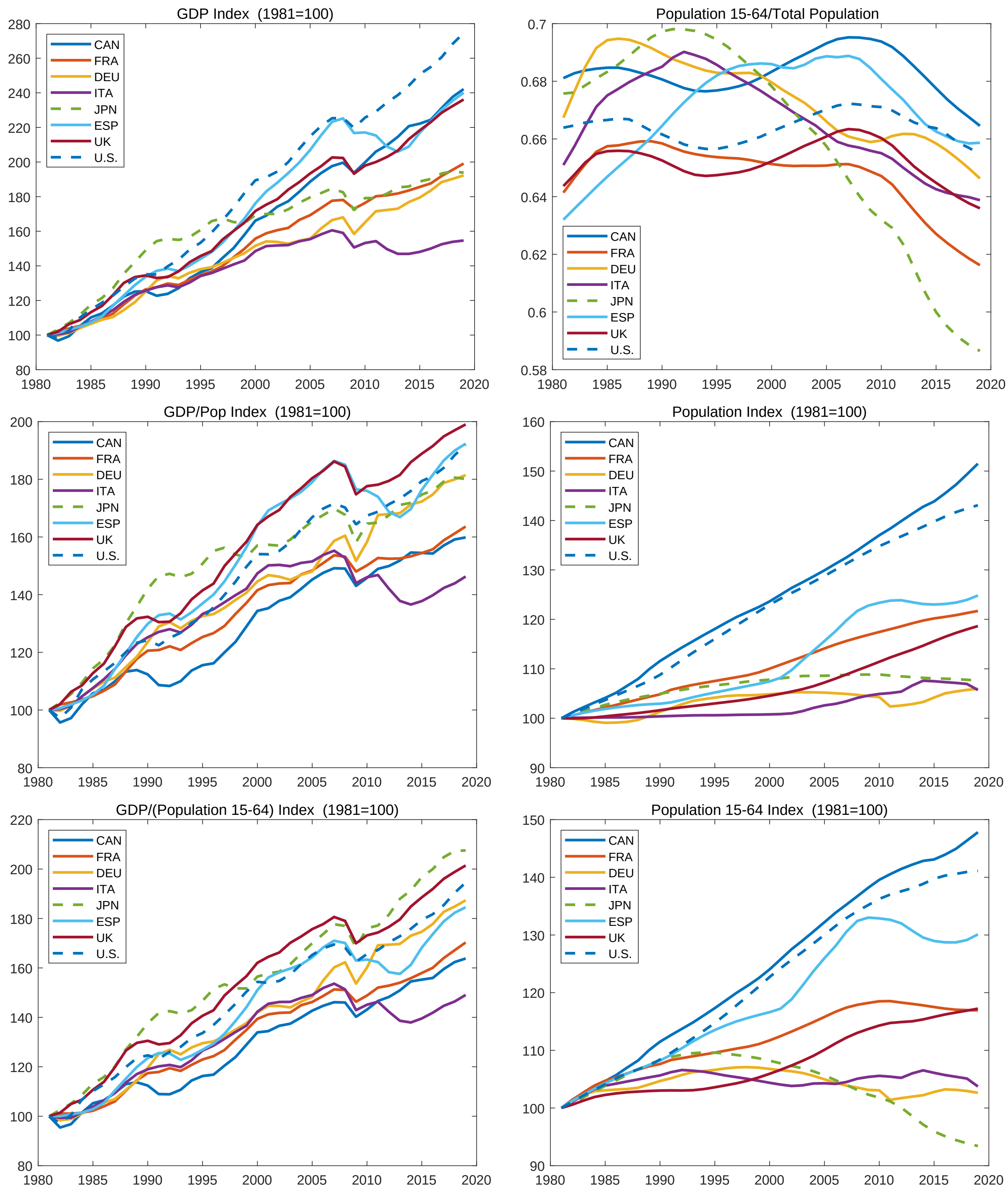

Figure 1: G7 and Spain: 1981 - 2019

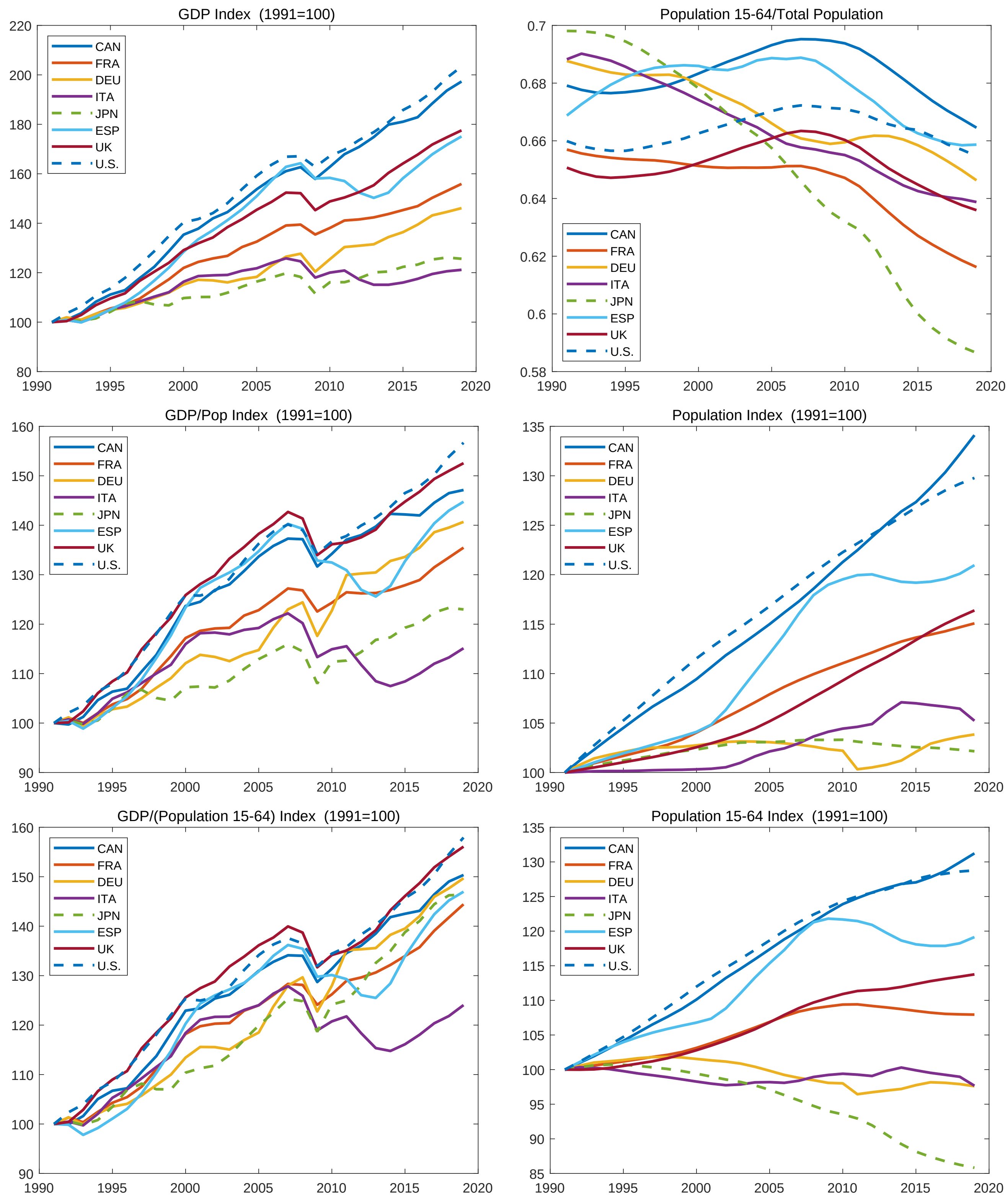

Figure 2: G7 and Spain: 1991 - 2019

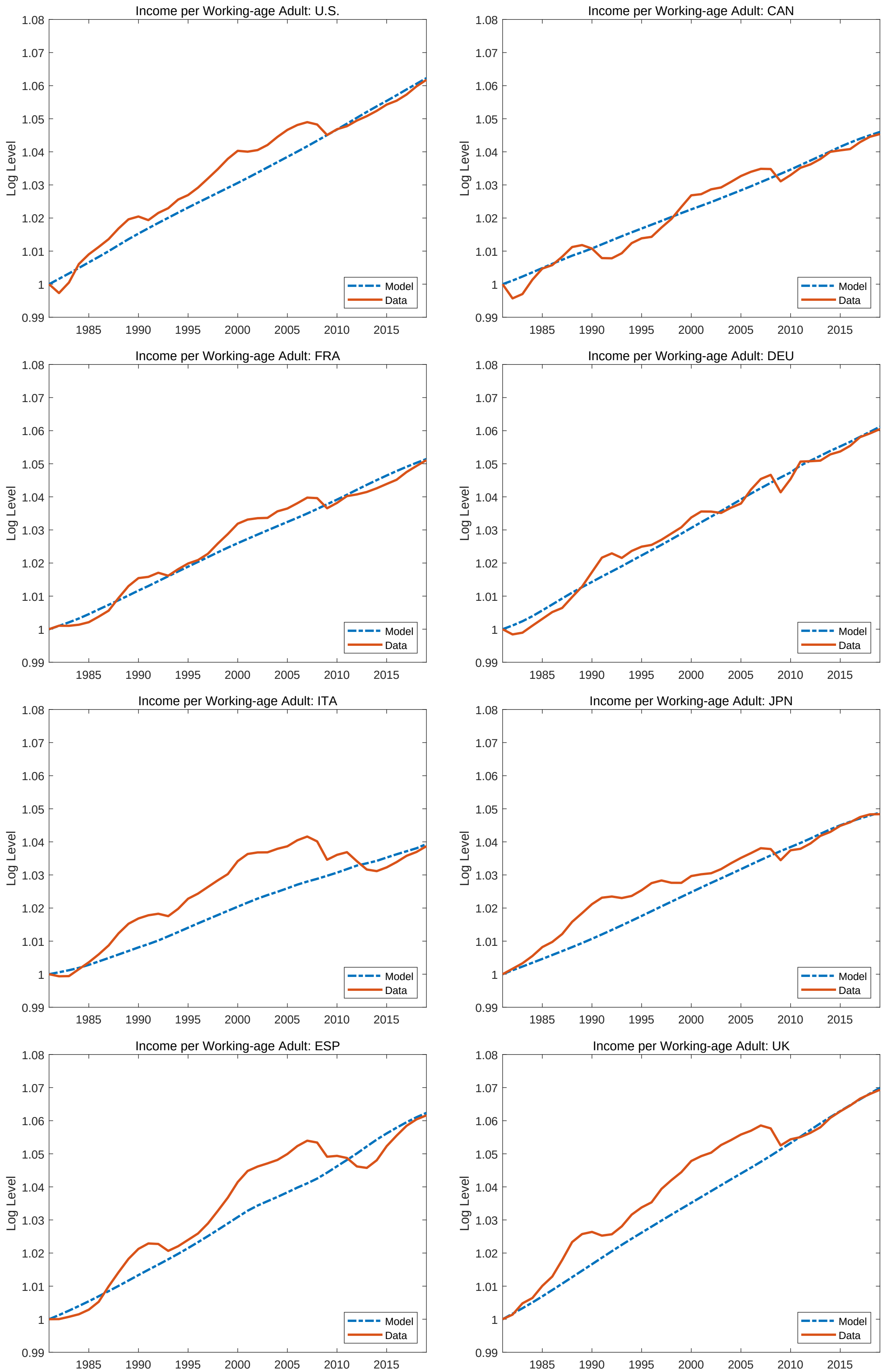

Figure 3: Transitional Dynamics: 1981-2019

Appendix to: “The Wealth of Working Nations”

Jesús Fernández-Villaverde, Gustavo Ventura, and Wen Yao*

April 3, 2024

This Appendix provides an additional figure (Figure 1, with the transitional dynamics of our model for 1991-2019) and a further discussion of our findings.

1 Using a Common g

In the main text, we calibrate a country-specific g. In our first robustness exercise, we instead impose the condition that each country's GDP growth rate per worker is the same as in the U.S., 0.0178. The U.S. GDP growth rate per working-age adult in 1980-2019 is the highest in our sample, behind Japan's (which, as we argued in the main text, was still catching up with its balanced growth path in the 1980s) and the U.K. (which in the 1980s was recovering from its turbulent economic maladies of the 1970s). Furthermore, the U.S. was the richest economy in our sample. Thus, as a first-order approximation, one can consider the U.S. g as a measure of the growth of the world's technological frontier.

Figure 2 shows our results. The model accounts well for the behavior of Germany (right panel in the second row) and Spain (left panel in the bottom row). This is not surprising since Germany's and Spain's output growth rates per working-age adult in 1981-2019 were only slightly below that of the U.S. Thus, substituting their own g with the g of the U.S. makes little difference. Conversely, the model still does well, except for a lower level of the balanced growth path for Japan

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(right panel in the third row) and the U.K. (right panel in the bottom row). Here, the challenge for the model comes from the observation that Japan's and the U.K.'s own g's are a bit higher than that of the U.S.

The interesting observation from this exercise comes from Canada (right panel in the top row) and France (left panel in the second row), which now join Italy in showing a clear underperformance of their economies with respect to the model's prediction. Even if we use the working-age population, Canada, France, and Italy are falling behind with respect to what is achievable.

2 Changing Trends

Our quantitative findings suggested the importance of considering changes in the growth trend of technology. To explore this possibility, we split our sample between the periods 1981-2007 and 2008-2019, or before and after the financial crisis. Table 1 presents the same statistics as in Table 1 of the main text but for different subperiods. We see large drops in the rates of GDP growth per working-age adult.

We illustrate the effects of a time-varying trend in our neoclassical growth model in Figure 3. In the interest of space, we only report the case of the U.S. and Italy (the results for the other countries are roughly similar). The growth of g from 1981 to 2007 is given by its value at the top of Table 1, and the economy is transitioning along its balanced growth path. Then, in 2008 and in an unanticipated way, the growth of g drops to its value at the bottom of Table 1 from that moment on, and we compute the transition to a new balanced growth path in 2050 (sufficiently far in the future to ensure we have a complete view of the transition).

The model now does a better job of matching the observations for the U.S. and Italy, including the stagnation of the latter. However, our model is completely silent about the sources of the change in g.

However, the fit is still not perfect. A possible alternative to having two trends would be to have a shock to the growth path's level. In terms of our model, this would correspond to a sudden drop in A. We report the results in Figure 4. Now, the fit of the model to the data is much better. This suggests that a fruitful way to think about the financial crisis is as a permanent drop in the level of A, not a change in the slope of the trend.

3 China and India

Table 2 follows the same format as Table 1 in the main text but for China and India. Figure 5 plots the time series for these two countries. No matter in which terms we compute output growth rates, the difference between China and India is staggering.

We do not include a simulation of our neoclassical growth model for these two countries and compare it to the data. To understand China's and India's growth paths through the lenses of the neoclassical growth model, we need to consider the process of convergence to the advanced economies. This exercise would require the introduction of additional elements in the model. See, for example, Fernández-Villaverde et al. (2023), where a neoclassical model similar to the one in this paper is calibrated to capture China's technological catch-up with the U.S.

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Table 1: G7 plus Spain: Basic Growth and Population Facts

1981-2007	Canada	France	Germany	Italy	Japan	Spain	UK	U.S.
GDP	2.68	2.24	1.99	1.84	2.41	3.15	2.76	3.19
GDP per capita	1.57	1.67	1.80	1.71	2.08	2.44	2.43	2.11
Population	1.09	0.56	0.19	0.13	0.32	0.70	0.33	1.05
GDP per working-age adult	1.49	1.61	1.84	1.67	2.25	2.10	2.31	2.06
Working-age population	1.17	0.62	0.15	0.17	0.15	1.03	0.44	1.10
2008-2019	Canada	France	Germany	Italy	Japan	Spain	UK	U,S.
GDP	1.79	1.03	1.27	-0.23	0.58	0.61	1.43	1.81
GDP per capita	0.65	0.61	1.16	-0.36	0.68	0.38	0.71	1.11
Population	1.13	0.42	0.11	0.14	-0.10	0.23	0.71	0.70
GDP per working-age adult	1.07	1.11	1.35	-0.11	1.49	0.78	1.10	1.34
Working-age population	0.71	-0.07	-0.08	-0.12	-0.90	-0.16	0.33	0.46

Table 2: China and India: Basic Growth and Population Facts

1981-2019	China	India
GDP	9.60	6.08
GDP per capita	8.60	4.25
Population	0.92	1.76
GDP per working-age adult	8.18	3.79
Working-age population	1.31	2.21
1990-2019	China	India
GDP	9.53	6.25
GDP per capita	8.72	4.57
Population	0.75	1.61
GDP per working-age adult	8.50	4.05
Working-age population	0.95	2.12

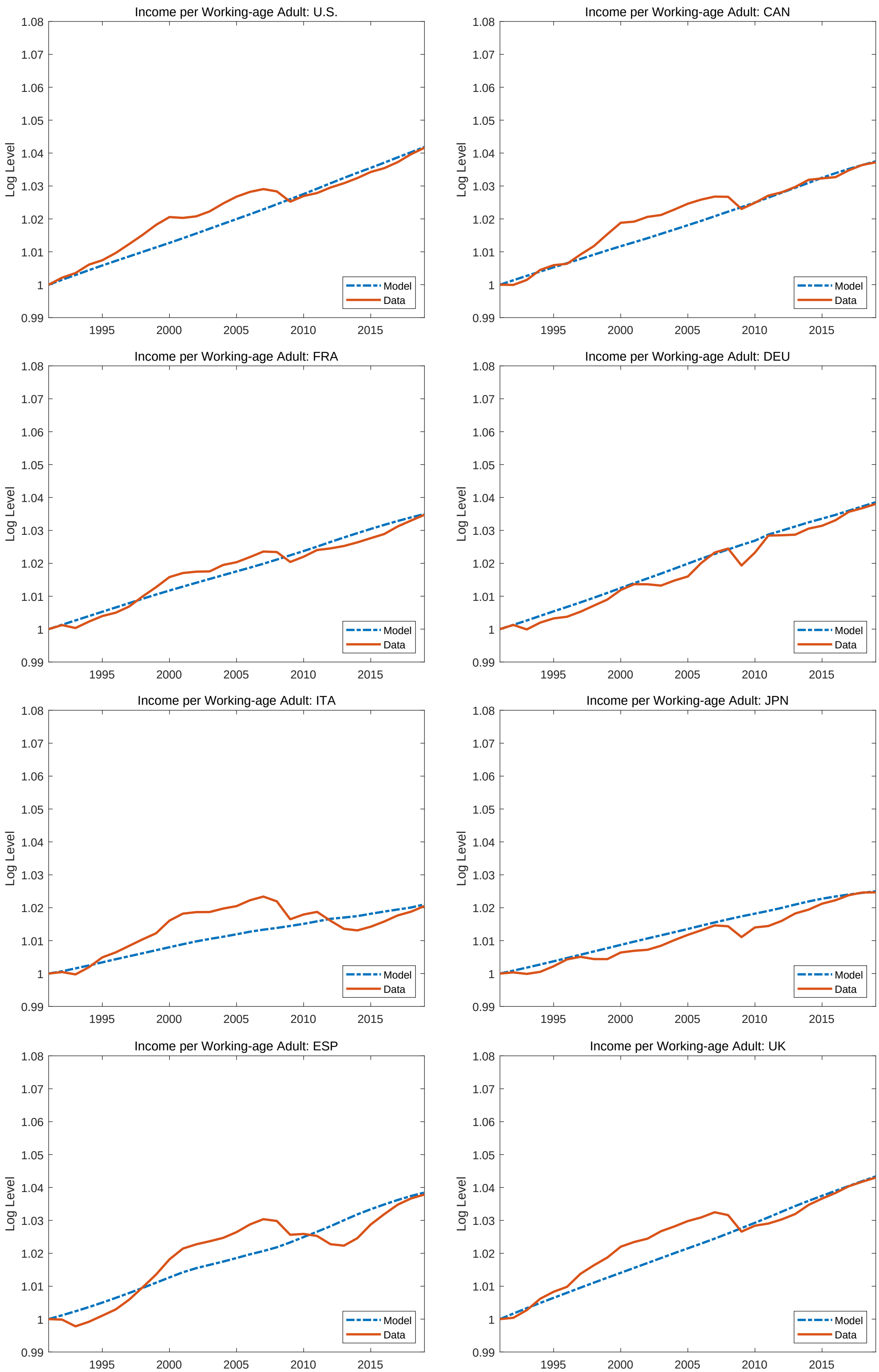

Figure 1: Transitional Dynamics: 1991-2019

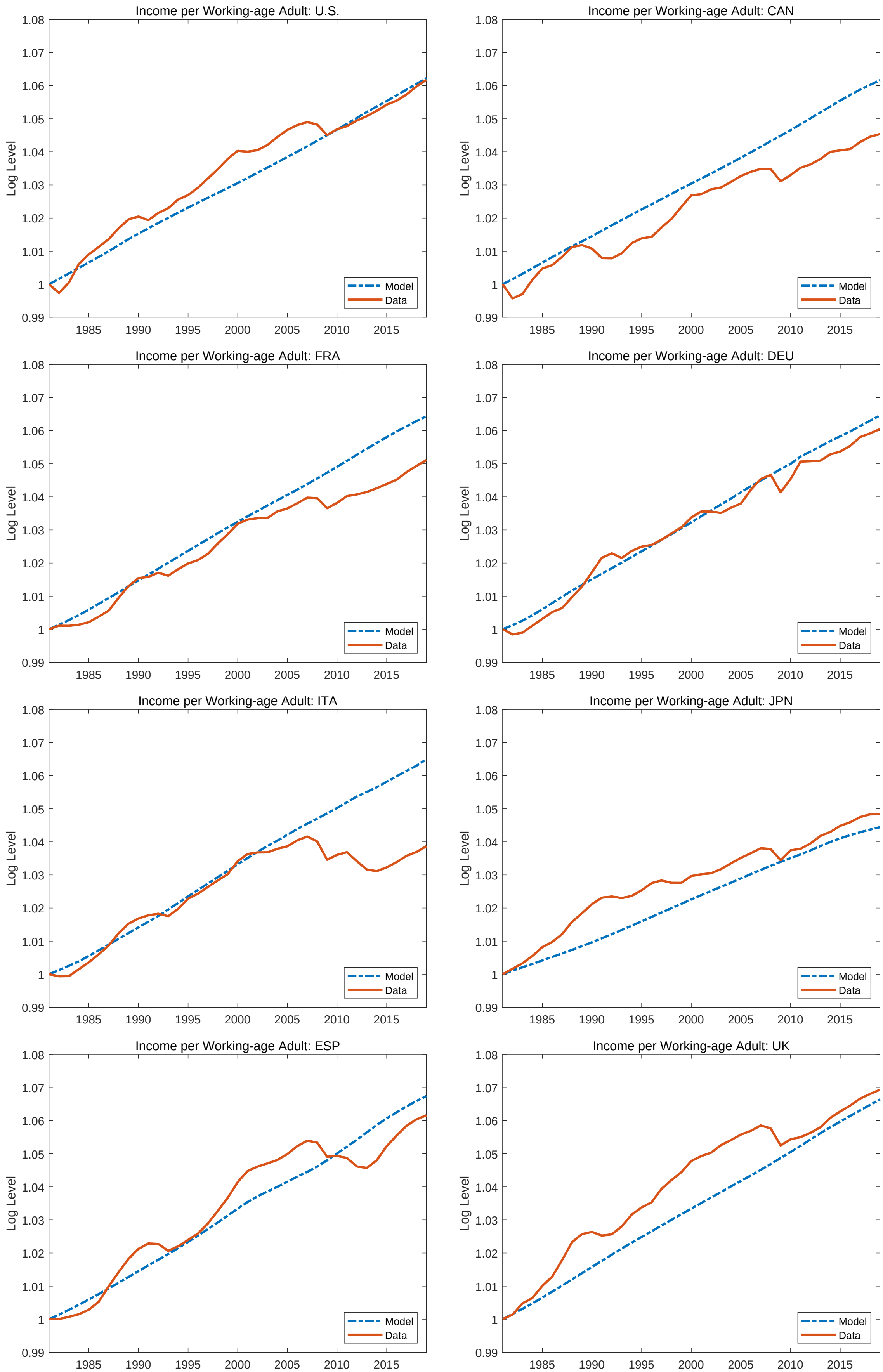

Figure 2: Transitional Dynamics: 1981-2019, common g

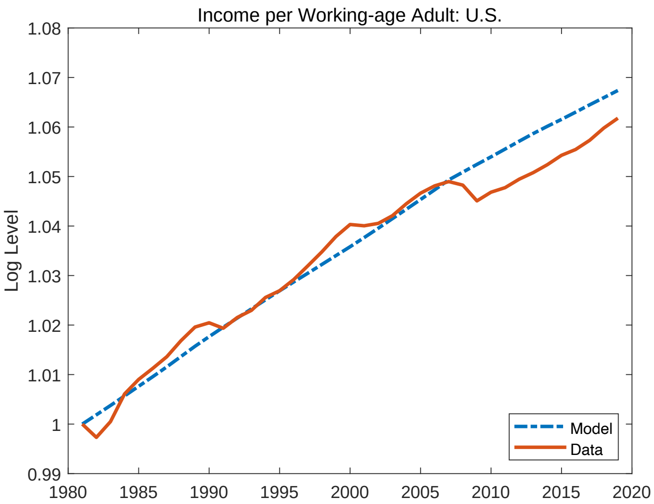

Figure 3: U.S. and Italy: 1981 - 2019, change in trend

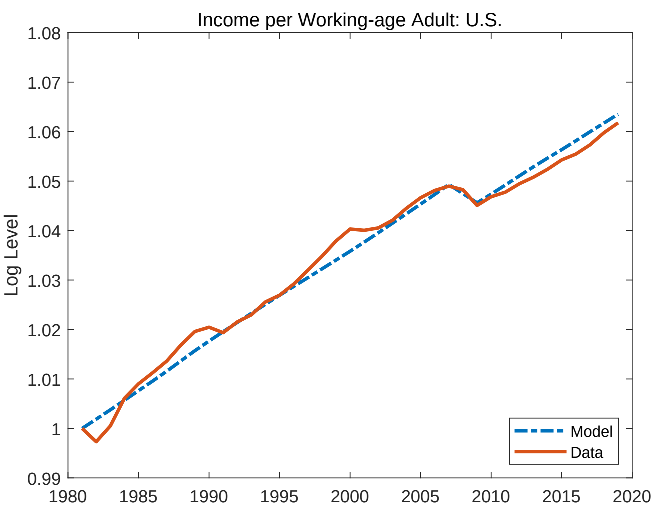

Figure 4: U.S. and Italy: 1981 - 2019, drop in trend

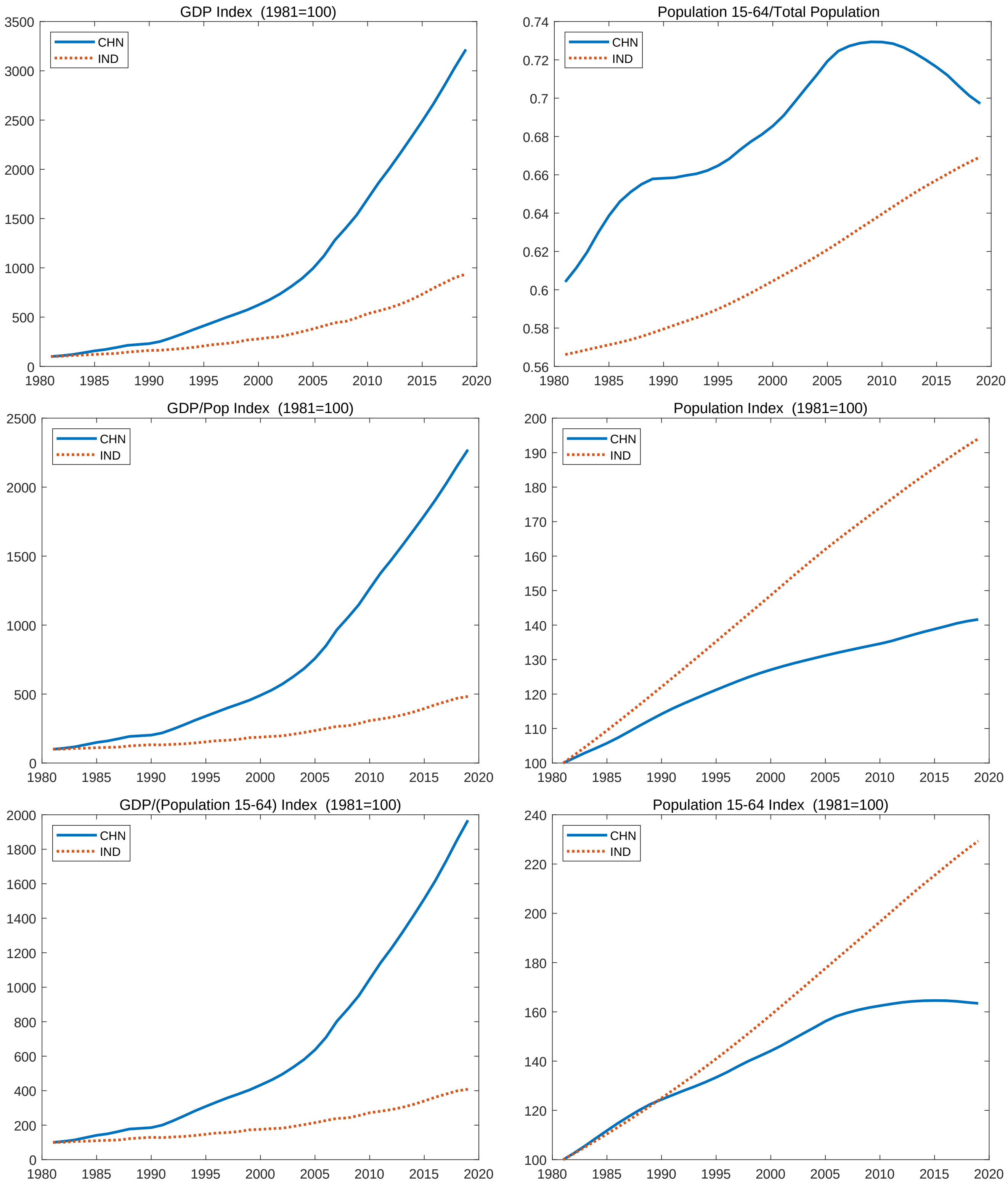

Figure 5: China and India: 1981-2019