IDENTIFYING THE SOURCES OF THE SLOWDOWN IN GROWTH: DEMAND VS. SUPPLY*

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Abstract: This paper proposes an empirical approach to identify the structural forces behind the recent slowdown in US GDP growth. I use time series techniques to extract low-frequency fluctuations in GDP growth and inflation and identify their underlying drivers: demand and supply. Identification is achieved with a set of sign restrictions. While supply-side factors account entirely for the slowdown in trend GDP growth during the 1970s and its acceleration in the 1990s, "super-hysteresis" effects explain half of its decline since 2000. Overall, this paper establishes an important role of demand factors as drivers of long-run GDP growth.

JEL classification codes: *C32, E3, O47.*

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1 Introduction

Economic growth has been exceptionally low in many advanced economies in the aftermath of the Great Recession. In the United States, real GDP per capita growth averaged 1.3% during 2010-2019, well below pre-crisis averages of about 2%, see Figure 1, and shows no sign of a clear rebound. The surge of the COVID-19 pandemic casts further doubts that this trend will be reversed in the near future. The causes and implications of this phenomenon prompted a huge debate in both academic and policy circles, reviving the spectrum of secular stagnation (see Hansen (1939) for an early reference) and questioning standard macroeconomic models. Why has long-run GDP growth declined? Several studies strived to understand the drivers of this puzzling secular trend, providing many appealing stories which result from two main views: demand-side and supply-side. The aim of this paper, in short, is to quantify the relative importance of these two sets of explanations in accounting for the slowdown in GDP growth.

The supply-side view identifies the roots of the recent slowdown in growth well before the Great Recession, suggesting that structural forces other than demand are behind this phenomenon (see Fernald, Hall, Stock, and Watson (2017), Antolin-Diaz, Drechsel, and Petrella (2017), Eo and Morley (2020)). After controlling for cyclical effects, Fernald et al. (2017) show that the slowdown reflects essentially two pre-existing trends: slower productivity growth and falling labor force participation. A number of factors could explain these trends: slower technological progress due to diminishing returns from the digital revolution (see Gordon (2015) and IMF (2017a) for a review), demographic changes such as slowing population growth (see Gordon (2015) and Jones (2020)) and aging (see Gordon (2017) and Jones (2018)), a rise in market power of firms (see Gutiérrez and Philippon (2017) and Midrigan, Philippon, Jones, et al. (2016)), a decline in business dynamism (see Akcigit and Ates (2019)) and a rise in intangible inputs (see De Ridder (2019)).

An alternative hypothesis relates the recent slowdown in growth to a shortfall in demand, as advocated by Summers (2014, 2015). The main argument is that if the slowdown was entirely a supply-driven phenomenon, we would have observed an increase in inflation, when the latter has been below trend in the decade following the financial crisis. The formal idea that recessions might have permanent effects on the growth rate of output was introduced by Ball (2014) with the term "super-hysteresis". Blanchard, Cerutti, and Summers (2015) document that a non-negligible share of crises in a cross-section of 23 countries indeed featured long-lasting effects on the growth rate of output, suggesting evidence of super-hysteresis effects. Several theoretical studies suggest that growth can be sluggish as an endogenous response to the crisis, through a variety of channels. Demand-driven factors can affect productivity growth persistently due to a lack of productivity-enhancing investments, see Anzoategui, Comin, Gertler, and Martinez (2019), due to a shortfall of intangible investments, see De Ridder (2017), or due to the tightening of financial constraints, see Queralto (2020). While the focus of these theoretical studies is typically on potentially persistent, rather than formally permanent, effects on output growth of demand-driven factors, these are usually difficult to distinguish in typical macroeconomic samples, especially so if the focus is on the last decade. Growth stagnation can also be the result of the crowding-out effect of future bubbles, especially in advanced economies, see Guerron-Quintana, Hirano, and Jinnai (2019).

While most papers typically examine the role of particular channels of supply-side and demand-side forces in isolation, or decompose the slowdown in growth in its drivers in a growth-accounting setup, an empirical framework that evaluates jointly their relative importance is lacking. The key contribution of this paper is to fill this gap. To this end, I estimate, first, a VAR with common trends in order to isolate low-frequency movements in GDP growth and inflation from typical business cycle fluctuations. As common in the time series literature, the trends are assumed to follow unit root processes, thus reflecting fluctuations in the *growth rates* that are permanent in the context of the model. That is, the focus of this study is not on whether GDP is permanently below or above its trend, but if the trend itself changed, and what is behind this phenomenon. Second, I identify the structural drivers of trend GDP growth and trend inflation, namely demand and supply, using a general set of sign restrictions guided by economic wisdom: supply-side forces move output and inflation in opposite directions, while demand-side forces imply a positive co-movement. These restrictions are motivated by the argument raised by Summers (2015), and are imposed in the same fashion as standard SVARs with sign restrictions. The difference with typical SVAR studies is the focus on permanent shocks to the growth rates, and the extraction of structural trends from the estimated trends of GDP growth and inflation. To the best of my knowledge, this is the first paper estimating explicitly *super-hysteresis effects* and their *relative importance* in explaining the slowdown in trend GDP growth. In addition, a second contribution of this paper is the analysis of the determinants of the economic slowdown in the four largest Euro Area countries: France, Germany, Italy and Spain.

I document the following findings. First, the trend component of US real GDP per capita growth exhibits a substantial decline over the sample considered, about 1.16 percentage points from 1959Q2 to 2019Q4. An interesting feature is the timing of the decline. Trend GDP growth decreased during the late 1960s and early 1970s, reached a peak in 2000 after a rapid acceleration in the mid-1990s, and fell remarkably in the last two decades. I estimate the current rate to be around 1.2%. Notably, my estimate of trend GDP growth resembles closely the estimate of Antolin-Diaz et al. (2017), despite using a rather simple model. Second, while supply-driven factors contributed entirely to the slowdown in US growth during the 1970s and its acceleration during the 1990s, demand-driven factors explain essentially half of its decline since 2000, suggesting an *important role of super-hysteresis effects* since the onset of the Great Recession. Interestingly, the pass-through of super-hysteresis is particularly relevant for investment growth. Demand-driven forces play also a determinant role in keeping inflation below target in the last decade, when supply-driven factors put upward pressure on inflation since 2000. This suggests a potential rationale for two puzzling phenomena: missing deflation during the Great Recession (see Ball and Mazumder (2011) and Hall (2011), among others) and missing inflation during the recovery (see IMF (2016, 2017b)). Christiano, Eichenbaum, and Trabandt (2015), for instance, highlight that the slowdown in productivity played a key role in explaining missing deflation, which is in line with the empirical evidence provided in this paper. Third, focusing on the four largest Euro Area countries, trend GDP growth declines substantially for all the countries starting in the early 1980s. Differently from the United States, the slowdown is more gradual and persistent, and it is, to a larger extent, explained by demand-driven factors. Thus, super-hysteresis effects seem to be particularly important in Euro Area countries. This finding pairs well with the general narrative of a chronic lack in demand in European countries in the last decades. Overall, these findings highlight a key role of demand factors as drivers of long-run growth.

While this paper focuses on demand forces with potentially permanent effects on the *growth rate* of output, a body of the empirical literature studies permanent effects of demand shocks on the *level* of output, the so-called hysteresis effects (see Blanchard and Summers (1986) for an early reference). Cerra and Saxena (2008) show important and persistent output losses from financial crises using a large panel of countries, while Furlanetto, Røbstad, Ulvedal, and Lepetit (2020) propose an approach to directly estimate hysteresis effects, and show that permanent demand shocks are quantitatively important for the US. In their framework, these lead to a permanent decline in employment, while output per worker is largely unaffected.

The remainder of the paper is organized as follows. Section 2 lays out the macroeconometric model used to estimate the trend components of GDP growth and inflation, and depicts these. Section 3 presents the identification strategy to disentangle demand-side and supply-side forces. Section 4 discusses the relative importance of these in accounting for the slowdown in growth. Section 5 extends the baseline model to include additional macroeconomic variables of interest, and to account for the slowdown in the four largest Euro Area countries.

Section 6 presents a battery of robustness checks, and section 7 concludes.

2 Estimating trend GDP growth and trend inflation

This section discusses in detail the empirical methodology used to separate low-frequency movements in GDP growth and inflation from typical business cycle fluctuations. Then, it provides estimates of these over the period 1959Q2-2019Q4.

2.1 A VAR with common trends

Consider the following reduced-form VAR with common trends:

$$\begin{aligned} y_t &= \Lambda \bar{\tau}_t + \tilde{y}_t \\ \bar{\tau}_t &= \bar{\tau}_{t-1} + v_t, \quad v_t \sim N(0, \Sigma) \\ \tilde{y}_t &= A_1 \tilde{y}_{t-1} + \cdots + A_p \tilde{y}_{t-p} + u_t, \quad u_t \sim N(0, \Omega) \end{aligned} \tag{1}$$

where y_t is a nx1 vector containing all the n endogenous variables, τ_t is a qx1 vector of trend components, with $q \leq n$, $A_1, ..., A_p$ are the nxn matrices of coefficients associated with the p lags of the stationary component $\tilde{y}_t$, and v_t and u_t are the reduced-form residuals of the trend and stationary components respectively, which are assumed to be orthogonal. Λ is the nxq matrix of loadings, which maps the trend component τ_t to the dependent variable y_t. It is restricted depending on the choice of cointegrating relations between the variables in the system. It has rank q, thus the number of cointegrating relations are $n - q$. The model follows closely the specification of Del Negro, Giannone, Giannoni, and Tambalotti (2017), which is a variation of the model of Villani (2009) that features a stochastic trend instead of a deterministic one.

In the baseline specification, y_t contains the following set of macroeconomic variables in differences of log levels[1]: real GDP per capita, real consumption per capita (excluding durable goods), GDP deflator and hours worked in the non-farm business sector per capita. Thus, the model features trend components of *growth rates*, as opposed to trend components of *levels*. Indeed, the main interest of this paper is not whether GDP is permanently below its pre-recession trend, but if the trend itself changed permanently and, if so, why. As common in the trend-cycle literature, the trend components of the growth rates are specified as unit roots, thus reflecting permanent changes in the context of the model. In practice, however,

[1]The variables are then multiplied by 400, in order to consider annualized quarter-on-quarter growth rates.

we can think of these as slow-moving fluctuations since we cannot distinguish between a very persistent process and a unit root in typical macroeconomic samples like the current one, which spans the period 1959Q1-2019Q4. Data on the period 1948Q1-1958Q4 is also available for the variables in the system and it is used as pre-sample to inform the priors described below.

I use the assumption that there are two macroeconomic trends ($q = 2$) characterizing the set of variables in the system. The first is trend growth, which is restricted to be common across GDP per capita growth and consumption per capita growth. This reflects a usual assumption in the literature (see Antolin-Diaz et al. (2017), and Cochrane (1994) for an early reference), that is consumption is informative to extract the permanent component of GDP, as suggested by the permanent income hypothesis. The second is a nominal trend, which is extracted from inflation only. This leaves the growth rate of hours per capita trendless, being characterized only by the stationary component.[2] There are two main reasons for the choice of two trends for the set of variables included in y_t. On the one hand, two trends are needed to implement the identification scheme presented in the next section to disentangle demand-driven and supply-driven factors, and the assumption of a "growth" trend and a "nominal" trend seems quite natural given the variables in the system. On the other hand, the eigenvalues of the autocovariance matrix of the trend components are in absolute value close to zero when additional trends are introduced. This suggests the presence of only two trends across the variables specified in the system. Nonetheless, I add additional trends to the baseline specification in sections 5 and 6.

In order to estimate the model in (1), I need to specify a distribution for the initial conditions of the trend and cycle components:

$$\begin{aligned} \bar{\tau}_0 &\sim N(\underline{\tau_0}, I) \\ \tilde{y}_0 &\sim N(0, \Omega_0) \end{aligned} \tag{2}$$

where the prior mean $\underline{\tau_0}$ is set as the pre-sample average (2.7 for year-on-year GDP growth and 2.3 for year-on-year inflation).[3] The model described in (1) and (2) is a linear, Gaussian state-space model. As such, it is estimated using simulation smoothing techniques, see Carter and Kohn (1994) and Durbin and Koopman (2002). The details of the estimation are laid out

[2]This assumption, in line with the framework of Antolin-Diaz et al. (2017), is relaxed in the robustness section. However, it turns out to be irrelevant for the main conclusions of the paper.

[3]The choice of the initial prior mean, however, is mostly inconsequential for the estimation of the trend components. Even extremely different choices lead to the same result. What matters in the estimation of the trend components is the choice of the priors on their covariance matrix (see Figure 6 in Appendix B).

in section A of the Appendix.

I specify the following priors for the VAR coefficients, $A = (A_1, ..., A_p)'$, and the covariance matrices of the transitory and trend components, Ω and Σ respectively:

$$\begin{aligned} p(vec(A)|\Omega) &\sim N(vec(\underline{A}), \Omega \otimes \underline{\Omega})I(vec(A)) \\ \Omega &\sim IW(\kappa_u, (\kappa_u + n + 1)\underline{\Omega}) \\ \Sigma &\sim IW(\kappa_v, (\kappa_v + n + 1)\underline{\Sigma}) \end{aligned} \tag{3}$$

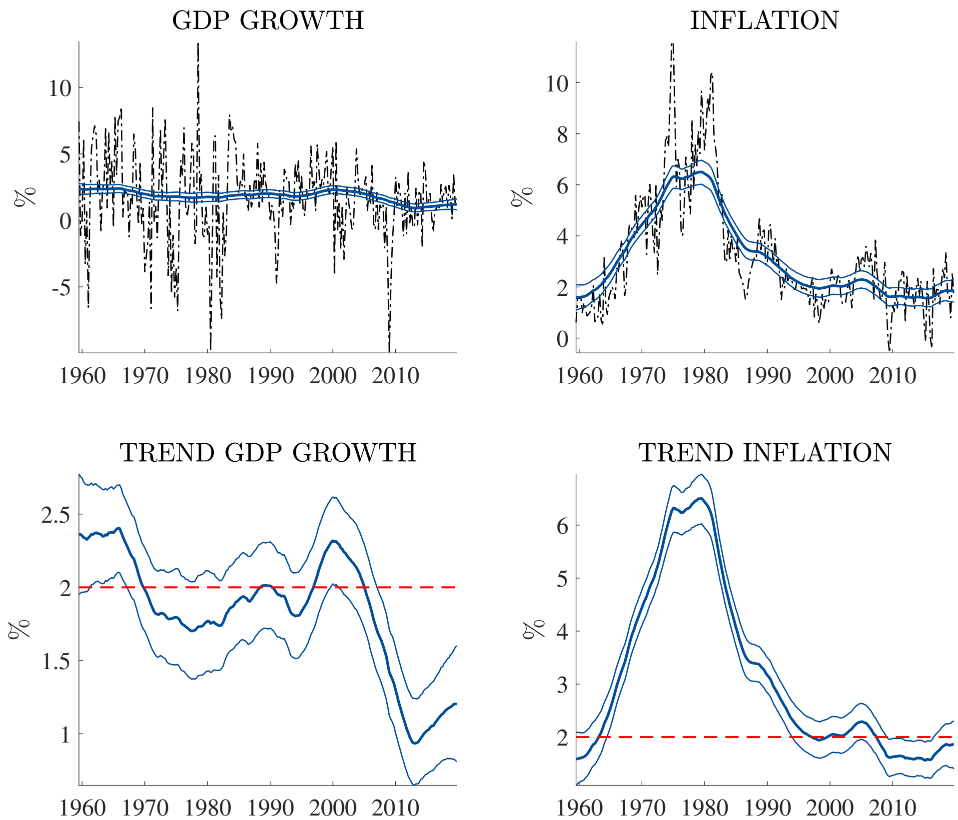
where $I(vec(A))$ is an indicator function which takes value 1 if the system is stable, and 0 otherwise, and $IW(\kappa, (\kappa+n+1)\underline{\Omega})$ denotes an inverted wishart distribution with mode $\underline{\Omega}$ and κ degrees of freedom. The lags of the transitory component are set to four, in order to cover a year's worth of data. The priors on the VAR coefficients are standard Minnesota priors with the hyperparameter of the overall tightness set to 0.2, a common value in VAR studies (see Giannone, Lenza, and Primiceri (2015) and the references therein). Since $\tilde{y}_t$ is a stationary component, the prior on the own lag is centered around zero. The choice of the priors for the stationary components follows Del Negro et al. (2017).

I specify priors on the trend components that are tight and conservative to make sure that these do not reflect business cycle fluctuations. The tightness κ_v is set to 100 and the prior on trend GDP growth, for instance, is such that the standard deviation of the expected change over a period of a hundred years is 0.25 percentage points. The prior on trend inflation is looser, and such that the standard deviation of the expected change is 1 percentage point over a century. Therefore, I am feeding the system with rather strong priors on trend GDP growth and trend inflation moving very little over the sample. Clearly, it could be the case that these trends fluctuate much more than what the priors suggest. Regardless, I am not imposing the priors dogmatically. If data spoke loudly in favor of relevant movements in the low-frequency components of GDP growth and inflation, it could push away from the prior assumptions. In the robustness section, I perform a sensitivity analysis where I explore how the main findings are affected by using alternative prior specifications.

2.2 Slow-moving fluctuations in GDP growth and inflation

Figure 1 shows the estimated trend components of GDP growth and inflation in relation to the actual data. The dotted black lines correspond to the actual data, while the thick blue lines represent the point-wise median estimates of the trend components, with the associated 68% credible bands. The trend components seem to capture accurately the slow-moving behavior

Figure 1: Estimated trends and actual data of real GDP per capita growth and inflation



Note: Median (solid blue line) and 68% credible bands are based on 10,000 draws. Actual growth rates are defined in annualized quarter-on-quarter terms.

of GDP growth and inflation, and with relatively small uncertainty. Over the sample considered, there is a significant slowdown in trend GDP growth, of about 1.16 percentage points from 1959Q2 to 2019Q4 based on the point-wise median estimate. The median estimate for the current long-run real GDP per capita growth rate is about 1.2%, well below pre-crises averages of around 2%. The most striking feature of this decline is its timing. Trend GDP growth slowed down appreciably in the late 1960s and early 1970s, accelerated quickly in the mid-1990s, reaching a new peak in 2000, and fell sharply afterwards. These findings are well in line with the common narrative that the early 1970s were a historical period characterized by a slowdown in productivity growth and the 1990s experienced a rapid increase in growth due to the outbreak of the information technology (IT) revolution. The recent decline, however, is less uncontroversial. Some studies place a structural break around the mid-2000s (see Eo and Morley (2020), Fernald et al. (2017), Grant and Chan (2017), Kamber, Morley, and Wong (2018)), while this paper favors a more gradual decline that starts in 2000, as documented in Antolin-Diaz et al. (2017) and Antolin-Diaz, Drechsel, and Petrella (2020).

At a first glance, the timing of the decline seems to favor explanations that are unrelated to the Great Recession, as the slowdown starts well before 2007. Having a closer look at inflation, however, can intuitively suggest a potential role for demand. The slight increase in trend inflation from 2000 to 2006 seems to suggest that structural forces other than demand are in place from early 2000s. However, trend inflation declines after the Great Recession and remains well below the 2% target for over a decade. This finding could point towards the argument that factors other than supply might be in place to account for the disappointing growth experienced since the onset of the financial crisis, as highlighted by Summers (2015). A comment on inflation is warranted. The recent decline in trend inflation is rather small compared to its fluctuations over the sample. The trend increases substantially starting in the mid-1960s and peaks around 1981, after which a substantial decline is in place. This increase reflects the Great Inflation period, which is recognized as a period of fiscal and monetary policies that fueled excessive inflation (see Ascari and Sbordone (2014) for a survey of the macroeconomics of trend inflation).

All in all, the findings point towards substantial fluctuations in the trend components of GDP growth and inflation over the sample considered, despite the tight priors imposed on the covariance matrix of these. Thus, the data seems to speak loudly in favor of substantial low-frequency fluctuations in GDP growth and inflation over the sample considered. Interestingly, the results above highlight that both demand-side and supply-side factors might be relevant to explain the recent slowdown in US GDP growth. Now, having obtained estimates of the trend components of GDP growth and inflation, a natural question is what drives fluctuations in these trends. The next section discusses in detail the identification strategy used to extract the structural drivers of these trends, and section 4 analyzes their determinants.

3 Identifying the structural drivers

The basic rationale of the supply-side view of the slowdown in growth is that, as the decline started prior to the crisis, the latter cannot be its cause and thus other structural forces are at play, for instance technological or demographic changes (see Fernald et al. (2017) and Gordon (2015)). On the other hand, as Summers (2015) argues, if supply-driven factors were the only explanation of this phenomenon, this would have translated into an increase in inflation which, however, did not materialize in the data. If anything, inflation declined following the financial crisis and is still below target, as shown in Figure 1, suggesting the relevance of demand-driven factors. In his own words:

"Economists have a general approach to distinguishing demand and supply shocks. When quantity goes down and price does as well, shocks are thought of as coming from demand. Quantity going down and prices going up is suggestive of supply shocks. During the current episode, inflation rates both contemporaneously and prospectively have declined — suggesting the importance of demand."

— Summers (2015)

In what follows, I take the argument of Summers (2015) seriously and propose an approach to identify the supply-driven and demand-driven components of the slowdown in growth starting from the estimated model in (1). Consider the trend component of y_t:

$$\bar{y}_t = \Lambda\bar{\tau}_t = \Lambda\Big(\bar{\tau}_0 + \sum_{j=0}^{t-1} v_{t-j}\Big) \tag{4}$$

Since $v_t \sim N(0, \Sigma)$, where Σ is not diagonal, the errors of the trend components are correlated. Thus, the two trends are not independent one another. At this stage, we cannot give a proper structural interpretation to the results of the previous section, unless we make additional assumptions. In order to map the economically meaningful structural shocks from the estimated residuals, we need to impose restrictions on the variance-covariance matrix Σ. Let the mapping between reduced-form and structural trend residuals be $v_t = \tilde{Q}\epsilon_t$, where $\tilde{Q}$ is a non-singular matrix such that $\tilde{Q}\tilde{Q}' = \Sigma$ and $\epsilon_t \sim N(0, I)$ are the structural shocks to the trend components normalized, without loss of generality, to have unit variance. We can rewrite the equation (4) as follows:

$$\begin{aligned} \bar{y}_t = \Lambda\tilde{Q}\tilde{Q}^{-1}\bar{\tau}_t &= \Lambda\tilde{Q}\Big(\tilde{Q}^{-1}\bar{\tau}_0 + \sum_{j=0}^{t} \tilde{Q}^{-1} v_{t-j}\Big) \\ &= \Gamma\Big(\bar{s}_0 + \sum_{j=0}^{t} \epsilon_{t-j}\Big) = \Gamma\bar{s}_t \end{aligned} \tag{5}$$

where $\bar{s}_t$ are the structural contributors. Notice that Γ represents the effect of a structural shock on impact on the trend $\bar{y}_t$, since:

$$\frac{\partial \bar{y}_t}{\partial \epsilon_t'} = \Gamma \tag{6}$$

Therefore, we can identify demand and supply shocks by restricting the sign of the elements in Γ corresponding to the variables of interest. Then, the structural contributors are backed out from equation (5). The set of restrictions imposed is presented in Table 1. Following the common macroeconomic wisdom and the argument of Summers (2015), I assume that movements in demand produce a positive co-movement in the trend components of GDP growth and inflation, while supply implies a negative co-movement. Sign restrictions are

Table 1: Baseline sign restrictions

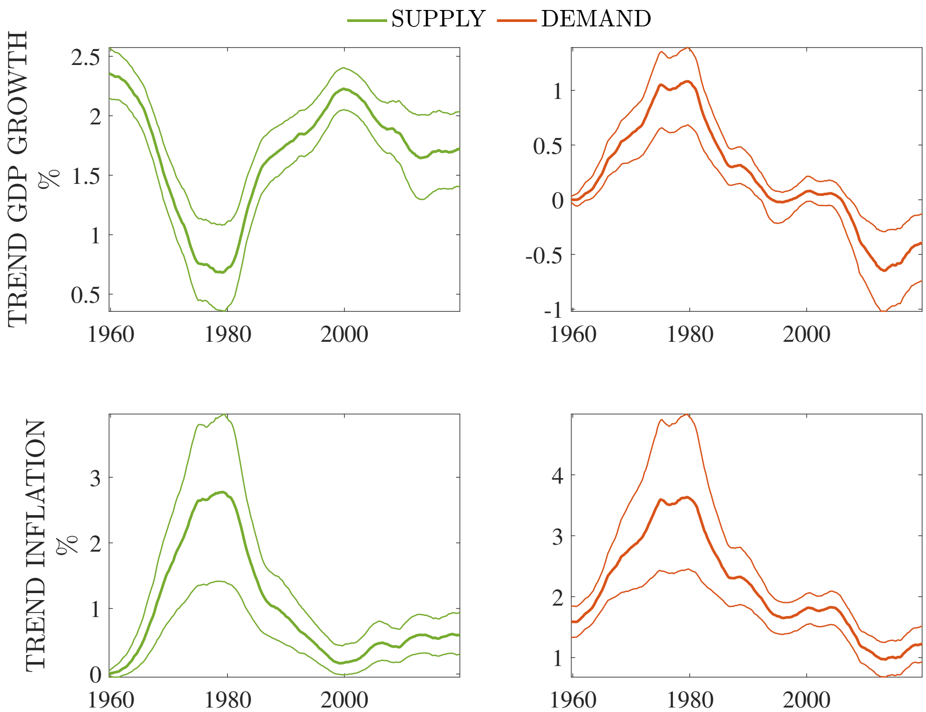
	Supply	Demand
GDP growth	+	+
Inflation	-	+

implemented using the QR decomposition algorithm of Rubio-Ramírez, Waggoner, and Zha (2010) and by defining the candidate draw as $\tilde{Q} = SQ'$, where S is the lower triangular Cholesky decomposition of Σ. Thus, this approach is implemented in the same way as for traditional SVARs with sign restrictions. The only difference with respect to standard SVAR studies is the focus on identifying movements in growth rates that are permanent. To the best of my knowledge, this is the first empirical paper formally featuring demand and supply shocks with such properties. A comment on the methodology is warranted. While the focus of this paper is on identifying the drivers of low-frequency movements in GDP growth and inflation, this framework accommodates, potentially, the study of business cycle shocks, which can be identified by imposing restrictions on the variance-covariance matrix of the transitory shocks Ω. The actual series of GDP growth could then be disentangled into drivers of its trend components and drivers of its transitory component.

4 Why has trend GDP growth slowed down?

Now, I decompose the estimated trends of GDP growth and inflation into their supply-side and demand-side drivers. Figure 2 plots the results. The thick line represents the point-wise median estimate, while the areas show the 68% credible bands.

Figure 2: Estimated contribution of demand and supply to trend GDP growth and inflation



Note: Median (thick line) and 68% credible bands are based on 10,000 draws.

Focusing on GDP growth (first row), supply-driven factors (left panel) explain the bulk of its long-run fluctuations over the entire sample. Not surprisingly, these factors play a key role in driving down trend GDP growth in the late 1960s and early 1970s, in line with the common view that a large productivity slowdown took place in that historical period. Also, the rapid rise in trend growth during the 1990s appears entirely supply-driven, reflecting the positive effects of the digital revolution. Focusing on the early 2000s, supply-driven forces are behind the dawn of the slowdown and its further decline in the aftermath of the crisis, in line with the narrative that structural forces other than demand are at play before the Great recession and contributed negatively to the slowdown. All in all, it seems that the supply-side component captures well changes in technological progress. However, I do not take a stand on the particular micro-foundation behind the supply side. Potentially, many factors could be at play, as highlighted above.

At the same time, demand-driven factors (right panel) are relevant as well in explaining fluctuations in the long-run component of GDP growth. The findings suggest that, absent an upward pressure of demand-driven factors, trend growth would have been much lower during the 1970s. Thus, it seems that the monetary and fiscal policies that fueled inflation in the 1970s had indeed some positive effect on GDP growth, masked by the negative pressure of supply-side forces. Thus, super-hysteresis effects can also have a positive nuance in this context, as these can be referred to increases in growth and not just slowdowns.[4] Moreover, half of the shortfall in GDP growth from 2000 appears to be due to demand-driven factors, providing evidence of strong super-hysteresis effects that exacerbated the slowdown since the onset of the Great Recession.

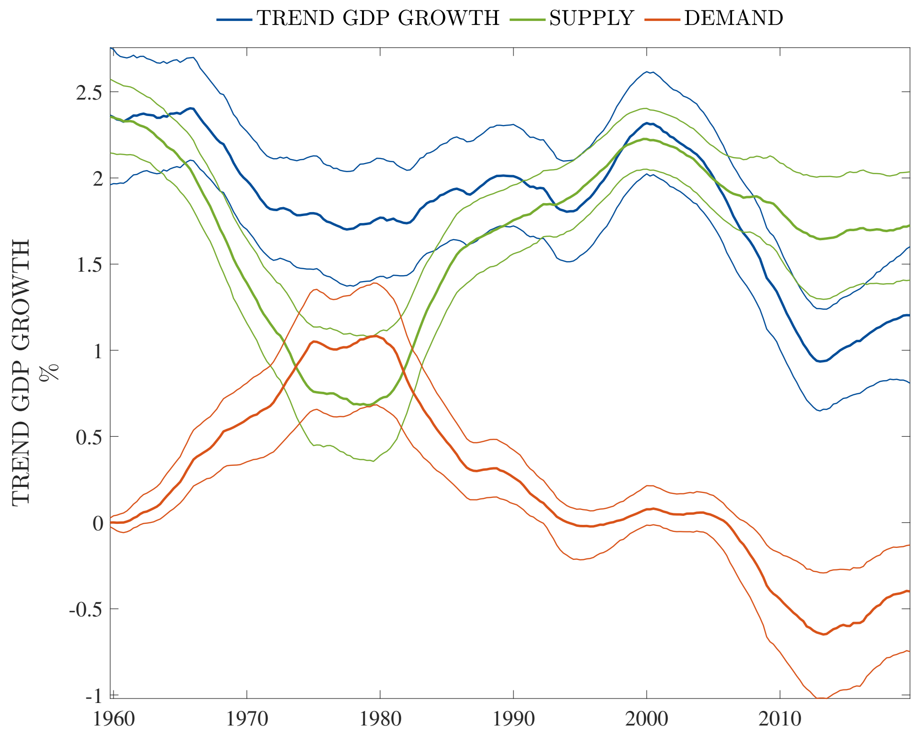
Figure 3 summarizes the results for trend GDP growth in one plot. While the slowdown of GDP growth in the 1970s and its acceleration during the 1990s are entirely supply-driven phenomena, the decline after 2000 is explained by both supply-driven and demand-driven factors. Using the median estimates, 49% of the decline is attributed to demand, and 51% due to supply. While the dawn of the slowdown in 2000 is due to supply forces only, demand contributes importantly to further exacerbate this trend after the financial crisis. Notably, these findings pair well with the timing of both the supply-side and demand-side views. The importance of demand-driven factors in the aftermath of the financial crisis is intuitive once we have a closer look at inflation, see second row of Figure 2. While supply factors put upward pressure on inflation after 2000, these have been more than counterbalanced by demand-driven forces pulling in the opposite direction in the aftermath of the financial crisis. These findings could provide an intuitive explanation for why there was missing deflation during the recession and missing inflation during the recovery. During the 1970s, instead, inflation was largely driven by supply-side phenomena. This decomposition attributes 58% of the Great inflation to supply-driven factors, while 42% to demand factors. Overall, these results document an important role for demand-driven factors in accounting for long-run fluctuations in the growth rate of GDP, which is novel in the literature.

5 Extensions

This section extends the baseline model in two directions. First, I augment the baseline framework with additional macroeconomic variables of interest, and explore the presence of additional trends. Second, I estimate the baseline model for the four largest Euro Area countries.

[4] See Guerron-Quintana et al. (2019) for a potential interpretation to permanently higher growth rates in response to demand-driven factors.

Figure 3: Estimated contribution of demand and supply to trend GDP growth



Note: Median (thick line) and 68% credible bands are based on 10,000 draws.

5.1 Additional variables and trends

In order to have a better understanding on the potential sources and channels through which demand-side and supply-side forces explain the slowdown in growth, I augment the baseline system of variables by including, one at a time, the growth rates of real investment per capita, TFP, real wages and labor force participation. These variables are important to shed some light on the channels highlighted in the introduction. Regarding the growth rates of investment, TFP and wages, I make the assumption that these share a trend with the growth rates of GDP and consumption, and have their own trend. In the case of investment, for instance, one could think that the presence of investment-specific technological progress implies a different low-frequency component of investment growth with respect to output and consumption. Regardless, I do not give a specific interpretation to this additional trend. It could measure any series-specific trend that is not common with the other variables in the system, including measurement error. The introduction of this additional trend implies the presence of an additional structural contributor to identify. Table 2 presents the additional restrictions imposed to separately identify demand, supply and the additional structural contributor, which I label as residual and to which I do not give a formal interpretation.[5]

Table 2: Additional sign restrictions

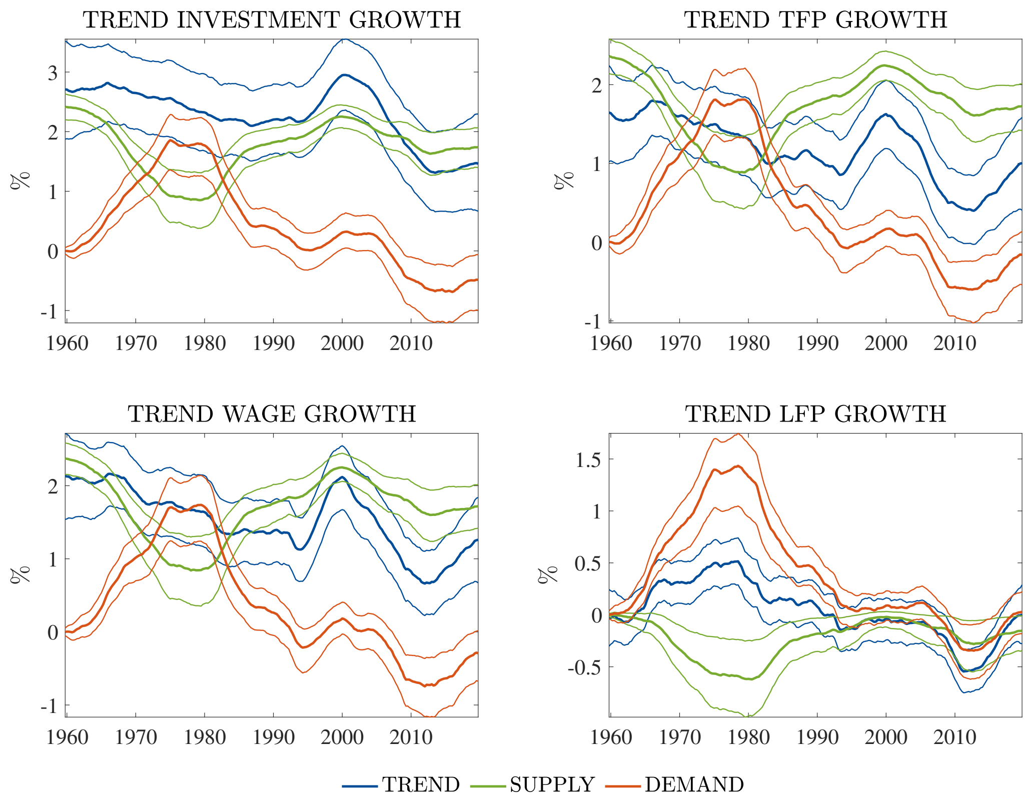
	Supply	Demand	Residual
GDP growth	+	+	+
Inflation	-	+	-
Additional macroeconomic variable	+	+	-

Figure 4 presents the results of the baseline SVAR with common trends augmented with the additional macroeconomic variables. The trend component of investment (first panel, first row) exhibits a similar evolution to trend GDP growth, though surrounded by wider uncertainty. It declines during the 1970s, increases rapidly in the mid-1990s, then falls substantially after 2000. Fluctuations in this trend, however, appear more gradual than trend GDP growth. Interestingly, and perhaps not surprisingly, super-hysteresis is very relevant for investment growth, and doesn't show signs of recovery at the end of the sample. This is in line with the narrative that demand-driven forces can produce a substantial slowdown in investment and this can act as a drag for growth. Focusing on TFP growth (second panel, first row), its trend resembles closely GDP growth, however it features a gradual recovery upon the end of the sample.[6] Also wage growth (first panel, second row) exhibits a similar behavior. This is because, unlike the case of investment growth, demand-driven factors gradually recover for these two trends. Finally, the recent decline in labor force participation growth (second panel, second row) appears to be mainly due to demand-driven forces, which play a relevant role for this variable over the sample. While this result is related to the growth rate of the participation rate, a similar finding has been found in Furlanetto et al. (2020) for its level, highlighting an important role of demand-driven factors to understand low-frequency movements in labor force participation. In line with the previous findings, demand-driven factors seem to play a relevant role, especially for trend investment growth.

[5]Alternative identifications of the residual contributor do not seem to play a role for any of the variables above, regardless on the sign restrictions imposed. Results are available upon request.

[6]Trend GDP growth is, however, unaffected and is essentially identical to Figure 3.

Figure 4: Estimated contribution of demand and supply to the trends of additional macroeconomic variables



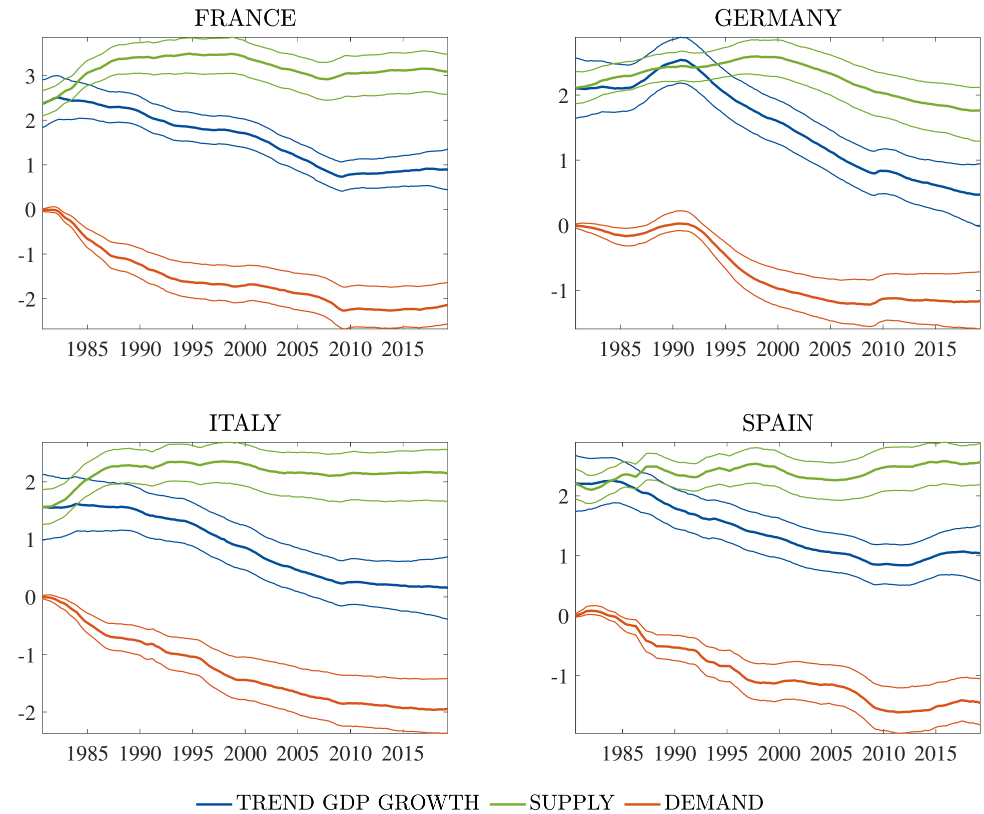
Note: Median (thick line) and 68% credible bands are based on 10,000 draws.

5.2 International Evidence

The slowdown in growth is a phenomenon present in a wide range of advanced economies. This is certainly the case of most Euro Area countries. In this section, I estimate the model of section 2.1 for the four largest Euro Area countries: France, Germany, Italy and Spain. Due to data availability, I focus on a smaller time span, 1980Q1-2019Q4. Data at quarterly frequency previous to 1980Q1 is not publicly available. To the best of my knowledge, this is the first paper that estimates explicitly long-run GDP growth for the four largest Euro Area countries and analyses its determinants.

Figure 5 shows the results. There is a substantial slowdown in real GDP per capita growth from the early 1980s common to all the four largest Euro Area countries. There are two interesting features. There are substantial differences with respect to the estimated trend GDP growth from the United States. First, for all the countries considered, the slowdown in

Figure 5: Estimated contribution of demand and supply to trend GDP growth



growth appears more gradual and persistent, and different in its timing. Indeed, the decline in trend GDP growth started well before 2000 for all the four largest Euro Area countries. Second, demand-driven factors seem to explain the bulk of the slowdown in growth over the entire sample. Thus, not just the timing but also the drivers of the slowdown are different. Supply factors, however, contribute to the decline in France, Germany and, only slightly, Italy from 2000, as in the United States. Thus, there is some heterogeneity in the determinants of the slowdowns of the four largest Euro Area countries. Overall, these findings point towards a crucial important role of super-hysteresis effects in Euro Area countries, further corroborating the idea that demand factors can be important drivers of long-run growth.

6 Robustness

This section discusses the robustness of the main findings to a battery of sensitivity checks. First, I assess whether alternative specifications of the model produce different results. Second, I check the sensitivity of the main findings to a sub-sample analysis. The figures of this section are presented in section B of the Appendix.

6.1 Different specifications of the model

Figure 6 shows trend GDP growth and its structural drivers when we change the model along several dimensions. The first row focuses on different lag specifications of the cyclical component. The second row illustrates how choosing more or less conservative priors on the trend components affects the main findings. The third row shows the results obtained using alternative definitions of inflation, and defining the growth rates in equation (1) as year-on-year rates, rather than quarter-on-quarter rates as in the baseline framework.

All in all, the model is robust to different specifications of the model. Indeed, changing the number of lags is largely inconsequential for the main findings. The second row shows the results by changing the assumptions on the priors of the covariance matrix of the trend components. The first panel represents a prior that is half conservative as the baseline, while the second and third panels are twice and three times as conservative as the baseline. Once I loosen the prior on the variance of the trend components, trend GDP growth seems to capture more business cycle fluctuations, as expected. Instead, when I make the priors more conservative, not surprisingly, the fluctuations are reduced substantially. Notice, however, that such strict priors might be unreasonable, as these priors imply almost no movement in the trend components, while it is clear from a visual inspection of the time series of GDP growth and inflation that this is not the case. While such strict priors are probably unreasonable, they highlight the properties of the methodology, and are thus quite informative. Nonetheless, the main findings of this paper, especially the importance of demand-driven forces, go through even under this extreme assumption.

The results appear robust also to different definitions of inflation. The first panel of the third row refers to personal consumption expenditure (PCE) inflation, while the second to consumer price index (CPI) inflation. If anything, the decline in growth in the late 1960s and early 1970s is more pronounced when I use PCE inflation, with supply factors exhibiting a further downward pressure on growth and demand playing a smaller role in the Great Inflation period. The results since 2000 are almost identical to the baseline findings when PCE inflation is used, while demand seems to play a more relevant role with CPI inflation. All in all, while the main finding that super-hysteresis effects are in place after the Great Recession is robust to different specifications of inflation, or might be even stronger, the same is not the case for the rise in trend GDP growth in the Great Inflation period, which is somewhat more muted once PCE inflation or CPI inflation are used. Using year-on-year growth rates (third panel, third row) produces similar results, but the trend component fluctuates more. The year-on-year specification appears more sensitive to changes in the prior and in the sample used.

In the baseline, I assumed that there are two trends for the macroeconomic variables in the system, leaving hours per capita growth trendless. Figure 7 plots trend GDP growth and its underlying drivers once I include an additional trend component related to hours per capita growth ($q = 3$). On top of the baseline assumptions on the trend components, the first column introduces a trend common to hours growth only, while the second column assumes a common trend between GDP growth and hours per capita growth. As in the previous section, I do not give a formal interpretation to the additional trend introduced. The residual structural contributor is obtained by assuming, in the first row, that the demand-driven contributor implies an increase in hours per capita growth, while the residual implies a negative response. In the second row, the assumption is that the supply-driven contributor implies an increase in hours per capita growth, while the residual implies a negative response. Regardless on the assumptions used, introducing additional trends does not affect the behaviour of trend GDP growth and the relevance of super-hysteresis effects.

Overall, the main findings of the paper are robust to a battery of sensitivity checks on the specification of the model. Notably, the importance of super-hysteresis effects in accounting for the slowdown in growth after the Great Recession is confirmed under all the specifications.

6.2 Sub-sample analysis

One potential concern with the empirical analysis could be that the sample used to recover the trend components is driving the main conclusions of this paper. For instance, the estimated trend components could be affected by the fact that the baseline sample includes the pre-Great Moderation period, without though introducing stochastic volatility, or simply that the contribution of supply factors in the early 2000s are driven by the Great Recession.

In what follows, I consider the robustness of the main findings to the usage of two sub-samples. The first excludes the period since the onset of the financial crisis, i.e. from 2008Q1 onwards. The second considers the period after 1984Q1, thus including the Great Moderation and the recent years after the financial crisis. Figure 8 shows the results. The main findings are robust to alternative sample specifications. If anything, trend GDP growth seems to be surrounded by lower uncertainty in the Great Moderation sample, in line with the narrative that the Great Moderation period is characterized by lower volatility. Moreover, demand seems to contribute even more to the decline in growth.

7 Conclusions

Economic growth in the United States has been oddly slow in the decade following the Great Recession. While this observation prompted a lively debate, both among policy makers and academics, a consensus view regarding the underlying drivers is lacking. This paper proposes a simple empirical approach to quantify the relative importance of demand-side and supply-side factors in accounting for the the slowdown in long-run GDP growth. To this end, I estimate, first, a VAR with common trends to separate low-frequency movements in GDP growth and inflation from typical business cycle fluctuations. Second, I identify demand-side and supply-side forces using a general set of sign restrictions on the trend components, implemented as in standard SVARs. Supply and demand factors are identified using the common macroeconomic assumption that the former imply a negative co-movement between output and inflation, while the latter imply a positive co-movement. To the best of my knowledge, this is the first paper to quantify the relative importance of these forces within a unified empirical framework.

The main findings can be summarized as follows. First, the trend component of US real GDP per capita growth exhibits a remarkable decline over the sample considered, about 1.16 percentage points from 1959Q2 to 2019Q4. The interesting feature of this decline is its timing. Trend GDP growth decreased during the late 1960s and early 1970s, accelerated quickly in the mid-1990s, reaching a new peak in 2000, and fell remarkably in the last two decades. Second, while supply-driven factors account entirely for the slowdown in US growth during the 1970s and its acceleration during the 1990s, demand-driven factors explain basically half of its decline since 2000, highlighting an important role of super-hysteresis effects since the onset of the Great Recession. Interestingly, demand-driven forces play also a key role in keeping inflation below target in the last decade, when supply-driven factors put upward pressure on inflation since 2000. This finding suggests a potential rationale for two puzzling phenomena: missing deflation during the Great Recession and missing inflation during the recovery. Third, trend GDP growth declines substantially for the four largest Euro Area countries starting in the early 1980s. Unlike the United States, the slowdown is more gradual and mostly explained by demand-driven factors. Overall, these findings highlight a key role of demand factors as drivers of long-run growth.

While this paper offers a horse-race between the demand-side and supply-side views of the slowdown in growth, it is silent on the micro-foundations behind these, and their potentially distributional effects. Extending the setup of this paper in this direction will likely be an important topic for my future research.

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APPENDIX

A Estimation of the VAR with common trends

The VAR with common trends specified in (1) and (2) is estimated using a Gibbs sampler, which involves the following steps:

1. The first block involves draws from the joint distribution $\bar{y}_{0:T}, \tilde{y}_{-p+1:T}, \lambda|vec(A), \Omega, \Sigma, y_{1:T}$, which is given by the product of the marginal posterior of $\lambda|vec(A), \Omega, \Sigma, y_{1:T}$ times the distribution of the initial observations $\bar{y}_{0:T}, \tilde{y}_{-p+1:T}|\lambda, vec(A), \Omega, \Sigma, y_{1:T}$. The marginal posterior of $\lambda|vec(A), \Omega, \Sigma, y_{1:T}$ is given by:

$$p(\lambda|vec(A), \Omega, \Sigma, y_{1:T}) \propto \mathcal{L}(y_{1:T}|\lambda, vec(A), \Omega, \Sigma)p(\lambda)$$

where $\mathcal{L}(y_{1:T}|\lambda, vec(A), \Omega, \Sigma)$ is the likelihood obtained by using the Kalman Filter in the state-space model specified in (1). Since $p(\lambda|vec(A), \Omega, \Sigma, y_{1:T})$ does not feature a known form, this step involves a Metropolis-Hastings algorithm. Then, I use Durbin and Koopman (2002)'s simulation smoother to obtain draws for the trend and cycle components $\bar{y}_{0:T}, \tilde{y}_{-p+1:T}$, for given λ and $vec(A), \Omega, \Sigma, y_{1:T}$.

2. The second block involves the estimation of two VARs, given $\bar{y}_{0:T}, \tilde{y}_{-p+1:T}$ and λ. In the trend component equation, the coefficients are known and the posterior distribution of Σ is given by:

$$p(\Sigma|\bar{y}_{0:T}) = IW(\underline{\Sigma} + \hat{S}_v, \kappa_v + T)$$

where $\hat{S}_v = \sum_{t=1}^{T}(\bar{y}_t - \bar{y}_{t-1})(\bar{y}_t - \bar{y}_{t-1})'$ is the sum of squared errors of the trend components. In the transitory component equation, the posterior distribution of $vec(A)$ and Ω is given by:

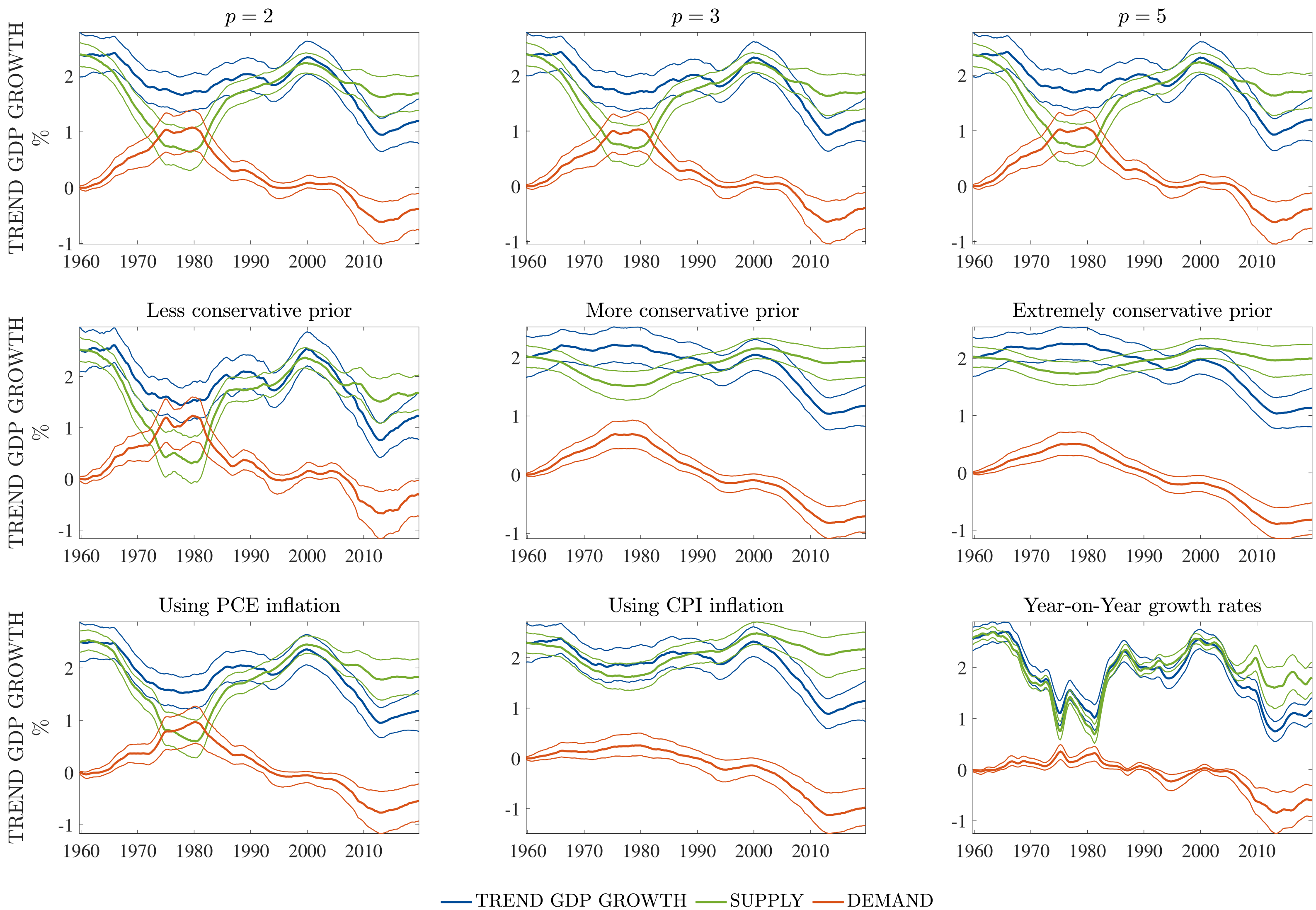
$$p(\Omega|\tilde{y}_{0:T}) = IW(\underline{\Omega} + \hat{S}_u, \kappa_u + T)$$
$$p(vec(A)|\Omega, \tilde{y}_{0:T}) = N(vec(\hat{A}), \Omega \otimes (\tilde{X}\tilde{X}' + \underline{\Omega}^{-1})^{-1})$$

where $\tilde{X} = (\tilde{y}_1', ..., \tilde{y}_T')'$, $\hat{S}_u = uu' + (\hat{A} - \underline{A})'\underline{\Omega}^{-1}(\hat{A} - \underline{A})$ and $\hat{A} = (\tilde{X}\tilde{X}' + \underline{\Omega}^{-1})^{-1}(\tilde{X}'\tilde{y} + \underline{\Omega}^{-1}vec(\underline{A}))$.

B Additional figures

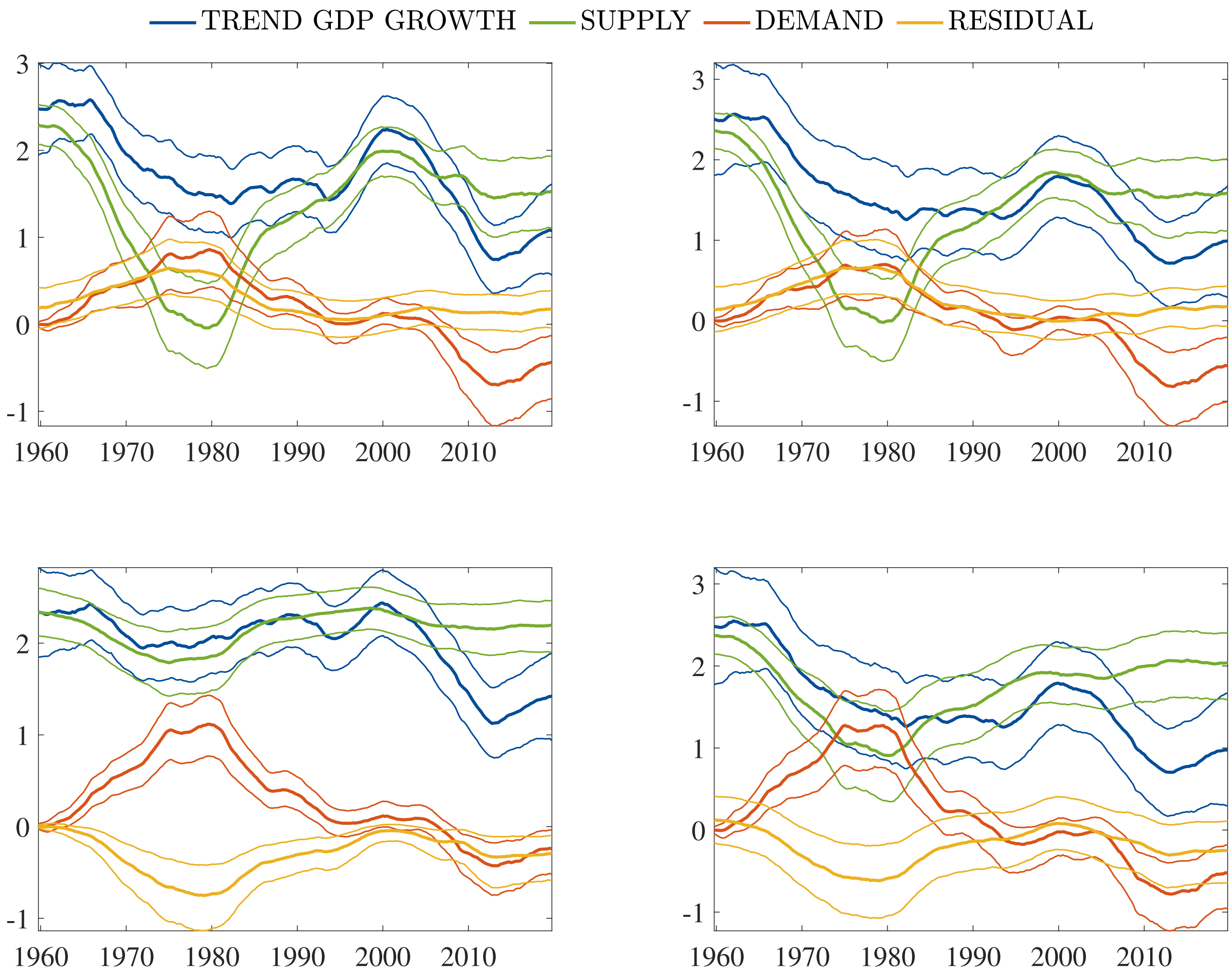
This section of the Appendix includes the figures corresponding to the sensitivity analysis of section 6 of the main text. In order to keep the presentation of the robustness intuitive and sharp, I show only the plots concerning trend GDP growth. Results on trend inflation and trend hour per capita growth are available upon request.

Figure 6: Alternative lag, prior and variable specifications



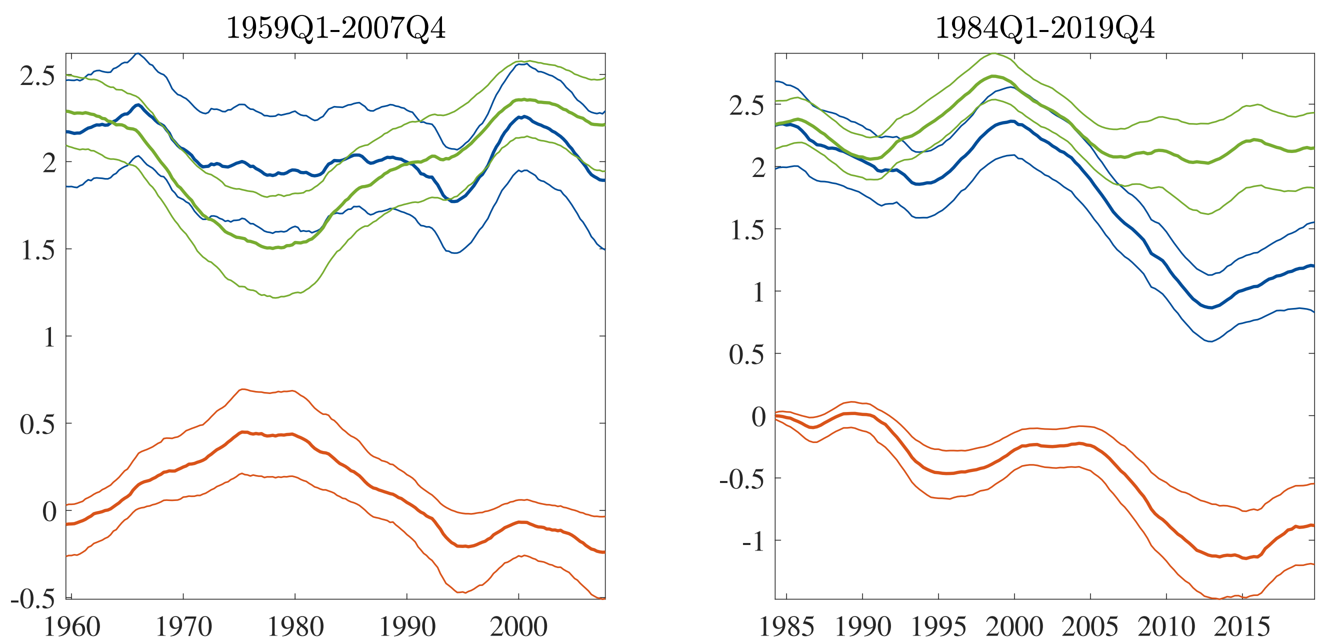
Note: Median (thick lines) and 68% credible bands are based on 10,000 draws.

Figure 7: Additional trends



Note: Median (thick lines) and 68% credible bands are based on 10,000 draws.

Figure 8: Estimated contribution of demand and supply - Sub-sample anlysis



Note: Median (thick lines) and 68% credible bands are based on 10,000 draws.