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

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Abstract: Long-run GDP growth has declined in the United States over the past two decades. Two competing views take the stage in accounting for this slowdown: demand-side and supply-side. I empirically quantify their relative importance in a Bayesian SVAR with common trends, identified using sign restrictions based on the co-movement of prices and quantities. While supply-side factors were the main driver of long-run GDP growth prior to 2000, demand-side factors explain half of its slowdown afterwards. The findings suggest a relevant role of demand forces as drivers of long-run growth.

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

Keywords: *Long-run growth, Super-hysteresis, SVAR.*

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1 Introduction

Economic growth in the United States has been low following the Great Recession. 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 causes and implications of this phenomenon sparked a major debate in academic and policy circles, reviving the hypothesis of secular stagnation [1] and calling into question standard macroeconomic models. Why has long-run GDP growth declined? Several studies strove to understand the drivers of this puzzling trend, providing many appealing explanations that reflect two main views: demand-side and supply-side.

The supply-side view identifies the roots of the slowdown in growth well before the Great Recession, suggesting that structural forces other than demand, as for instance technological progress, are behind this phenomenon (see Fernald, Hall, Stock, and Watson (2017) and Gordon (2015)), as suggested by standard growth models. The demand-side view, on the other hand, challenges this hypothesis on the basis of the observed co-movement of inflation and output growth in the aftermath of the financial crisis. As Summers (2015) puts it: *"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."*

While most studies examine the role of supply-side and demand-side factors in isolation, typically using theoretical models or decomposing the slowdown using growth-accounting decompositions that lack a structural interpretation, a framework that empirically quantifies the relative importance of these two competing views is missing. The key contribution of this paper is to fill this gap. To this end, I embed in a macroeconometric model the intuitive argument of Summers (2015) that demand and supply shocks are separately identified based on the different co-movement of prices and quantities. Through the lenses of these simple sign restrictions, one can observe low-frequency movements in output growth and inflation and infer the relative importance of demand and supply in explaining fluctuations in these trends.

I estimate, first, a Bayesian VAR with common trends (see Del Negro, Giannone, Giannoni, and Tambalotti (2017)) in order to isolate low-frequency movements in GDP growth and inflation from typical business cycle fluctuations. The slow-moving components are assumed to follow unit root processes, thus reflecting changes in the mean of the *growth rates* that are permanent in the context of the model. Thus, the focus of this study is on long-lasting changes to the *growth rate* of GDP, rather than to its *level*. Second, I identify the structural drivers of low-frequency changes in GDP growth and inflation, namely demand-side and supply-side factors, using a general

[1] See Hansen (1939) for an early reference.

set of sign restrictions motivated on the basis of the above argument: supply-side forces move output growth and inflation in opposite directions, while demand-side forces imply a positive co-movement. Unlike standard SVARs, the identification assumptions are imposed on the trend, rather than cycle, components. As a result, the structural analysis is on low-frequency movements rather than business cycle fluctuations. This is the first paper decomposing trend growth in its structural drivers and estimating demand shocks with long-lasting effects on GDP growth, the so-called *super-hysteresis effects* (see Ball (2014)).

I document the following findings. First, US trend 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 early 1970s, reached a peak in 2000 after a rapid acceleration in the 1990s, and fell remarkably in the last two decades.[2] 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 half of its decline since 2000. Specifically, the decline starts in the early 2000s due to supply-side factors and it is further exacerbated by demand-side factors since 2008, suggesting an *important role of super-hysteresis effects* since the onset of the Great Recession. Third, these effects also explain a relevant share of the decline in investment growth, TFP growth and in GDP growth expectations. When the model is extended to account for changes in labor force participation, the savings rate and the natural rate of interest, namely r^*, demand-side forces explain the bulk of the decline in labor force participation after the financial crisis and contribute to an increase in the savings rate. Instead, supply-side factors account for most of the decline in r^*. Fourth, demand-side 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 finding offers a potential rationale for two puzzling phenomena: missing deflation during the Great Recession (see Ball and Mazumder (2011) and Hall (2011)) and missing inflation during the recovery (see IMF (2016, 2017b)).[3]

Overall, these findings highlight a relevant role of demand factors as drivers of long-run GDP growth and other macroeconomic trends.

Related Literature. This paper relates to a large literature documenting a decline in trend GDP growth over the past two decades (see Fernald et al. (2017), Antolin-Diaz et al. (2017), Eo and Morley (2020)). Most studies offer a supply-side view of the slowdown. Fernald et al. (2017), after controlling for cyclical effects, show that the slowdown essentially reflects two pre-existing trends: slower productivity growth and falling labor force participation. A number of factors could

[2]This measure closely resembles the estimate of long-run GDP growth in Antolin-Diaz, Drechsel, and Petrella (2017), despite using a rather simple model.

[3]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.

explain these trends: slower technological progress due to diminishing returns from the digital revolution (see Gordon (2015) and IMF (2017a) for a review) or a general lack of ideas (see Bloom, Jones, Van Reenen, and Webb (2020)), 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, see Summers (2014, 2015). Blanchard, Cerutti, and Summers (2015) empirically document that a non-negligible share of (demand-driven) crises in a cross-section of 23 countries featured long-lasting repercussions on the *growth rate* of output. In theoretical models, protracted periods of low output growth, low investment and low inflation can arise due to insufficient aggregate demand when agents expect growth to be low, see Benigno and Fornaro (2018). Growth stagnation can also be the result of a crowding-out effect of future bubbles, especially in advanced economies, see Guerron-Quintana, Hirano, and Jinnai (2019).[4]

While this paper focuses on demand-driven forces with potentially long-lasting effects on the *growth rate* of output, an important body of the literature studies demand shocks with potentially permanent effects on the *level* of output, the so-called hysteresis effects (see Blanchard and Summers (1986) for an early reference). Demand-driven factors can affect productivity growth, and thus permanently the level of output, 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). Blanchard et al. (2015) show that the bulk of the crises they consider feature lower output than the pre-recession trend. Cerra and Saxena (2008) show important and persistent output losses from financial crises using a large panel of countries. Furlanetto, Lepetit, Ørjan Robstad, Rubio-Ramírez, and Ulvedal (2021) propose an approach to directly estimate hysteresis effects, and show that permanent demand shocks are quantitatively important for the US.

Structure. The remainder of the paper is organized as follows. Section 2 lays out the econometric methodology used to estimate low-frequency movements in GDP growth and inflation, and identify demand-side and supply-side forces with *permanent* effects on long-run GDP growth. Section 3 presents the main results. Section 4 extends the baseline model to include additional macroeconomic variables and trends. Section 5 presents a battery of robustness checks, and section 6 concludes.

[4] When agents anticipate the emergence and collapse of future bubbles, these increase consumption and leisure and decrease investment and labor supply, thus slowing down economic growth.

2 Econometric Methodology

This section discusses in detail the empirical methodology used to extract low-frequency movements in GDP growth and inflation and identify their underlying structural drivers, namely demand-side and supply-side factors.

2.1 The Model

Consider the following reduced-form VAR with common trends:

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

where y_t is a $n \times 1$ vector containing all the n endogenous variables, τ_t is a $q \times 1$ vector of common trend (i.e. low-frequency) components, with $q \leq n$, $A_1, ..., A_p$ are the $n \times n$ 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. $\Lambda(\lambda)$ is a $n \times q$ 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, and depends on the vector of free parameters λ. It has rank q, thus the number of cointegrating relations are $n - q$.

In the baseline specification, y_t contains four macroeconomic variables in annualized quarter-on-quarter differences: the logarithm of real GDP per capita, the logarithm of real consumption per capita, the logarithm of GDP deflator and the unemployment rate.[5] The model thus features trend components of *growth rates*, as opposed to trend components of *levels*. The main focus of this paper is in long-lasting changes to the *growth rate* of GDP, rather than its *level*. Indeed, the low-frequency components are specified as unit roots, reflecting permanent changes to the mean of the growth rates in the context of the model. In practice, we can think of these as slow-moving changes that are different from typical business cycle fluctuations. The sample spans the period 1959Q1-2019Q4.[6]

[5]The raw data is retrieved from the FRED database. Real GDP, the GDP deflator and the unemployment rate correspond, respectively, to the following mnemonics: GDPC1, GDPDEF and UNRATE. Real consumption is the sum of Personal Consumption Expenditures: Services (PCESV) and Personal Consumption Expenditures: Nondurable Goods (PCND), deflated by the GDP deflator. Real GDP and consumption are transformed in per capita terms using the population level (CNP16OV).

[6]The series used in the baseline specification are available from 1948Q1. The period 1948Q1-1958Q4 is used as pre-sample to inform the priors on the initial conditions of the trend and the cycle, which I discuss in the next section. In the robustness section, the baseline sample is extended to 1948Q1.

Table 1: Time series used in the baseline SVAR with common trends

	Frequency	Transformation	Time period	Trend
Real GDP per capita	Quarterly	Annualized quarter-on-quarter growth rate	1959Q1-2019Q4	*Growth*
Real consumption per capita	Quarterly	Annualized quarter-on-quarter growth rate	1959Q1-2019Q4	*Growth*
GDP deflator	Quarterly	Annualized quarter-on-quarter growth rate	1959Q1-2019Q4	*Nominal*
Unemployment rate	Quarterly	Quarter-on-quarter difference	1959Q1-2019Q4	/

Note: Annualized quarter-on-quarter growth rates are obtained by taking the first difference of the logarithm of the series, multiplied by 400. The last column indicates the trend on which every variable of the system loads.

I make 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 unemployment changes trendless, being characterized by the stationary component only.[7] Table 1 summarizes the time series used in the baseline specification, and indicates which variables load on the two trends.

There are two main reasons for the choice of two trends for the set of variables included in y_t. On the one hand, the assumption of a growth trend and a nominal trend seems quite natural given the variables included in the system, and two trends are necessary to implement the identification scheme presented in the next section to disentangle demand-side and supply-side factors. On the other hand, the eigenvalues of the variance-covariance matrix of the trend components are in absolute value close to zero when additional trends are introduced, suggesting the presence of only two trends across the variables included in the system.[8]

2.2 Inference

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

$$\begin{aligned} \tau_0 &\sim N(\underline{\tau_0}, I) \\ \tilde{y}_{0:-p+1} &\sim N(0, \Omega_0) \end{aligned} \tag{2}$$

[7]As the unemployment rate is particularly sensitive to cyclical fluctuations, its inclusion is important for proper estimation of the stationary component. For instance, Fernald et al. (2017) use the unemployment rate to measure the cycle.

[8]Nonetheless, I add additional variables and trends to the baseline specification in section 4.

where the prior mean $\underline{\tau_0}$ is set at pre-sample averages (2.6 for GDP growth and 2.3 for inflation) and Ω_0 is the unconditional variance of $\tilde{y}_{0:-p+1}$ implied by the third equation in (1). The model described in (1) and (2) is a linear, Gaussian state-space model. As such, it is estimated using Bayesian techniques.[9] Bayesian estimation is particularly convenient for the question at hand, as the approach is flexible to the inclusion of additional variables and trends, it allows to discipline econometrically the low-frequency components and to incorporate priors on both cyclical and trend components.

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 inverse 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). 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 tight and conservative priors on the trend components to ensure these do not reflect business cycle fluctuations. The tightness κ_v is set to 100. The prior on the variance-covariance matrix, $\underline{\Sigma}$, is such that the standard deviation of the expected change in GDP growth and inflation over a period of a hundred years is 0.25 percentage points. Therefore, I am feeding the system with rather strong priors on both trend components moving very little over the sample. Clearly, it could be the case that these trends fluctuate substantially more than what the priors suggest, as it is certainly the case for inflation. 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 would push away from the prior assumptions.

Notice that, while in the baseline specification I specify the same prior on the variance-covariance matrix of the trend components of GDP growth and inflation, this could be in principle different for the two low-frequency components. In the robustness section, I perform a sensitivity analysis where I assess the robustness of the main findings to alternative prior specifications on the trend components and different lag specifications for the transitory component.

[9] The details of the Bayesian estimation are laid out in section A of the Appendix.

2.3 Identification strategy

The basic rationale of the supply-side view of the slowdown in GDP 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)), as suggested by standard growth models. On the other hand, as Summers (2015) argues, if supply-driven factors were the only explanation of this phenomenon, this would have led to an increase in inflation which, however, did not materialize in the data. If anything, inflation declined persistently following the financial crisis and is still below the 2% target, as shown in Figure 1, despite the implementation of important expansionary policies, suggesting the relevance of demand-driven factors.

In what follows, I take the argument of Summers (2015) seriously and propose an approach to identify the supply-side and demand-side components of low-frequency movements in GDP growth starting from the estimated model in (1). Specifically, I map the reduced-form low-frequency components into their structural drivers by identifying the structural shocks to these trend components using a set of sign restrictions based on the above argument. Giving a structural interpretation to the estimated trend components is a novel feature of this paper.

Consider the trend component of y_t:

$$\bar{y}_t = \Lambda\tau_t = \Lambda\Big(\tau_0 + \sum_{j=0}^{t-1} v_{t-j}\Big) \tag{4}$$

Since $v_t \sim N(0, \Sigma)$, where Σ is not necessarily diagonal, the residuals of the trend components are potentially correlated. Thus, the growth trend and the nominal trend 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 $v_t = B\epsilon_t$, where B is a non-singular matrix such that $BB' = \Sigma$ 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 equation (4) as follows:

$$\bar{y}_t = \Lambda\Big(\tau_0 + \sum_{j=0}^{t-1} B\epsilon_{t-j}\Big) \tag{5}$$

Notice that ΛB represents the impact effect of the structural shock ϵ_t on the low-frequency com-

Table 2: Baseline sign restrictions

	Supply	Demand
GDP growth	+	+
Inflation	-	+

ponent $\bar{y}_t$, since:

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

Therefore, demand and supply shocks can be separately identified by restricting the signs of the elements in ΛB corresponding to the variables of interest. Then, the structural contributors are backed out from equation (5). Table 2 illustrates the set of sign restrictions imposed. Demand-side factors produce a positive co-movement in the low-frequency components of GDP growth and inflation, while supply-side factors imply a negative co-movement.

Sign restrictions are implemented using the QR decomposition algorithm of Rubio-Ramírez, Waggoner, and Zha (2010) and by defining the candidate draw as $\Lambda S Q'$, where S is the lower triangular Cholesky decomposition of Σ and Q is the QR decomposition of a $n \times n$ matrix drawn from a MN$(0, I)$, with the diagonal of R normalized to be positive and $QQ' = I$. This approach is implemented in the same way as for traditional SVARs with sign restrictions. The key difference with respect to standard SVARs is that the identification assumptions are imposed on the trend, rather than cycle, components. As a result, the structural analysis is on low-frequency movements rather than business cycle fluctuations. This is the first empirical paper formally featuring demand and supply shocks with such properties, and identifying the structural drivers of the low-frequency components in the context of VARs with common trends à la Del Negro et al. (2017).

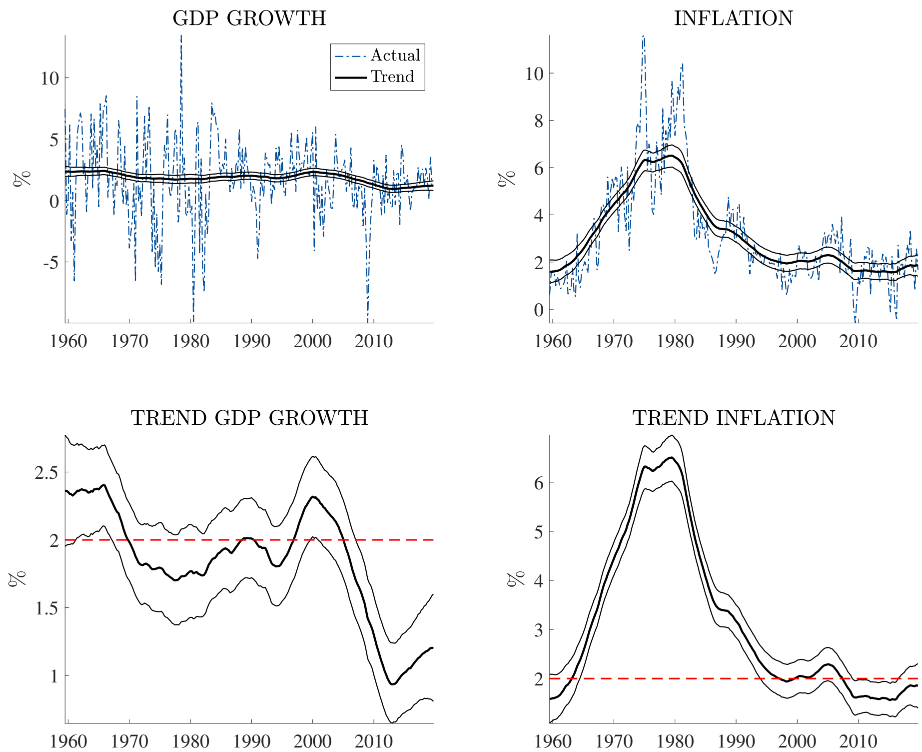
3 Results

3.1 Slow-moving fluctuations in GDP growth and inflation

Figure 1 shows the estimated low-frequency components of GDP growth and inflation together with the actual data. The dotted blue lines correspond to the actual data, while the thick black lines represent the point-wise median estimates of the trend components, with the associated 68% credible bands.

The trend components capture accurately the slow-moving behavior of GDP growth and inflation, and with relatively small uncertainty. Overall, there are substantial fluctuations in the trend components of both GDP growth and inflation over the sample, despite the tight priors imposed on the variance-covariance matrix Σ. The data thus speaks loudly in favor of significant low-frequency

Figure 1: Actual data and estimated trends of real GDP per capita growth and inflation

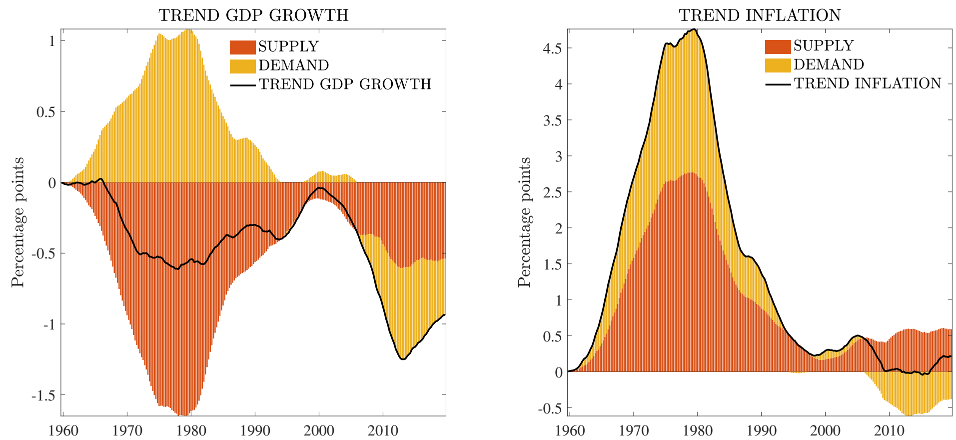


Note: Point-wise median (solid black line) and 68% credible bands are based on 10000 draws. Actual growth rates are defined in annualized quarter-on-quarter terms.

variation in the mean of the growth rates, τ_t.

There is a significant slowdown in trend GDP growth over the sample considered, of about 1.16 percentage points from 1959Q2 to 2019Q4. The point-wise 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 the slowdown is its timing. Trend GDP growth declined appreciably in the late 1960s and early 1970s, accelerated quickly in the mid-1990s, reaching a new peak in 2000, and fell remarkably afterwards. These findings are well in line with the 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 (see Gordon (2015)). The recent decline, however, is more controversial. 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).

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



Note: The black line is the point-wise median estimate in percentage point deviations from initial conditions. The colored bars represent the point-wise median contribution of demand-side and supply-side factors.

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 in the aftermath of the financial crisis. The slight increase in the low-frequency component of inflation from 2000 to 2006 seems to suggest that structural forces other than demand are in place from early 2000s. However, the trend component of inflation declines after the Great Recession, and remains well below the 2% target for over a decade. This finding leans towards the argument that factors other than supply might be in place to account for the lackluster growth experienced since the onset of the financial crisis, as highlighted by Summers (2015).

A comment on inflation is warranted. The recent decline in the low-frequency component of inflation is rather small compared to its fluctuations over the sample. The trend increases substantially starting in the mid-1960s and peaks around 1980-1981, reflecting the Great Inflation, after which a substantial decline is in place (see Ascari and Sbordone (2014) for a survey of the macroeconomics of trend inflation).

3.2 Why has trend GDP growth slowed down?

Figure 2 plots the contribution of supply-side and demand-side factors in accounting for low-frequency movements in GDP growth and inflation. The thick black line represents point-wise median estimates of the trends in deviations from their initial conditions, while the colored bars show the estimated drivers.[10]

[10]The uncertainty surrounding the estimated drivers is represented in Figure B1 of Appendix B.

Focusing on GDP growth (left panel), supply-driven factors explain the bulk of its long-run fluctuations over the entire sample. These factors play a key role in driving trend GDP growth downwards in the late 1960s and early 1970s, in line with the common view that a large productivity slowdown took place during this historical period. Also, the rapid rise in trend GDP 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 initial slowdown in trend GDP growth, and contribute further to its 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. Overall, it seems that the supply-side component captures remarkably well changes in technological progress. Indeed, the timing resembles closely the arguments of both Gordon (2015) and Fernald et al. (2017).[11]

At the same time, demand-side forces appear relevant drivers of fluctuations in the long-run component of GDP growth. The findings suggest that demand-side factors contributed positively to trend GDP growth during the 1970s. This could indicate, for instance, that the monetary and fiscal policies that fueled inflation in the 1970s had positive effects on GDP growth, masked however by the negative pressure of supply-side forces. 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. Moreover, half of the shortfall in GDP growth from 2000 appears to be due to demand-side factors, providing evidence of important super-hysteresis effects that exacerbated the slowdown since the onset of the Great Recession.

While the slowdown of GDP growth in the 1970s and its rise during the 1990s are entirely supply-driven phenomena, the decline after 2000 is explained by both supply-side and demand-side factors. Using the median estimates, 49% of the decline is attributed to demand, and 51% due to supply. While the beginning of the slowdown in 2000 is due to supply forces only, demand factors contribute importantly to further exacerbate this trend after the financial crisis. These findings pair remarkably 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 clear once we have a closer look at inflation (right panel). While supply factors put upward pressure on inflation after 2000, these have been more than counterbalanced by demand forces pulling in the opposite direction in the aftermath of the financial crisis. These findings can also provide an intuitive explanation for 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-driven factors.

[11] Notice, however, that I do not take a stand on the particular micro-foundation behind the supply side. Many factors could be potentially at play, as highlighted in the introduction.

Overall, these results document an important role for demand-side factors in accounting for long-run fluctuations in the growth rate of GDP, which is a novel finding in the literature.

4 Additional macroeconomic variables and trends

In order to have a better understanding of the potential channels through which demand-side and supply-side forces affect long-run GDP growth, I augment the baseline VAR with common trends with the following variables, one at a time: the growth rates of real investment per capita, utilization-adjusted TFP, real wages, hours, labor force participation, the personal savings rate, expectations on the growth rate of real GDP from the Survey of Professional Forecasters, and a set of real yields to estimate the natural rate of interest, r^*.[12]

Regarding the growth rates of investment, TFP, wages, hours and the participation rate, I make the assumption that these series 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. Regarding expectations, I make the assumption that both one-year ahead GDP growth expectations and long-run GDP growth expectation share a trend with GDP and consumption growth, and have their own shared trend. Thus, the trend in expectations about GDP growth could potentially deviate from the trend of GDP growth. Finally, to obtain an estimate of the natural rate of interest, r^*, I follow Del Negro et al. (2017) and augment the baseline specification with the 3-months treasury bill, the 20-year treasury constant maturity rate and long-run expectations on the 3-months treasury bill from the Survey of Professional Forecasters in real terms. The real yields share a common trend, namely r^*.

The introduction of these additional trends implies the presence of an additional structural driver to identify. Table 3 presents the additional restrictions imposed to separately identify demand, supply and the additional structural driver, which I label as residual and to which I do not give a formal interpretation. Notably, I do not restrict the sign of the additional macroeconomic

[12] Real investment is constructed as the sum of Gross Private Domestic Investment (GPDI) and Personal Consumption Expenditures: Durable Goods (PCEDG), deflated by the GDP deflator (GDPDEF). Real hourly wages, hours, labor force participation and savings rate correspond to the following mnemonics: COMPRNFB, HOANBS, CIVPART and PSAVERT. The real yields are constructed by substracting, respectively, 3-Month Treasury Bill: Secondary Market Rate (TB3MS) and 20-Year Treasury Constant Maturity Rate (GS20) with long-run PCE inflation expectations from the Survey of Professional forecasters. Long-run expectations on the TBILL and GDP growth are retrieved from the Survey of Professional Forecasters. I use median responses for the variables from the Survey of Professional Forecasters.

Table 3: Additional sign restrictions

	Supply	Demand	Residual
GDP growth	+	+	+
Inflation	-	+	-
Investment growth	+	/	-
GDP growth expectations	+	/	-
TFP growth	+	/	-
Wages growth	+	/	-
Hours growth	+	/	-
Participation rate growth	+	/	-
Savings rate	+	/	-
r^*	+	/	-

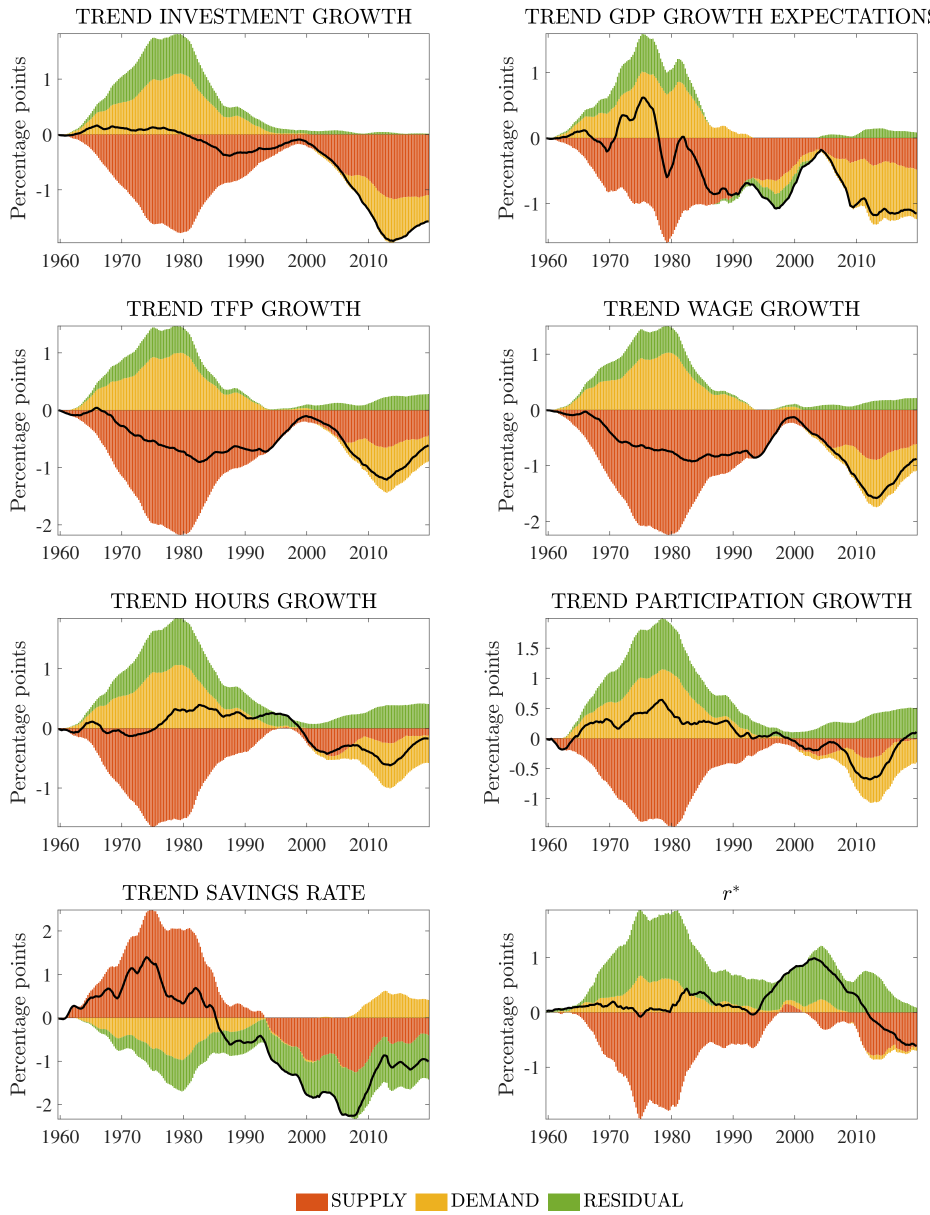
variables to demand shocks.

Figure 3 presents the results of the baseline SVAR with common trends augmented with the additional macroeconomic variables. The low-frequency components of the growth rates of investment, TFP and wages exhibit a similar evolution to trend GDP growth. Demand-side factors explain a substantial share of the decline in these variables in the aftermath of the financial crisis, while supply-side factors explain the decline in the early 2000s. Focusing on GDP growth expectations (right panel, first row), the trend component is substantially different from GDP growth and features a more persistent decline which starts in the late 1970s. Notably, demand-side factors explain entirely the decline after the financial crisis, highlighting the expectation channel as a potentially important pass-through of super-hysteresis effects. The above results pair well with the theoretical channel proposed by Benigno and Fornaro (2018).

Focusing on labor market variables, the decline in hours growth and labor force participation growth (third row) in the aftermath of the financial crisis appears to be mainly due to demand-driven forces, which play a relevant role in accounting for slow-moving changes of these variables 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. (2021) for its level, highlighting an important role of demand-driven factors to understand low-frequency movements in labor force participation.

Finally, demand-side factors explain a non-negligible share of the increase in the personal savings rate, highlighting the role of precautionary savings as a potential channel contributing to the decline in GDP growth. Interestingly, demand-side factors play a negligible role in accounting for the decline in the natural rate of interest, which is explained mostly by supply-side factors and the residual shock. The fact that estimated drivers of growth (demand and supply) do not explain the bulk of the decline in the natural rate is in line with the evidence in Del Negro et al. (2017)

Figure 3: Estimated contribution of demand and supply to the trends of additional macroeconomic variables



Note: The black line is the point-wise median estimate in percentage point deviations from initial conditions. The colored bars represent the point-wise median contribution of the structural drivers.

which points towards the importance of the convenience yield as driver of this trend.

5 Robustness

This section discusses the robustness of the baseline 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 and to the extension of the baseline sample from 1948Q1. The figures of this section are presented in section B of the Appendix.

Figure B2 shows trend GDP growth and its structural drivers when I 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, or specifying the growth rates in year-on-year terms, affects the main findings. The third row shows the results obtained using alternative definitions of inflation, and by using a larger set of variables, which includes all the additional macroeconomic series of section 4 and the different measures of inflation, namely CPI and PCE.

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 variance-covariance matrix of the trend components, namely Σ. The first panel represents a prior that is half conservative as the baseline, while the second panel is twice 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. When I make the priors more conservative, instead, the results are very similar to the baseline. Using year-on-year growth rates produces similar results, but the trend component fluctuates more than the baseline.

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 and CPI 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. Once I include a larger set of variables to the baseline specification, the results are virtually identical to the baseline.

As mentioned in section 2.2, in the baseline VAR with common trends I assume the same prior for the variance-covariance matrix of trend GDP growth and inflation. These priors, however, can be in principle different. For instance, one might have the prior that trend inflation fluctuates more than trend growth on average over the sample. Figure B3 shows the main results when I fix the prior for trend growth and make the prior on trend inflation twice as loose. Figure B4, instead, fixes the prior on trend inflation and uses a prior on trend GDP growth twice as loose. The results appear very similar to the baseline specification in both cases. The main difference is that both trends seem to fluctuate more when either prior is looser.

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. 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 B5 shows the results. The main findings are robust to these alternative sample specifications. Moreover, Figure B6 plots trend GDP growth and trend inflation and their drivers once the sample is extended to include data from 1948Q2. If anything, demand seems even more important in accounting for the decline in trend GDP growth.

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 demand-side factors in accounting for the slowdown in growth after the Great Recession is confirmed in all the different specifications.

6 Concluding remarks

Economic growth in the United States has been slow in the decade following the Great Recession. While there is wide agreement in the macroeconomic literature that a decline in trend GDP growth took place from the early 2000s, a consensus view regarding its underlying drivers is lacking. This paper empirically quantifies the relative importance of demand-side and supply-side factors in accounting for this phenomenon.

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 their underlying drivers, namely demand-side and supply-side factors, using a general set of sign restrictions. Supply-driven and demand-driven forces are identified assuming that the former imply a negative co-movement between output growth and inflation, while the latter imply a positive co-movement. This is the first paper that quantifies the relative importance of these forces in accounting for the slowdown in GDP growth within a unified empirical framework.

The main findings can be summarized as follows. First, US trend 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 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 entirely account 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. These effects appear particularly relevant in explaining the decline in investment growth and GDP growth expectations, suggesting a potential link to the theoretical channel proposed in Benigno and Fornaro (2018). 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 offers a potential rationale for two puzzling phenomena: missing deflation during the Great Recession and missing inflation during the recovery. Overall, these findings highlight a relevant role of demand factors as drivers of long-run GDP growth.

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APPENDIX

A Bayesian 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:

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

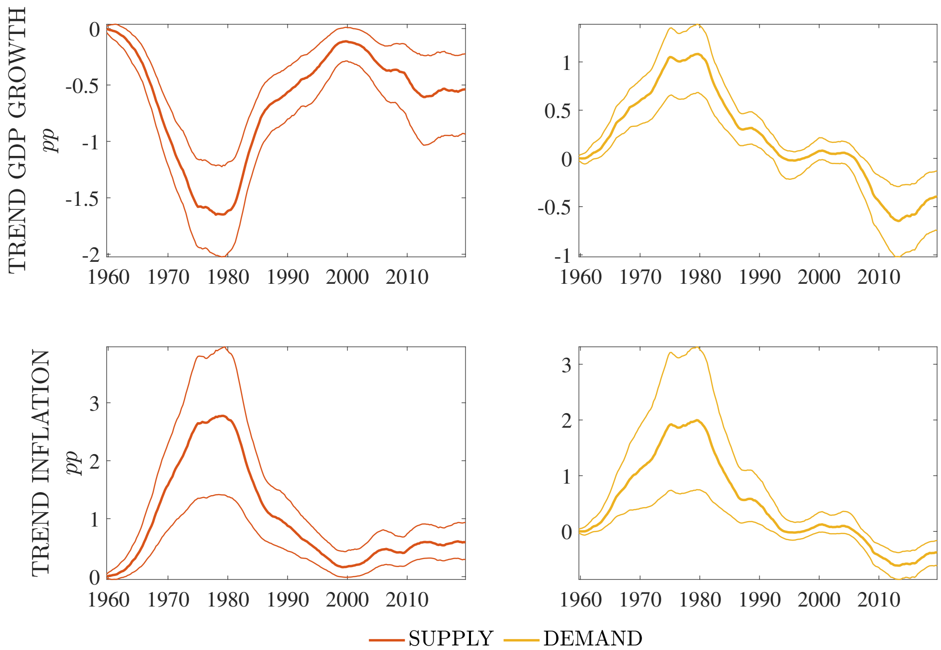
   where $\hat{S}_v = \sum_{t=1}^{T} (\bar{y}_t - \bar{y}_{t-1})(\bar{y}_t - \bar{y}_{t-1})'$ is the sum of squared errors of the trend components. In the transitory component equation, the posterior distribution of $vec(A)$ and Ω is given by:

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

   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 $\hat{A} = (\tilde{X}\tilde{X}' + \underline{\Omega}^{-1})^{-1}(\tilde{X}'\tilde{y} + \underline{\Omega}^{-1} vec(\underline{A}))$.

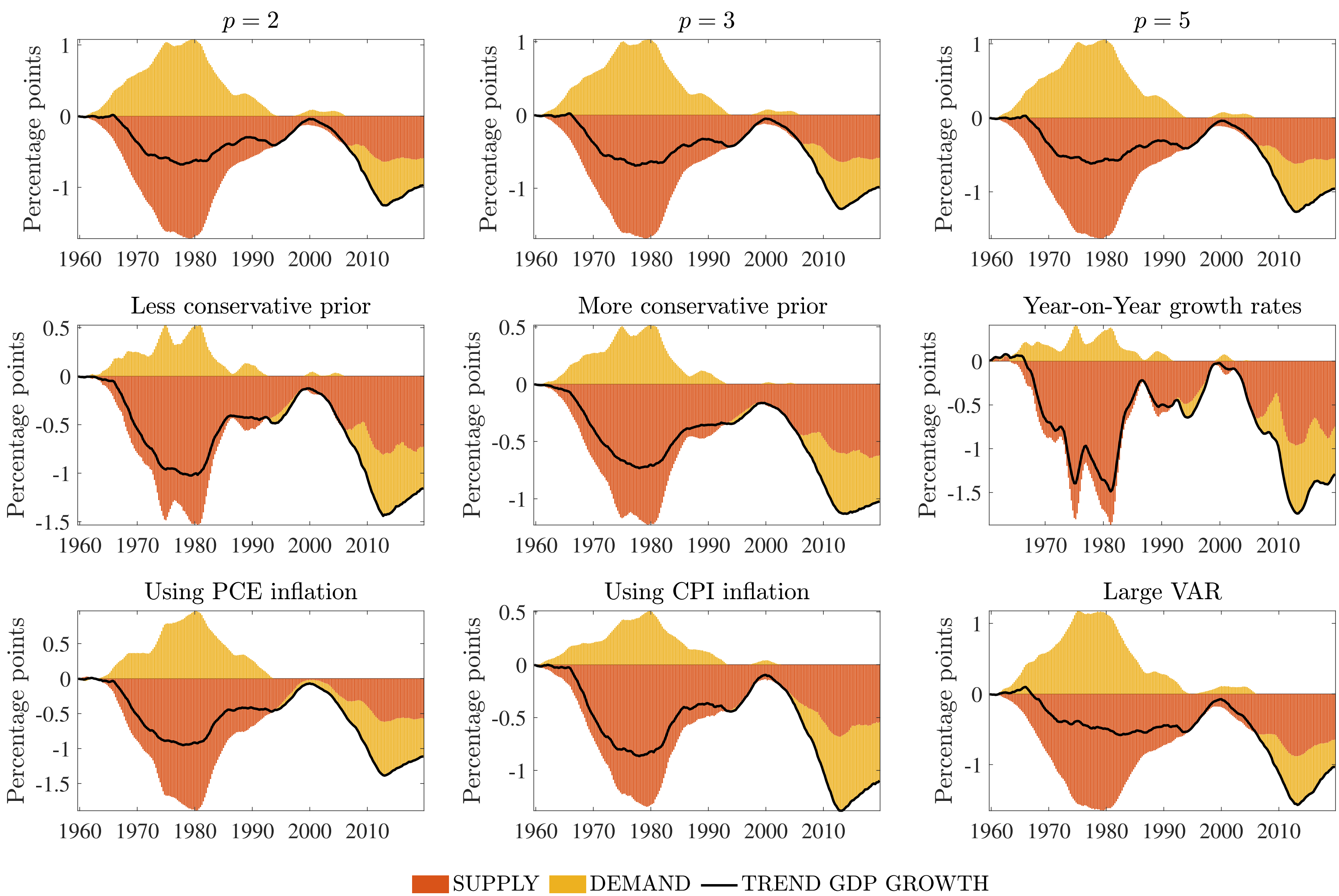
B Additional figures

Figure B1: Estimated contribution of demand and supply to the trends of GDP growth and inflation



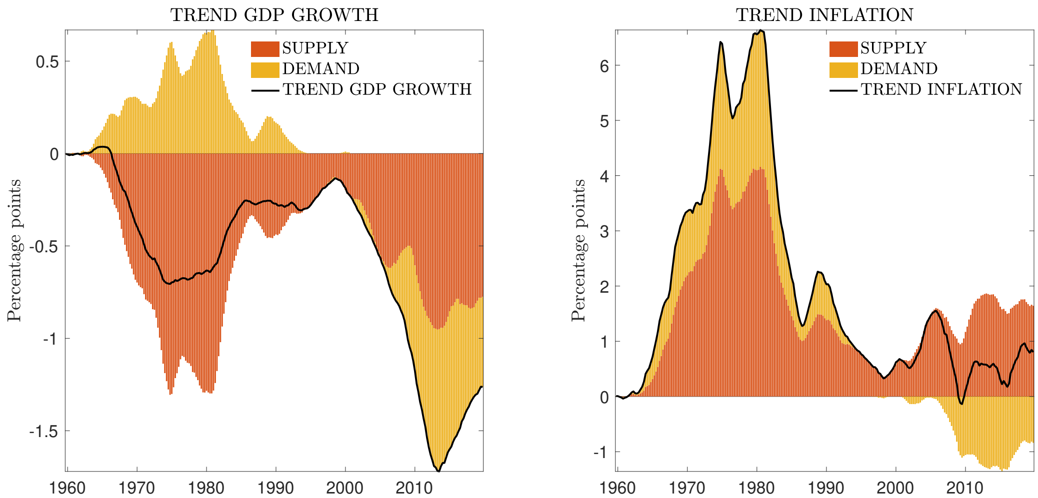
Note: Median (thick line) and 68% credible bands are based on 10000 draws.

Figure B2: Alternative lag, prior and variable specifications



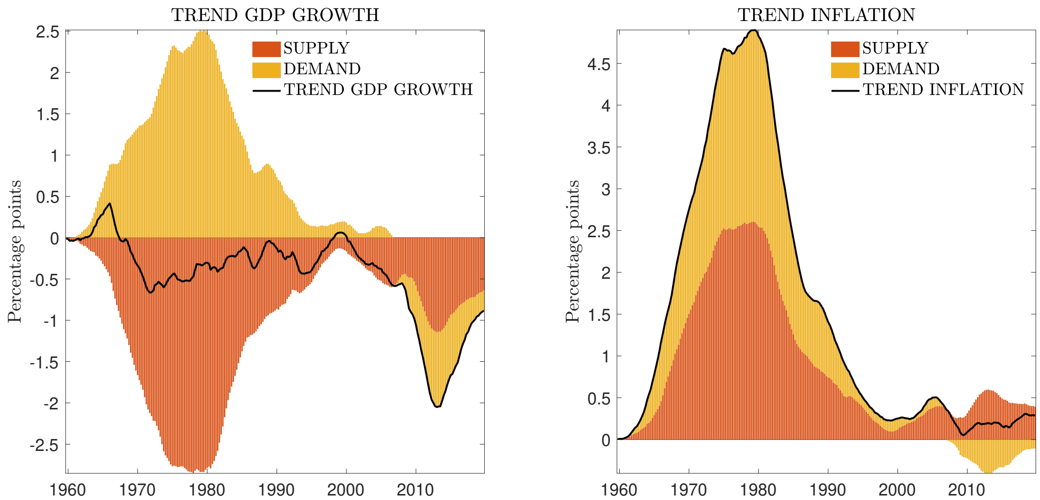
Note: The black line is the point-wise median estimate of trend GDP growth in percentage point deviations from its initial condition. The colored bars represent the point-wise median contribution of the structural drivers.

Figure B3: Loose prior on trend inflation



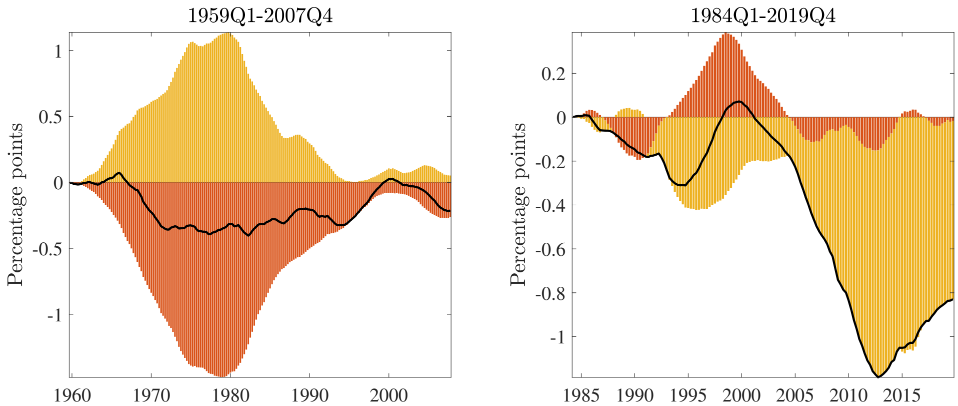
Note: The black line is the point-wise median estimate of trend GDP growth and trend inflation in percentage point deviations from their initial condition. The colored bars represent the point-wise median contribution of the structural drivers.

Figure B4: Loose prior on trend GDP growth



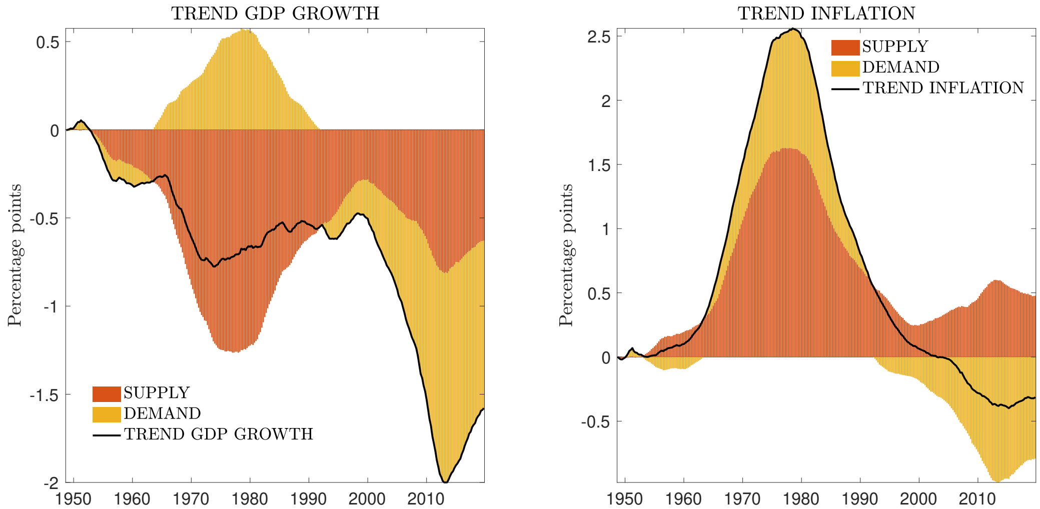
Note: The black line is the point-wise median estimate of trend GDP growth and trend inflation in percentage point deviations from their initial condition. The colored bars represent the point-wise median contribution of the structural drivers.

Figure B5: Sub-sample analysis



Note: The black line is the point-wise median estimate of trend GDP growth in percentage point deviations from its initial condition. The colored bars represent the point-wise median contribution of the structural drivers.

Figure B6: Full sample - 1948Q1-2019Q4



Note: The black line is the point-wise median estimate of trend GDP growth and trend inflation in percentage point deviations from their initial condition. The colored bars represent the point-wise median contribution of the structural drivers.