Hysteresis and Business Cycles

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Abstract

Traditionally, economic growth and business cycles have been treated independently. However, the dependence of GDP levels on its history of shocks, what economists refer to as "hysteresis," argues for unifying the analysis of growth and cycles. In this paper, we review the recent empirical and theoretical literature that motivates this paradigm shift. The renewed interest in hysteresis (or "scarring" in recent parlance) has been sparked by the persistent impact of the Global Financial Crisis, as GDP in advanced economies remained far below the pre-crisis trends for over a decade, and recent concerns about the lasting impact of the COVID-19 shock. The findings of the recent literature have far-reaching conceptual and policy implications. In recessions, monetary and fiscal policies need to be more active to avoid the permanent scars of a downturn. And in good times, running a high-pressure economy could have permanent positive effects.

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I. Introduction

Ten years after the Global Financial Crisis started there was still a perception that many advanced economies had not properly recovered from this event. The crisis had left scars on investors, firms, workers, and consumers' memories who suffered its negative consequences. These perceptions were supported by the fact that, objectively, the recovery from the crisis was slow among all advanced economies (as Ball (2014), Rawdanowicz et al. (2014), Reifschneider, Wascher, and Wilcox (2015), Cerra and Saxena (2017), Fatas and Mihov (2013), among many others, have shown). This slow recovery meant that GDP, or GDP per capita, was clearly below its pre-crisis trend a decade after the crisis. The Global Financial Crisis was quite unique because of its depth and length and for many countries it represented the worst crisis since the Great Depression. But the fact that recoveries might not always be strong enough to bring GDP back to its pre-crisis trend is not just about this particular crisis. There is plenty of empirical evidence that GDP fluctuations are persistent, that their effects are still with us years after the shock takes place.

In 2020, the world fell into yet another global crisis, this time caused by a pandemic, renewing questions about how long it will take to go back to pre-crisis GDP levels and the potential long-term scars that the crisis will leave on the most affected economies.

The persistent and possibly permanent effects of recessions mean that what we refer to as cyclical events are not simply movements along a trend. They, themselves, affect the trend. The possibility that the trend is not orthogonal to business cycles became a central stylized fact in the Real Business Cycle Theory and supported the hypothesis that exogenous permanent technology shocks could be a fundamental driver of the cycle. But there are alternative views that can also explain the persistence of cyclical fluctuations. In particular, in models where the state of the economy and the level of GDP are history dependent, cyclical shocks can also leave a permanent imprint on economic activity. This is what it is known as hysteresis.

Hysteresis is a concept used in many natural sciences to describe the "dependence of the state of a system on its history".[1] In economics, explicit references to hysteresis appeared in different fields in the late 1980s (Franz (1990)). For example, as a way to explain how certain shocks can have permanent effects on trade variables (Baldwin (1990), Baldwin and Krugman (1989) or Dixit (1989)) or how small differences in its history can affect capital accumulation by firms (Dumas (1989)).

The focus of our paper is on the application of hysteresis to business cycle models. The earliest explicit references to hysteresis in the business cycle literature was in the context of labor markets. Blanchard and Summers (1986) and Clark (1989) used the term to refer to the experience of European labor markets during the 1970s and 1980s. Consistent with the other

[1] "Hysteresis," in *Wikipedia: The Free Encyclopedia*; (Wikimedia Foundation Inc., updated 12 July 2020, 07:47 UTC); available from https://en.wikipedia.org/wiki/Hysteresis; Internet; retrieved 17 August 2020.

strands of the hysteresis literature, their definition of hysteresis was that of path dependence in steady states.[2] But scars from business cycles do not just need to come from the labor market. In models where growth is endogenous, business cycles can temporarily alter the drivers of growth and, as a result, GDP does not return to its previous trend after the crisis. This form of hysteresis was explicitly described and modeled as endogenous growth theory was becoming mainstream in the late 80s (King, Plosser, and Rebelo (1988), Stadler (1990)).

The notion of hysteresis in business cycles also appears in other strands of the macroeconomics literature. Nonlinear models with multiple equilibria characterize cycles as fluctuations between a low and a high growth state. Recessions, seen as periods where the economy is in its low-growth state, leave permanent scars on the GDP level (Durlauf (1991), Durlauf (1994), Evans and Honkapohja (1993)). Finally, we also find references to hysteresis in the post-Keynesian literature, referring to economies that do not return by themselves to a natural state. This argument is used against the idea of the natural rate hypothesis (Cross (1988)).

Hysteresis in business cycles not only has implications for the way we think about the drivers of fluctuations and long-run growth, but also for the optimal economic policies that fiscal authorities and central banks should follow. If cyclical deviations leave permanent scars, there should be more urgency for policy makers to counteract low aggregate demand during a recession. And, in good times, running a "high-pressure" economy can not only allow for a fuller utilization of resources but can also have a long-term effect on the level of GDP.

This paper is organized as follows. We start in Section II with a short chronological overview on how the views on the definition and characterization of business cycles have evolved over time, with a focus on the distinction between the cycle and the trend. Section III summarizes the evidence on persistence of business cycles and its potential causes. Section IV reviews the models that have incorporated this phenomenon. Section V discusses the policy recommendations in a world with hysteresis and Section VI concludes.

II. Cycle and Trend

The separation of long-term trends from business cycles has been at the core of how economists think about the existence, causes and remedies of economic fluctuations. In this section we provide a quick historical overview on how the thinking about business cycles has evolved over time.

[2] "Formally, a dynamic system is said to exhibit hysteresis if it has at least one eigenvalue equal to zero (unity, if specified in discrete time). In such a case, the steady state of the system will depend on the history of the shocks affecting the system. Thus, we should say that unemployment exhibits hysteresis when current unemployment depends on past values with coefficients summing to 1" (Clark (1989)).

A. The cycle in the business cycle

The early 20th century analysis of business cycles culminated with the NBER efforts and the work of Burns and Mitchell (1946) to define, measure and date business cycles in the US.[3] Two decades before, Mitchell (1923) had described economic cycles as a succession of crises that followed periods of prosperity. He saw crises as caused by shocks such as weather, uncertainty, innovation, savings, or by over-production, what he referred to as a "*slow accumulation of stresses within the balanced system of business – stresses which ultimately undermine the conditions upon which prosperity rests*." (Mitchell (1923) and Mitchell (1927))

Burns and Mitchell (1946) provided a historical characterization of business cycles as phenomena that are recurrent in time. They are cyclical in nature although they do not follow a given frequency (i.e. they are not periodic). In their words "*expansion is followed by recession, recession by contraction, contraction by revival, and revival by a fresh expansion.*" Given this characterization, their focus was on identifying turning points, referred to as peaks or troughs.

Burns and Mitchell (1946) had in mind a theoretical underpinning based on the concept of short-term fluctuations around a trend driven by fundamentals. In their words: "*Defining business cycles as recurrent departures from and returns toward 'a normal state of trade', or 'a position of economic equilibrium'.*" But they explicitly avoided imposing such a theoretical framework on their empirical work because of the difficulty in constructing variables that are relevant from a theoretical point of view, but not directly observed. "*To say that business cycles are departures from and returns toward a normal state of trade or position of equilibrium, or that they are movements resulting from discrepancies between market and natural rates of interest, will not help, because we cannot observe normal states of trade, equilibrium positions, or natural interest rates*."

Their choice of following a data-driven approach in the characterization of business cycles instead of one based on theory led to criticisms as in, for example, Koopmans (1947) who argued that "*the decision not to use theories of man's economic behavior, even hypothetically, limits the value to economic science and to the maker of policies, of the results obtained or obtainable by the methods developed. This decision greatly restricts the benefit that might be secured from the use of modern methods of statistical inference.*"

Koopmans' criticism was based on the view that without a specific hypothesis to be tested, the empirical characterization of business cycles cannot provide enough insights to policy makers or those trying to understand the causes of economic fluctuations.

[3] Attention to business cycles was rare among economists in previous centuries. Their focus was typically on the understanding of fundamental, long-run economic principles. Mitchell (1927) describes the work of some of the 19th century economists who were concerned with economic fluctuations and their early references to cycles.

The idea of cycles as deviations from normal states of trade was not uncommon among economists in the early 20th century. Keynes (1936) emphasized deviations from the long-term equilibrium analysis of the classical model to explain the existence of economic fluctuations. Cycles could be described as periods of low growth or high unemployment driven by demand changes. Hicks (1933) saw business cycles as states of "*disequilibrium*" from the "*idealized state of dynamic equilibrium.*" Changes in "*structural elements that have the most direct effect on prices – the rate of interest and the value of money*" were the main sources of economic fluctuations.

B. Modeling the trend and the cycle

Much of the academic work in the decades that followed used the Keynesian tradition with a focus on the importance of demand factors in order to understand business cycles. While in this framework cycles were seen as deviations from a classical equilibrium determined by full employment, the determination of long-run equilibrium was typically not explicitly modeled (as in, for example, the large-scale econometric model of Klein and Goldberger (1955)).

However, the high inflation period of the 1970s shifted the focus of the academic research towards the understanding of long-run equilibrium and in particular the role of the nonaccelerating inflation rate of unemployment (NAIRU) as an anchor to the Phillips Curve. The existence of the NAIRU made a long-term tradeoff between inflation and unemployment impossible. Over time this led to the development of macroeconomic models with a much more structured view of full employment and a clear separation between the long-run equilibrium state of an economy and the cycle (Friedman (1968), Phelps (1968) and Lucas (1977)).

This emphasis on the need to provide a theoretical basis for the understanding of the long-term equilibrium was a key argument in the seminal work of Kydland and Prescott (1982). They presented their methodology partly as a contrast to the unstructured view of Burns and Mitchell (1946).[4] Business cycles were explicitly defined as deviations from long-term equilibrium values, and those were properly grounded in the theory of long-run growth. For this purpose, Kydland and Prescott (1982) made use of the neoclassical Solow growth model to capture the trend or steady state. An additional innovation was to formalize the idea that the trend could be stochastic; a deviation from the view of long-run dynamics as slow-moving forces. A stochastic trend meant that technology shocks could be a source of short-term fluctuations, leading to the development of Real Business Cycles (RBC) models. Based on this theoretical framework, a series of papers developed econometric methods to estimate the trend and, by default, the business cycle. This is the methodology made popular by Beveridge and Nelson (1981) of decomposing GDP into a trend and a cycle.[5]

[4] Kydland and Prescott (1990) build on the earlier criticism that Koopmans (1947) had made of Burns and Mitchell (1946) by referring to their methodology as "measurement without theory".

[5] There are alternative view of the cycles such as those summarized in Zarnowitz and Ozyildirim (2006).

This methodological approach became the basis of most of the academic research that followed. Whether we are referring to a real business cycle model or a New-Keynesian one, the long-run dynamics of GDP were driven by a (possibly stochastic) long-run trend that was implicitly associated with the Solow-model growth dynamics. And business cycles were thought of as the movements of macroeconomic variables as they adjust, after a shock, to this steady state. In addition, fluctuations were typically modeled as symmetric and caused by small and frequent shocks (technology, preferences or economic policies).

Despite the structural nature of the RBC models, and their focus on technology as a source of cycles, long-term growth dynamics were treated as a black box, mostly as a drift in the stochastic process describing technology. This idea fit well with the exogenous-growth models a la Solow (1956). This very simple framework, which treated average growth as exogenous but emphasized short-term shocks to technology as a cause of persistent business cycles, was the basis of many empirical studies that tried to assess the sources of business cycles. Blanchard and Quah (1989) explicitly identified technology shocks from demand shocks by the persistence of its dynamics: technology shocks were permanent while demand shocks were transitory. From a policy point of view, traditional aggregate demand policies (monetary and fiscal) could only address the cyclical, temporary disturbances. And the costs of these disturbance were seen as small given their temporary and symmetric nature (Lucas (1987)).

An early exception to the symmetric view of the business cycle was Friedman (1964) and (1993). In some ways, his description of business cycles was similar to that of Burns and Mitchell. There is an inherent asymmetry in cycles where recessions are seen as downward deviations from potential output, seen here as a maximum. Empirically, the support from these dynamics comes from the observation that recessions do not depend on the length of expansions, but recoveries depend on the depth of recessions. In Friedman (1964)'s words: "*Our analytical models generally involve a conception of a self-generating cycle, in which each phase gives rise to the next, and which may be kept going by a sequence of random shocks each giving rise to a series of damped perturbations. (…) The asymmetric serial correlation pattern suggests that this analogy might be misleading, that a better one is what can be termed a plucking model. Consider an elastic string stretched taut between two points on the underside of a rigid horizontal board and glued lightly to the board. Let the string be plucked at a number of points chosen more or less at random with a force that varies at random and then held down at the lowest point reached. The result will be to produce a succession of apparent cycles in the string whose amplitudes depend on the force used in plucking the string*."

Friedman's "plucking" model of business cycles is an inherently asymmetric model of fluctuations. We can reconcile this model with the notion of an equilibrium steady state towards which GDP returns if we interpret that maximum level as the equilibrium or steady state level of output used. And, in principle, one could add to this framework the possibility that the trend itself is stochastic and driven by certain (low frequency) shocks. But what is central to the model is the idea that asymmetric and temporary disturbances are responsible for events that we can call business cycles and, as before, the (now asymmetric) cycle is distinct from the trend.

C. The cycle and trend when growth is endogenous

As endogenous-growth theory developed in the late 1980s, a set of papers explored the idea of analyzing the interactions between endogenous growth and business cycles. King, Plosser, and Rebelo (1988) and King and Rebelo (1988) found that temporary technology shocks can become permanent in the presence of endogenous growth. The otherwise temporary shocks would produce permanent effects on GDP because they temporarily altered the long-term growth engine. Because of their focus on technology shocks and the fact that in the original RBC models technology shocks were already seen as permanent, these papers did not differ much from standard RBC models. They shared the source of the shock (technology) as well as the unit root properties of the stochastic trend.

Using a similar logic but applied to any temporary shock, Stadler (1986) and Stadler (1990) established a much larger departure from RBC models. The novelty was that demand shocks, that had always been seen as temporary, could now have permanent effects on GDP. In Stadler (1990) monetary shocks affect employment and therefore the pace of knowledge accumulation, which is the driver of long-term growth. Stiglitz (1993) showed similar effects in a model where R&D expenditures react to the state of the business cycle. Martin and Rogers (1997) developed a model where human capital accumulation, via learning by doing, is driving long-term growth. In their model, fiscal policy used for stabilization purposes can have permanent effects. Fatas (2000a) showed that in a model where capital accumulation drives long-term growth, labor market or fiscal policy shocks have permanent effects on GDP.

While these papers focused on the potential permanent negative effects of recessions, the incorporation of endogenous growth to economic models of the business cycles can also open the door for positive, cleansing, effects of recessions. During recessions, as production is lower than normal, there are unused productive resources that can be deployed to research activities and this reassignment of resources could increase growth in the long term. Also, recessions can be seen as periods where uncompetitive firms go out of business. In these models, trend growth accelerates during recessions and once the cyclical effects are gone the economy continues in a trajectory of higher GDP. Gali and Hammour (1992), Caballero and Hammour (1994), Aghion and Saint-Paul (1991) or Hall (1991) developed models that describe this intuition.

All these papers, by introducing endogenous growth in traditional business cycle models, created a new paradigm in the decomposition of trend and cycle. If cyclical events can affect the trend, they become persistent and can possibly have permanent effects on GDP. And if this is the case, stabilization policies will result in long-lasting effects on GDP and welfare.

The intuition captured by all these models was not completely new to the academic literature. The idea that cyclical disturbances could have long-term effects had been suggested much earlier even if it had not been fully formalized. For example, Okun (1973) in a framework that relies on an asymmetric view of business cycle suggested that running a "high pressure" economy with lower unemployment can lead to an upgrade of skills, higher productivity and wages. While the logic of the paper is static in nature, it mimics that of the dynamic endogenous growth models developed decades later. It also reaches the conclusions that a more aggressive demand-management policy could improve the long-run equilibrium.

Tobin (1980) also acknowledged the importance of running a "high pressure" economy and how a clean separation of the long-run equilibrium and the business cycles was not possible. "*With respect to human capital, as well as to physical capital, demand management has important long-run supply-side effects. A decade of slack labor markets, depriving generations of young workers of job experience, will damage the human capital stock far beyond the remedial capacity of supply-oriented measures*."

But what the development of endogenous growth theory did is to allow these early intuitions to be formalized with models that established a view of business cycles where trend and cycles are not orthogonal to each other. But unlike in the tradition of RBC models where the stochastic nature of the trend could be a source of cycles, these papers emphasized the notion that the effects of cyclical fluctuations can be long-lasting, even permanent, and therefore the potential positive effects of stabilizing them can be much larger than previously thought. The path of GDP is dependent on its history and it is this dynamic feature what we refer to as hysteresis.

III. EMPIRICAL EVIDENCE

A. Persistence a key feature of business cycles

In the previous section, we have described the importance of the separation of trend and cycle for our understanding of economic fluctuations. The original notion that trends were slow-moving and possibly deterministic while fluctuations were temporary cyclical events was first challenged by the RBC literature and later by models with hysteresis effects. In these two strands of the literature a key implication was the persistence of fluctuations. In this section, we review the empirical literature on persistence, the early debate around the existence of unit roots, as well as the attempts to identify its source so as to discriminate between alternative explanations of the business cycle.

B. Early evidence on persistence and unit roots

In their seminal paper, Nelson and Plosser (1982) presented evidence that questioned the view of cycles as temporary deviations from long-run output. They investigated whether macroeconomic time series are better characterized as stationary fluctuations around a deterministic trend or as non-stationary processes that have no tendency to return to a deterministic path. Using long historical time series for the United States, they were unable to reject the hypothesis that these series are non-stationary stochastic processes (i.e., in essence they have a unit root). Campbell and Mankiw (1987) reached similar conclusions using a different methodology: If fluctuations in output are dominated by temporary deviations from the natural rate, then an innovation in output should not substantially change one's forecast of output in, say, ten or twenty years. They find that a one percent innovation in real GDP changes GDP forecasts over a long horizon by over one percent, suggesting that shocks to GDP are largely permanent.[6,7]

These results were significant because they cast doubt on both the existing empirical literature as well as theories. On the empirics, if aggregate output is thought of as consisting of a growth component plus a cyclical component, then the growth component must be a non-stationary stochastic process rather than a deterministic trend as had been generally assumed in early empirical work. Instead of attributing all variation in output changes to the cyclical component, the stochastic model allows for contributions from variations in both components. Therefore, empirical analyses of business cycles based on residuals from fitted trend lines are likely to confound the two sources of variation, greatly overstating the magnitude and duration of the cyclical component and understating the importance of the growth component.

These results also challenged theories in which output fluctuations are primarily caused by temporary shocks to aggregate demand, as we have discussed in our previous section. The fact that most shocks seem to be persistent in nature meant that the forces that restore equilibrium towards a steady state or a natural rate are very slow moving or, even more challenging, the steady state equilibrium is not stable and therefore not an obvious concept to characterize business cycles (Campbell and Mankiw (1987)).

C. Persistent or permanent?

The early evidence on persistence raised a fundamental question: is the adjustment towards equilibrium slower than what we thought or is the steady-state equilibrium stochastic? This is the origin of the debate on whether macroeconomic time series actually have a unit root. Is the coefficient on the autoregressive term exactly 1 or is it just persistent, i.e., it is close to but not exactly 1.

Unit root tests became especially important given the economic interpretation assigned to integration of macroeconomic time series. The Nelson and Plosser (1982) test of the null hypothesis of difference stationarity (DS) could not be rejected against trend stationarity (TS)

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[6] We refer to GDP in our text for consistency with the recent literature even if many of the early papers were using GNP as the measure of economic activity.

[7] Bluedorn and Leigh (2018) find similar result using professional long-term forecasts for 38 advanced and emerging market economies. They find that output forecasts are super-persistent—an unexpected 1 percent upward revision in current period output typically translates into a revision of ten year-ahead forecasted output by about 2 percent in both advanced and emerging markets.

for 13 out of 14 macroeconomic series, with the exception of unemployment. These results provided support for real business cycle models over monetary business cycle models. And they also led to econometric research on cointegration (e.g., Engle and Granger (1987)), which involved testing whether sets of difference stationary series move together. However, Nelson and Plosser (1982) could not reject the alternative of TS because the tests had low power. In this setting, it became important to determine whether inferences derived from conventional integration tests were fragile because of their potential low power against TS alternatives (DeJong and Whiteman (1991a)).

One strand of the vast literature on unit roots argued that a Bayesian approach to VAR estimation is superior to classical inference in distinguishing a unit root from a stationary AR process (Sims (1988), Sims and Uhlig (1988), DeJong and Whiteman (1991b)). Classical econometricians take p-values to represent probabilities, especially when their asymptotic distribution is considered equivalent to Bayesian posterior tail probabilities. However, the usual asymptotic equivalence fails in case of non-stationary dynamic models. In such cases, Bayesian econometricians consider their procedures to be superior as they involve specifying priors on the AR coefficients. In particular, they argue that flat priors are equivalent to assuming no prior at all, which means no learnings from past events and hence, all decisions are based on the data at hand. But Phillips (1991) rejected the claim that flat priors used by Sims (1988) and DeJong and Whiteman (1991b) are noninformative. He argued that even such flat priors unwittingly downweigh the possibility of a unit root and, hence, bias inferences towards stationarity. Instead, Phillips (1991) uses an alternative "ignorance prior" to explicitly accommodate time series models in which no stationarity assumption is made. Using such ignorance priors, Phillips (1991) shows that 7 out of 14 of Nelson and Plosser (1982) series have a unit root while they are mainly (11/14) stationary under flat priors. Although his analysis did not resolve the methodological disagreements between the classical and Bayesian approaches, it did demonstrate the fragility of the assumed priors in the context of the unit root debate. Even Sims (1991) conceded that flat priors are unreasonable when the model contains a constant and a trend.

Besides the asymptotic characteristics of parameters, lag length can also affect the power of unit root tests. For instance, Cochrane (1988) presented evidence of a significant degree of trend reversion in output, but it only occurs over a time horizon of many years. He argues that parsimonious time series models attach too much weight to short-term dynamics and too little weight to long-term dynamics, so that they incorrectly measure the variability of long-term growth. Hence, the low-order ARMA approach of Campbell and Mankiw (1987) and the unobserved components approach of Nelson and Plosser (1982) cannot match the short-run dynamics and the small random walk component in the long-run dynamics at the same time. Faced with the choice, they capture the short-run dynamics and incorrectly imply large random walk components. In essence, Cochrane (1988) shows that GDP growth is positively autocorrelated at short lags, but there are many small negative autocorrelations at long lags.

Indeed, the choice of lag length can bias the results one way or another because the data simply cannot discriminate between the trend stationary and the difference stationary views of U.S. real GDP. For instance, Christiano and Eichenbaum (1990) find that shorter lags in the ARMA series as Campbell and Mankiw (1987) favor difference stationarity, while longer lags support trend stationarity. Similarly, Phillips (1991) finds that the choice of lag length in DeJong and Whiteman (1991b) biases the results towards stationarity.[8] Ultimately, there is a more fundamental challenge because of the limitation of the available data to distinguish between the two types. For instance, inspecting the roots of Christiano and Eichenbaum (1990) trend and difference stationary models, Stock (1990) notes that the larger size of the AR roots in trend stationary series suggests that both the trend and difference stationary models will exhibit difference stationary properties in finite samples. Cochrane (1991) also shows that first-difference stationary time series or time series with a unit root are equivalent to time series that are composed of a stationary and a random walk component.[9] However, despite the fact that we might not be able to fully discriminate between the two models, Stock (1990) concludes that the difference stationary model provides a better basis for approximating the distribution of estimators and test statistics than the trend stationary formulations.

Besides lag length, the low power of unit root tests can also come from testing the alternative trend stationary model that mimics the difference stationary null, a point raised in Rudebusch (1993). He tests whether unit-root tests can distinguish between trend and difference stationary models that exhibit very different short-run persistence properties and finds that unit root tests display low power even when the plausible trend stationary models had quite different economic behavior than a plausible difference stationary null model. While agreeing that unit-root tests do suffer from low power in many situations of interest, Diebold and Senhadji (1996) find that Rudebusch's procedures produce evidence that distinctly favors trend-stationarity using long spans of data. Their results suggest that U.S. aggregate output is not likely to be difference-stationary: the dominant autoregressive root is likely close to, but less than, unity, implying a high degree of persistence.

While unit roots provide evidence on the existence of persistence of shocks, there was also interest in quantifying the extent of persistence. For instance, Campbell and Mankiw (1987) directed attention away from the question of the existence of a unit root in real GDP, and towards the question of its quantitative importance for GDP (persistence). Their unrestricted ARIMA model produced a persistence estimate of 1.52, vis-à-vis the estimate of 0.6 by the unobserved component models of Watson (1986) and Clark (1987). Recognizing that mean reversion in economic time series depends crucially on correlations at long lags, which can be misspecified in simple ARIMA representations, Diebold and Rudebusch (1989) generalize the ARIMA model to capture a variety of long-run, low-frequency responses. They allow for fractional integration, which introduces long memory between observations widely separated

[8] DeJong and Whiteman (1991a) contend that Phillips (1991) biases his specification in favor of integration by summing up the AR coefficients even though the interest for persistence is in the dominant AR root.

[9] Cochrane (1988) established that the variance ratio (variance of cumulative growth over a horizon of many years divided by variance of 1-year growth) for a long time series of US GDP was only one-third.

in time. While the estimate of the fractional integration parameter for quarterly time series is high (around 0.9), it is lower (between 0.5 to 0.6) at annual frequency. They take this as evidence of long memory, which induces persistence, though this long memory need not be associated with a unit root.[10] Likewise, Perron (1988) introduced a non-parametric approach to hypothesis testing in time series regression with a unit root, which reduced the need to estimate nuisance parameters and could use the critical values tabulated by Dickey-Fuller. He confirmed the conclusions reached by Nelson and Plosser (1982) that the nonstationarity of most macroeconomic variables is best construed as stochastic rather than deterministic.

D. Non-linear models and regime-switching

So far, the literature that we have discussed was measuring the impact of shocks on macroeconomic time series using linear models, such as ARMA. These models fail to capture the non-linearities and/or asymmetries documented in macroeconomic series (Burns and Mitchell (1946), Keynes (1936) and Friedman (1964)). Perron (1989) Perron (1989) argued that unit root tests can mask a one-time change in the level or slope of the trend—the simplest form of non-linearity. He rejects the unit root hypothesis after adjusting for a one-time structural break in the level and slope of the real GNP series for the 1929 crash and the 1973 oil price shock, respectively. Darné (2009) uses an unobserved components model to identify unknown outliers in US GDP over 1869-1993. He finds large, but infrequent, permanent and temporary shocks that correspond to major economic or financial events, especially the Great Depression and World War II. Adjusting for outliers, he finds that output contains small, permanent innovations corresponding to a stochastic trend. Beyond demonstrating the statistical sensitivity of unit root tests to structural breaks and outliers, these papers raise the issue of economic interpretation. The unit root analysis treated all output fluctuations as arising from a single data generating process without regard to different types of shocks or the magnitude of their impact. In many, if not most, economic applications, the behavior of output associated with major economic and financial events (e.g., the Great Depression, Global Financial Crisis, or COVID-19 pandemic) is the object of interest, rather than small fluctuations in data adjusted to exclude these episodes.

Embedding recurrent breaks into the data generating process, Hamilton (1989) specified the first differences of the observed series as a nonlinear stationary process instead of a linear stationary process. In his regime-switching model, the parameters of an autoregression are viewed as the outcome of a discrete-state Markov process. For example, the mean growth rate of a nonstationary series may be subject to occasional, discrete shifts. The econometrician is presumed not to observe these shifts directly, but instead must draw probabilistic inference about whether and when they may have occurred based on the

[10] Diebold and Rudebusch (1989) suggested that the rate of convergence of output to trend is very slow – potentially decades – raising questions about the wisdom of treating output as returning to trend within the two- to five-year range commonly used by policy-making institutions and businesses for their forecasts.

observed behavior of the series. He presented a filter that permitted estimation of population parameters and provided the foundation for forecasting future values of the series.[11]

An empirical application of Hamilton (1989) technique to postwar U.S. real GDP suggested that the periodic shift from a positive growth rate to a negative growth rate is a recurrent feature of the U.S. business cycle, and indeed could be used as an objective criterion for defining and measuring economic recessions. The estimated parameter values suggested that a typical economic recession is associated with a 3 percent permanent drop in the level of GDP. The results complement the findings by Nelson and Plosser (1982) and Campbell and Mankiw (1987), who concluded that business cycles are associated with a large permanent effect on the long run level of output. The estimates also provide empirical support for the proposition that the dynamics of recessions are qualitatively distinct from those of normal times in a clear statistical sense, and reinforce Neftçi (1984) and Sichel (1993) evidence on the asymmetry of U.S. business cycles.[12] He introduces randomness in states and in the error that has different implication for future path of output.

A significant part of the literature that introduced business cycle asymmetry into the impulse responses found the persistence of shocks to be lower than previously thought. For instance, Beaudry and Koop (1993) were the first to allow for the conditional expectation of future output to depend on whether current output is above or below its previous maximum. Augmenting the basic linear ARMA model, they consider whether real GDP falls below a threshold defined by its historical maximum – known as “current depth of recession” (CDR). They find that the inclusion of the CDR variable implies much less persistence for large negative shocks than for small negative shocks or positive shocks. By introducing a “bounce-back”, many papers found duration dependence. For instance, Kim and Nelson (1999) allow for this type of business cycle asymmetry by modelling regime switching in the cyclical component of output only and find GDP to be well characterized by the Friedman (1964) plucking model. Augmenting Hamilton (1989) model with a bounce-back variable, i.e., introducing asymmetry in both the trend and the cyclical components, Kim, Morley, and Piger (2005) find that the bounce back is substantial and the permanent impact of recessions is small. Hence, once the 'bounce-back' effect is taken into account, there is little or no remaining serial correlation, suggesting that expansionary shocks are permanent.

Duration dependence is also highlighted by Diebold, Rudebusch, and Sichel (1993). They use a parsimonious yet flexible hazard model, and find that, regardless of country, time period, or measure of the business cycle (contractions, expansions, or full cycle), durations display constant or increasing hazard. So, the longer the economy has been in a state, the more likely

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[11] Extending Hamilton (1989) fixed transition probabilities to time varying probabilities, Filardo (1994) finds that this flexible and non-linear structure captures and predicts accurately the expansions and contractions of monthly U.S. output.

[12] DeLong and Summers (1986), on the other hand, look at skewness in data from the United States and 5 OECD countries and were unable to support the hypothesis that contractions are shorter and sharper than expansions.

a transition will occur. While there is positive duration dependence in the prewar period, postwar expansion hazards display less duration dependence and are lower on average, while postwar contraction hazards display more duration dependence and are higher on average.[13]

It should be noted that the Kim, Morley, and Piger (2005) bounce-back effect was very small for non-U.S. countries, implying large permanent effects of recessions. Similarly, Cerra and Saxena (2005a) do not find any evidence of duration or amplitude of expansion to have any effect on the duration and amplitude of subsequent recession in a sample of 192 countries. Hence, evidence of significant reduction in persistence of shocks is a U.S. phenomenon, and is overturned when applied to a broader set of countries – a point we refer to below.

In essence, regime-switching models seem to improve on linear models in terms of the variability of growth rates observed for different business cycle phases. Markov-switching models may perform better because they can potentially proxy for the structural break or other forms of heteroskedasticity, rather than simply capturing nonlinearity related to the business cycle. The observation that the dynamics of macroeconomic series change over the course of the business cycle suggests that the forces that cause some variables, say such as employment, to rise may be quite different from those that cause it to fall.

E. Comovement and cointegration

In the study of business cycle dynamics, including persistence, another strand of literature departs from a univariate approach and instead exploits the common movement among macroeconomic variables.[14] Burns and Mitchell (1946) considered that each individual series measures only a partial aspect of the overall state of the economy (or "reference cycle"). Because of this, they focused on comovement among many macroeconomic variables as a defining attribute of the business cycle: "*…a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle*."

Drawing on this notion, the National Bureau of Economic Analysis, the Bureau of Economic Analysis, the Commerce Department, and the Conference Board have developed indices of coincident, leading, and lagging indicators of the state of the U.S. economy. Vector autoregressions (Sims 1980) provide a parameterization of the dynamic relationship between macroeconomic variables, but may require too many degrees of freedom than are available in the short time series of most macroeconomic data.

Dynamic factor models provide parsimonious modeling of comovement of variables based on the idea that it is driven by a common factor. Early contributions include Sargent and Sims (1977) and Geweke (1977). Stock and Watson (1989, 1991, 1993) develop a composite index

[13] Hansen (1993) finds a problem with their splitting the data between pre- and post-war samples as the point at which to split the sample is not exogenous to the data. Since the choice has been made after (informally) examining the data, the tendency is to select a sample split point that is particularly tough on the null hypothesis of a constant hazard model. The critical values used implicitly by the authors to justify rejecting a constant model are too low, and a spurious rejection may have occurred.

[14] See Cerra and Saxena (2000) for a detailed survey of the methods of this section in an application to Sweden.

of coincident indicators based on a linear unobserved factor, which is estimated with a Kalman filter. Each macroeconomic variable is the sum of the common unobserved factor and an idiosyncratic component. The study of persistence can then be reformulated in terms of the dynamic property of the common factor, in particular whether it constitutes a common stochastic trend. The multivariate approach also helps filter out idiosyncratic noise.

A common stochastic trend is consistent with some classes of theoretical models and has additional econometric implications. Real business cycle theory (Section IV) assumes that a permanent technology shock drives multiple variables (e.g., output, hours, and investment). While each variable contains a unit root (integrated of order one, I(1)), linear combinations of the variables can be stationary (I(0)). Thus, comovement implied by theory can be captured by cointegration rather than treating each variable in isolation. For instance, King, Plosser, Stock, and Watson (1991) argue that output is cointegrated with consumption and investment. A productivity shock has a long-run impact on each variable individually, but the log difference of any pair is stationary. They find that post-war U.S. data is consistent with cointegration and a common stochastic trend driving output, consumption, and investment. In this three-variable system, the balanced-growth shock explains more than two-thirds of the variation in output at business cycle horizons (1-5 years), although the explanatory power of the real shock falls to less than 45 percent when introducing nominal variables.

Subsequent literature synthesizes business cycle comovement and asymmetry. Diebold and Rudebusch (1996) incorporate both comovement, in which production, income, employment, and sales share a common dynamic factor, and asymmetry, in which the factor switches regimes. They find evidence for comovement of business cycle indicators and for the regime-switching model to provide a good fit to the aggregate data. Likewise, Kim and Yoo (1995), Chauvet (1998), and Kim and Nelson (1998) estimate a unified model with a common regime-switching factor for the growth of the four indicators that comprise the coincident index. Kim and Murray (2002), Kim and Piger (2002), and Kim, Piger, and Startz (2007) allow for asymmetry in both permanent and temporary components of several economic series, which permits them to decompose the permanent versus temporary impact of shocks. They find evidence of both types of asymmetries in post-war U.S. recessions, though the contribution of each component varies across recession episodes.

An alternative multivariate approach to trend-cycle decomposition takes advantage of theoretical relationships between cyclical components. Rather than estimate a common stochastic trend for non-stationary cointegrated variables, this alternative approach estimates the system allowing for correlation between the cyclical components of each variable. If the cyclical components are perfectly correlated, they share a common cyclical factor. More broadly, innovations to the cyclical components can be jointly distributed with a general covariance matrix. Sinclair (2009) estimates a bivariate correlated unobserved components model of U.S. output and the unemployment rate based on the Okun's law relationship. She finds that movements in U.S. real GDP are largely permanent, contradicting the claim of Clark (1987) that using unemployment would strengthen the case for transitory movements in real GDP. In fact, results of these models critically depend on the assumed correlation between the innovations to the temporary and permanent components. Morley, Nelson, and Zivot (2003) show that the restriction of zero correlation between components, assumed in Clark (1987) unobserved components (UC) model, can be rejected in the data. When this restriction is relaxed, the UC decomposition is identical to the Beveridge-Nelson (BN) decomposition, in which the stochastic trend accounts for most of the variation in output. Basistha and Startz (2008) extend the multivariate model further to include a Phillips curve relationship. They find that using multiple indicators reduces filtering uncertainty and the estimation uncertainty of parameters.

F. Cross-country evidence on persistence of fluctuations

The debate on the existence of a unit root was often methodological and focused on the power of different tests or assumed priors. Most of this literature was tested using the same data from the United States (such as the annual GDP series from Nelson and Plosser (1982) or a slightly updated version). In addition, there were a small number of business cycles and most of the U.S. recessions between the Great Depression and the Great Recession tended to be shallow. Moreover, given that shocks are not directly observed, it is difficult to separate the effects of past from current shocks on output. For example, the sharp decline in output during the Great Depression persisted for most of the 1930s, but the rapid rebound in output during the 1940s is widely attributed to the subsequent shock of massive military spending during World War II (Darné (2009)). A U.S. sample covering the 1900s would be dominated by this one episode and it is hard to draw conclusions from one data point. Hence, the limited variability in the data made it difficult to distinguish a deterministic from a stochastic trend.

As the literature developed, data from other countries and also different econometric approaches helped shed light on the hypothesis of persistence. More countries allowed for an increasing number of observations. In addition, most other countries have larger shocks and recessions than those in the United States, so that frequent and clearly identified events could be studied.

Papers incorporating data from other countries resulted in a wide agreement that shocks are indeed very persistent. Cogley (1990) extended the methodology of Cochrane (1988) to nine OECD countries over the period 1871-1985. Using variance ratios to measure the relative stability of long-term growth, he showed that for other countries the average variance ratio was larger than the United States (1.16, as compared with Cochrane (1988)'s estimate of one-third for the US). Hence, relative to the United States, most countries have more variable dynamics at low frequencies.

Cerra and Saxena (2005a) was the first study to provide evidence on the permanent impact of *all* types of shocks on the levels of GDP for a sample of 192 countries. These results remain robust to specifications, sample size, and country coverage. Similarly, with more updated data, Cerra, Panizza, and Saxena (2013) and Cerra and Saxena (2017) provided robust evidence on the permanent impact of all shocks on the levels of GDP for 192 countries.

Haltmaier (2013) corroborated these results, focusing on a measure of potential output. She finds that the depth of a recession has a significant effect on the loss of potential for advanced countries. In the case of emerging markets, the length of the recessionary episode seemed to matter.[15] Blanchard, Cerutti, and Summers (2015), in a large sample of advanced economies, found that a high proportion of recessions (more than two-thirds) have been followed by lower output (hysteresis) or even lower growth (super-hysteresis).[16] Girardi, Paternesi Meloni and Stirati (2020) document that aggregate demand expansions exert positive persistent effects on GDP, the labor force participation rate, and the capital stock in OECD countries.

G. Persistence, sources of shocks and mechanisms

The consistent evidence that fluctuations were persistent led to a wave of papers incorporating the possibility that variation in long-term trends was an important feature of the business cycle. As we have discussed in Section II, initially this evidence was used to support models where technology shocks were a fundamental driver of these cycles. Based on the dominant traditional view of cycle and trend separation, Blanchard and Quah (1989) introduced a decomposition that became the basis of much subsequent research on identification of sources of shocks. Blanchard and Quah (1989) assumed that supply and demand disturbances were uncorrelated with each other and that only supply-side disturbances had a long-term impact on output, while demand shocks did not. Both types of shocks affected unemployment temporarily but not permanently (i.e. unemployment is a stationary variable). These assumptions are sufficient to just identify the two types of disturbances, and their dynamic effects on output and unemployment.[17]

But models with hysteresis emphasize that all type of shocks have a persistent impact on output, especially those associated with crises and severe recessions, invalidating the Blanchard and Quah (1989) identification strategy. But how do we test for which of the two hypotheses explains persistence? Are changes to technology or other structural changes explaining the persistence of GDP after crisis? Or are the scars that cyclical shocks leave on the trend the source of the permanent effects on GDP?

To answer these questions, the empirical literature on hysteresis has followed three different strategies. First, by focusing on large crises, in particular those that involved significant financial disruption. The advantage of this analysis is that identification of both the origin of the shocks and their dynamics can be sharper given the large magnitude of output loss

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[15] Haltmaier (2013) calculates trend output using HP filters, and average growth is compared for the two years preceding a recession, the two years immediately following a recession peak, and the two years after that. She acknowledges the concerns with using an HP filter, but nonetheless employs it to assemble larger dataset.

[16] Blanchard, Cerutti, and Summers (2015) build on the work of Martin, Munyan, and Wilson (2015), but recognize their contribution is in using a slightly different methodology, looking at the effect of recessions conditional on different types of shocks, and in the interpretation of the results. They rely on a non-parametric method, focused on recessions rather than on fluctuations more generally.

[17] King et al. (1987) identify the permanent component in output by assuming that it is also the permanent component in consumption and investment and find that about 60 to 80 percent of the movements in output at the two- to four- year horizon are explained by movements in permanent component. On the other hand, in a VAR framework for GDP and consumption, Cochrane (1994) finds a statistically and economically important transitory component in GDP. For instance, transitory shocks account for an estimated 70-80 percent of variance of GDP growth.

associated with crises. In addition, results are not as dependent on long-horizon or asymptotic assumptions as with the earlier unit root literature. Second, identifying and measuring mechanisms through which recessions persistently reduce output or even lower long-term GDP growth. Do we see changes in labor markets or capital accumulation or innovation that support the type of mechanisms implied by models of hysteresis? Third, by identifying shocks that are clearly driven by cyclical demand factors and measuring the response of GDP. If demand shocks also display permanent effects on output, this is strong evidence of the existence of hysteresis.

Of course, the identification of specific mechanisms through which fluctuations become persistent or the source of the shocks is not without controversy, and this explains the disagreements that might still be present when interpreting the observed persistence of macroeconomic variables.

We now delve into the empirical evidence about each of these three strands of the literature: persistence of large shocks, the potential channels though which hysteresis happens and the long-term scars of cyclical demand shocks.

H. Persistence after financial crises and deep recessions

In this section we highlight a few examples of the literature that have looked at persistence after large crisis, in particular those with a strong financial component. This literature consistently finds strong persistence after crises and the results are robust to different methodologies and country samples.

Cerra and Saxena (2005b) studied the impact of the Asian crisis on output in a set of six Asian countries. Using a regime-switching approach that introduces two state variables to decompose recessions into permanent and temporary components, they find evidence of permanent losses in the levels of output in all of the countries, even though growth recovered fairly quickly after the crisis. They find a similar permanent loss in output for Sweden in the aftermath of its banking crisis (Cerra and Saxena (2005c)).

Cerra and Saxena (2008) broadened the country sample and the types of shocks. In a sample of 190 countries, they find output falls relative to a baseline and remains permanently lower following financial and political crises. On average, the magnitude of the persistent loss in output is about 5 percent for balance of payments crises, 10 percent for banking crises, and 15 percent for twin crises.[18]

[18] Building on this work, International Monetary Fund (2009) finds that for a broad sample of countries the path of output trend is depressed substantially and persistently following banking crises, with no rebound on average to the pre-crisis trend over the medium term, even as growth returns to pre-crisis rate.

The sluggish aftermath of the global financial crisis reinvigorated interest in the dynamics of post-crisis recoveries. Reinhart and Rogoff (2014) corroborated the findings of earlier papers. They examined the evolution of real per capita GDP around 100 systemic banking crises and found that a significant part of the costs of these crises lies in the protracted and halting nature of the recovery. On average it takes about eight years to reach the pre-crisis level of income; the median is about 6.5 years. In a sample that covers 63 crises in advanced economies and 37 in larger emerging markets, more than 40 percent of the post-crisis episodes experienced double dips.

Ball (2014) estimates the long-term effects of the global financial recession of 2008–2009 on output in 23 countries. He measures these effects by comparing current estimates of potential output from the OECD and IMF to the path that potential was following in 2007, according to estimates at the time. The average loss, weighted by economy size, is 8.4 percent. Most countries have experienced strong hysteresis effects: shortfalls of actual output from pre-recession trends have reduced potential output almost one-for-one. In the hardest-hit economies, the current growth rate of potential is depressed, implying that the extent of lost potential is growing over time.[19]

Other papers connected persistence to the asset and credit booms observed prior to financial crises. Analyzing the properties of and linkages between business and financial cycles for 44 countries, 21 advanced OECD countries (1960–2010) and 23 emerging market countries (1978–2010), Claessens, Kose, and Terrones (2012a) find that recessions associated with financial disruption episodes, notably house and equity price busts, are often longer and deeper than other recessions. Conversely, recoveries following asset price busts tend to be weaker, while recoveries associated with rapid growth in credit and house prices are generally stronger. Using a long time series (1870 to 2008) and 14 advanced countries, Jordà, Schularick, and Taylor (2011) document that relative to typical recessions, financial crisis recessions are costlier, and more credit-intensive expansions tend to be followed by deeper recessions (in financial crises or otherwise) and slower recoveries.[20]

[19] The slow recovery after the global financial crisis is consistent with hysteresis effects caused by a prolonged and deep crisis. But, and as argued by Fernald et al. (2017), the slow recovery is also consistent with a decrease in TFP growth that started before the crisis, leaving limited room for hysteresis effects. Resolving this debate with just one cyclical event (the US economy in this particular crisis) is a challenge. The behavior of many other advanced economies during the same period combined with evidence we will discuss later about the effects of specific policy interventions is, however, not consistent with an explanation that simply relies on a structural break in productivity.

[20] This is at odds with Claessens, Kose, and Terrones (2012b) who find that length and duration of recessions are not affected by credit.

I. Scars in the labor market

The label hysteresis was possibly used for the first time in the business cycle literature in the context of labor markets. Clark (1989) used the term to refer to the experience of European labor market during the 1970s and 1980s.

Labor markets and in particular unemployment rates had always been central to the description of business cycles. In this context, fluctuations were seen as variations in the degree of economic slack and unemployment rates were the most obvious indicator of that slack, as formalized by the Phillips curve.[21]

In the case of the US labor market, the behavior of unemployment fit rather well the traditional business cycle model where temporary variations in the number of unemployed workers provided a good representation of the cyclical state of the economy. Unemployment increases sharply in recessions and declines in recoveries returning to its natural level. While there were and there still are discussions about the concept of a stable natural rate of unemployment, its estimates have remained within a narrow range.

The European experience was however very different. Blanchard and Summers (1986) started with the observation that European unemployment rates had remained significantly elevated after the economic crises of the 1970s, in a way that the normal macroeconomic or labor market frictions could not explain and they referred to these dynamics as hysteresis.[22] They also suggested that the degree of hysteresis in the labor market was probably larger than what was indicated by sticky unemployment rates as they found that participation rates or number of hours worked had also been affected and showed similar persistence.

Blanchard and Summers (1986) argued that temporary increases in unemployment could lead to increases in the NAIRU (non-accelerating inflation rate of unemployment). Once growth returned and unemployment declined, inflationary tensions would now appear at a level of unemployment higher than before. This higher NAIRU meant that policy makers needed to stop any additional demand stimulus otherwise they would be running into higher inflation despite the historically high unemployment rates.

How long was this horizon of higher unemployment rates? While in their formal definition of hysteresis, Blanchard and Summers (1986) had used the notion of a non-stationary series and permanent effects, in their text they admitted that it might just be about very persistent but

[21] Of course, unemployment rates do not need to be a comprehensive measure of labor market slack. Employment rates, that also take into consideration movements in labor force participation, can be better indicators in some circumstances (Murphy and Topel (1997) or Nickell (1997)).

[22] Similar observations about the persistence of labor market outcomes had been made earlier by, among others, Clark and Summers (1982) or Ellwood (1982).

not quite permanent changes in unemployment.[23] The years that followed their work provided support for this view of highly persistent but not permanent changes in unemployment. European unemployment indeed declined and returned towards levels that were much lower than when their original paper was written (see Bean (1994) or O'Shaughnessy (2011) for an analysis of those years). The result of high persistence has been later confirmed by many other papers as Cerra and Saxena (2005c), Bluedorn and Leigh (2019) or Bluedorn and Leigh (2018).

There is also a related literature that looks at the effects of losing a job or joining the labor market during recessions. Topel (1990), Ruhm (1991), Arulampalam, Gregg and Gregory (2001), Eliason and Storrie (2006), Davis and von Wachter (2011), among others, present evidence of persistent effects on earnings for workers that are displaced, especially during a recession. Mechanisms include erosion of skills, loss of firm-specific human capital, deterioration of job matches, and the employer's use of employment history as a signal of productivity. Raaum and Røed (2006), Kahn (2010), Schwandt and von Wachter (2020), Oreopoulos, Von Wachter, and Heisz (2012) show that there are negative effects of graduating in a weak economy and these effects are very persistent. Hershbein and Stuart (2020) find that recessions create drops in employment that are permanent. Local labor markets display hysteresis with permanent decreases in employment to population ratios. Such scarring effects are also prominent in developing countries where a majority of the labor force works in the informal sector (Pritadrajati, Kusuma and Saxena (2021)). However, job retention policies can help reduce scarring and reallocation polices can facilitate adjustment (IMF (2021). Hotchkiss and Moore (2018) present evidence that some of these effects can be reversed during years where we are running a high-pressure economy.[24]

More recently, the Great Recession generated employment losses in the United States that were very persistent. Not only the speed of reduction in unemployment was slow, but even after unemployment reached low levels, the employment to population ratio remained clearly below its pre-crisis trends. Yagan (2019) and Rinz (2019) both present evidence of strong persistence effects in labor market outcomes in the context of the Great Recession. The behavior of the labor market during these years led to a debate about how much of this was due to structural forces or to the persistent effects of a prolonged recession. Fukui, Nakamura, and Steinsson (2018), present evidence that secular factors were partly responsible for the labor market dynamics. In particular, they estimate that slower recoveries in employment for the last three recessions, relative to previous ones, can be attributed to the convergence in female employment ratios to male employment ratios since the 1970s. On the other hand, Yagan (2019) concludes that human capital decay (leaving workers scarred) and persistently low labor demand (leaving local regions scarred) are the most likely mechanisms. In order to better identify the channel through which persistence happened, Yagan (2019) exploits

[23] They refer to a loose definition of hysteresis "where the degree of dependence on the past is very high, where the sum of coefficients is close but not necessarily equal to 1."

[24] See von Wachter (2020) for a comprehensive survey of this literature.

spatial variation across U.S. localities to identify the impact of the crisis separate from the impact of secular nationwide forces. He finds that for each percentage point of higher local unemployment shock during 2007-09, the local working-age employment rate fell by over 0.3 percentage point.

J. Scars in capital accumulation, R&D and innovation

The development of endogenous-growth theory created a straightforward link between temporary shocks and persistence that did not involve the labor market. As long as temporary shocks affected the long-term engine of growth, their effects would become permanent.

There is a wide variety of endogenous growth models, each of them relying on a different set of drivers of long-term growth. Potentially, each of these variables could be a valid empirical channel to test for hysteresis by studying the persistence and possibly permanent effects of temporary shocks. Persistence could be the outcome of changes in capital accumulation (as emphasized in King, Plosser, and Rebelo (1988), King and Rebelo (1988) or Fatas (2000b)), or maybe learning by doing, human capital, R&D or knowledge accumulation (Stadler (1986) and Stadler (1990) Stiglitz (1993) or Fatas (2000a)). In all these papers the key factor is the procyclicality of the long-term source of growth.

Fatas (2000a) presents indirect empirical evidence supporting these mechanisms by showing that long-term growth rates are correlated with measures of persistence. This is consistent with any model where the growth engine stops during recessions. Under certain assumptions, countries with faster growth rates are more likely to show permanent scars than countries that are growing at slower rates because they have more to lose (given the higher steady-state growth rates).

More detailed evidence can be found by studying the procyclicality of specific variables that drive growth, such as investment or R&D. There is plenty of evidence that R&D expenditures are procyclical as in Fatas (2000a), Barlevy (2007) or Anzoategui et al. (2019).

In a similar vein, Haltmaier (2013) and Reifschneider, Wascher, and Wilcox (2015) present evidence of how cyclical variations in total factor productivity can explain persistence. And possible factors in reducing TFP include a decrease in the formation of businesses with new technologies (Haltiwanger, Jarmin, and Miranda (2013), Reifschneider, Wascher, and Wilcox (2015)) or overaccumulation of capital during expansions (Beaudry, Galizia, and Portier (2017)).

The role that financial conditions play as a source of low investment or innovation during recessions is also highlighted in several papers. Aghion et al. (2012) or Ouyang (2011) showed that the procyclicality of R&D is connected to financial constraints. In a similar vein, Duval, Hong, and Timmer (2020) used a rich cross-country firm level data, exploiting variation in preexisting exposure to the 2008 global financial crisis to study the post-crisis productivity slowdown. They find that firms with weaker pre-crisis balance sheets experienced a highly persistent decline in post-crisis total factor productivity growth relative to their less vulnerable counterparts, accounting for about one-third of the within-firm productivity slowdown. The financially fragile firms cut back on innovation activities, one channel through which financial frictions weakened post-crisis productivity growth. They show that firms with preexisting balance sheet vulnerabilities cut back on intangible investment more than their less vulnerable counterparts after the crisis, and that this divergence was larger in countries where credit conditions tightened more during Lehman. When they study the effect of financial vulnerabilities on innovation outcomes, using a newly available cross-country firm-level database for patents, they find that more vulnerable firms had a stronger reduction in the number of patent applications compared to less vulnerable firms.[25]

Jordà, Schularick, and Taylor (2011) also support the idea that financial factors play an important role in the modern business cycle. Increased leverage raises the vulnerability of economies to shocks; procyclical prices can lead to debt-deflation pressures; rising leverage can lead to more pronounced confidence shocks and expectational swings; financial accelerator effects are also likely to be stronger when balance sheets are large. Such effects could be more pronounced in a systemic crisis, due to banking failures, asset price declines, and expectational shifts that are better "coordinated." Claessens, Kose, and Terrones (2012b) find that the developments in housing markets are also important in shaping the length and magnitude of cyclical outcomes.

More recently, Bianchi et al. (2019) and Jordà, Singh, and Taylor (2020) provide evidence on the role of several potential mechanisms to explain the persistence of the Great Recession in a large panel of countries and years respectively.

K. The role of economic policy

The evidence we have presented so far supports the view that fluctuations are persistent. In addition, we have summarized empirical insights on the mechanisms through which persistence happens. But what are the sources of shocks that are causing this persistence? If hysteresis is relevant, we should see any shock, even those that are temporary in nature, producing persistent or permanent effects.

There is a strand of the hysteresis literature that has attempted to identify specific shocks, in particular demand shocks that are supposed to be temporary in nature, and trace the response of GDP to these shocks. If the response to these shocks matches the observed persistence in GDP fluctuations, this is strong evidence of hysteresis. The natural candidates are policy shocks, in particular monetary and fiscal policy. Using a non-parametric approach, Blanchard, Cerutti, and Summers (2015) identified 122 recessions for 23 advanced economies and measured their persistence as deviations from pre-crisis trends. Around 70 percent of these recessions display an "unambiguous" persistent gap relative to those trends.

[25] Although Sedgley, Burger, and Tan (2019) results suggest that the cyclicality of R&D expenditures is fairly symmetric and cannot fully be explained by financial constraints or conditions.

Each of these recessions was then characterized by whether or not “demand” shocks (including from those plausibly due to intentional disinflations) were likely responsible for them. The authors concluded that recessions associated with demand shocks are almost as likely to entail a sustained gap with the pre-recession trend as other shocks, indicative of hysteresis.

Jordà, Singh, and Taylor (2020) provided detailed analysis of the persistence of monetary policy shocks. Using a long panel data of 125 years and 17 countries with a local projections instrumental variable technique, they showed robust and consistent persistent effects of monetary policy shocks. They also exploited the exogenous variation in monetary policy from external monetary shocks for countries with fixed exchange rates and open capital accounts. According to the traditional monetary policy trilemma, domestic monetary policy in these countries must be driven by foreign monetary policy. Using this identifying assumption, they showed that exogenous monetary policy has a long-term impact on output. A one percentage point increase in domestic interest rates leads to a 6-percentage point decline in GDP over 12 years in the full sample from 1890, and a more muted decline of about 2.5 percent in the sample since WWII. The effects seem to be driven by a combination of slow capital accumulation and lower growth of TFP.

Fatas and Summers (2018) present evidence on the permanent effects of fiscal policy shocks by focusing on the fiscal consolidations that took place among some advanced economies after the Great Recession. Using the methodology developed by Blanchard and Leigh (2013) to identify fiscal policy shocks and measure multipliers, they conclude that countries that implemented larger fiscal policy consolidations saw much larger persistent effects on GDP. These effects are still present in the most recent GDP data (7 years after the policies were implemented) and they are also reflected in current estimates of potential GDP, signaling that they are likely to be permanent effects. Gechert, Horn, and Paetz (2019) provide additional evidence confirming these findings.

When we think about policy, we do not just think about shocks, but also about the ability of fiscal and monetary policy to smooth out fluctuations. In the presence of hysteresis, the benefits of such policies could be significantly larger as they can minimize the long-term scars of recessions. Econometrically, measuring the effects of endogenous monetary policy is always more challenging than measuring the effects of identified exogenous shifts in policy (Bernanke et al. (1997)).

Cerra, Panizza, and Saxena (2013) show that macroeconomic policies can influence the speed of economic recovery, helping to recover some of the lost ground from recessions and financial crises. Monetary and fiscal stimulus, real depreciation, foreign aid and more flexible exchange rate regimes can spur a rebound. In advanced countries suffering from recessions associated with banking crises, fiscal policy is particularly effective in boosting growth during the recovery. This is consistent with the earlier findings of International Monetary Fund (2009): the medium-term output loss after recessions is not inevitable – economies that apply countercyclical fiscal and monetary stimulus in the short run to cushion the downturn after a crisis tend to have smaller output losses over the medium run.

Reifschneider, Wascher, and Wilcox (2015) support the view that the damage from the recent crisis can be seen as the outcome of the endogenous effects on growth coming from weak cyclical conditions. Via a calibration of the modified FRB/US model that includes hysteresis, they also show that more aggressive policies would have reduced the size of these effects although they are cautious in their policy recommendation because of the potential effects of more aggressive policies on financial stability.

These effects can also be relevant to think about optimal policy outside of recessionary periods. Policymakers can somehow create a high-pressure economy to generate positive hysteresis effects. Procyclical investment could increase the capital stock; plentiful job opportunities could increase workers' attachment to the labor force; and so on. Ball, Mankiw, and Nordhaus (1999) and Ball (2009) provide evidence that hysteresis in the unemployment rate also works in good times; in the United Kingdom, for example, economic booms in the late 1980s and 1990s reduced the natural rate of unemployment.

Some researchers are less optimistic about the reversibility of hysteresis effects. For example, Reifschneider, Wascher, and Wilcox (2015) provide an asymmetric view by suggesting that while a recession can cause a persistent fall in labor force participation and rise in unemployment, the expansion that follows might not have the opposite effects. This asymmetry can also be present when we think about capital accumulation or innovation. It might not be obvious for policy makers to engineer an environment that generates above-normal rates of innovation to compensate for what is lost during recessions. If these views are correct, then macroeconomic policymakers might not easily be able to repair the long-term damage from recessions.[26]

IV. THEORY

In Section II, we provided a quick historical view of how the separation of the cycle and trend evolved in the academic literature. We highlighted the dominance of a view of the economic cycle as distinct from the long-term trend, underpinned by the neoclassical growth framework of Solow (1956) and Swan (1956) to understand the trend, and RBC or New Keynesian models with sticky prices to understand the cycle. But the increasing evidence of persistence led to new frameworks that either relied on stochastic trends or the possibility of hysteresis in which temporary demand shocks and the non-technological state of the economy can impact the long-run level of output. This section discusses in detail this shift: from the standard RBC and New Keynesian models toward hysteresis-generating models. These new models can be broadly grouped into: (i) various types of endogenous growth models, (ii) models with multiple equilibria linked to future expectations, and (iii) models in

[26]Jaimovich and Siu (2012) discuss related evidence for jobless recoveries driven by job polarization, i.e., shrinking concentration of employment in occupations in the middle of the skill distribution.

which a non-linearity or boundary condition leads to a stagnation trap that is highly persistent or permanent.

A. Traditional theory of business cycles without hysteresis

A prototypical RBC model has an aggregate production function of the general form:

$$Y_t = A_t\, f(K_t, L_t)$$

Where A_t is the level of technology and the model assumes diminishing marginal products of physical capital and labor, K_t and L_t, respectively. In this framework, capital is the only factor that can be accumulated but diminishing returns assure convergence to a steady state level of capital regardless of initial conditions (Johnson and Papageorgiou, 2020). The only source of growth in the steady state derives from exogenous technological advancement.

Shocks in these models can come from technology, preferences or policies. To illustrate the dynamics, let's think about technology shocks. If we use small cap letters to represent the natural logarithm of our variables, we can assume shocks to the technology parameter by assuming it follows an exogenous stochastic process summarized by

$$a_t = g + \rho a_{t-1} + \epsilon_t$$

Where we assume for the moment that $\rho < 1$. The factors of production react to cyclical shocks but, as the effect of the shocks die out, the economy returns to its steady state.

New Keynesian models are set in an environment of monopolistic competition in which each producer i of a differentiated good faces a demand curve

$$Y_{it} = f(P_{it}/P_t)Y_t$$

which is increasing in aggregate income Y_t and decreasing in the relative price, P_{it}/P_t. The assumption that a fraction of either the firms or the workers cannot immediately adjust their prices or wages leads to a nominal rigidity. Each firm can set its price optimally, for example on a staggered basis, following Calvo (1983). Alternatively, workers or labor unions of industries representing subsets of workers may set wages on a staggered basis.
In this environment monetary policy shocks have an effect on activity because of price rigidity. In addition, the cyclical dynamics of the economy are strongly linked to the assumptions about price rigidity. As a result, there is a stronger scope for demand policies (e.g. monetary and fiscal policy) to impact output as prices and/or wages do not fully adjust on impact.

We can connect these two strands of literature to the unit root empirical literature, the log of GDP (y_t) can be seen as the sum of a trend (τ_t) and a cycle (c_t) where the cycle is assumed to have mean zero.

$$y_t = \tau_t + c_t$$

The trend can be thought of as the long-term forecast of GDP once cyclical effects die out. Transitory shocks, even to technology shocks when $\rho < 1$, do not affect the trend. Assuming a steady state growth rate of g, the trend evolves as:

$$\tau_t = g + \tau_{t-1}$$

Shocks of any type will affect the cyclical component. This component depends on the technology shocks ϵ_t, and other (demand) shocks v_t.[27]

$$c_t = \phi(L)\, \epsilon_t + \varphi(L)\, v_t$$

The coefficients of the lag polynomials will be a function of the persistence and transmission of the shocks as well as the policies implemented by monetary and fiscal authorities. In New Keynesian models, fiscal and monetary policies will be key to understanding these polynomials and the persistence of the cyclical component.

To obtain very large persistence or permanent effects of shocks, RBC models set the parameter ρ equal to 1. We now have a stochastic trend and shifts in trend GDP via permanent shocks to the exogenous productivity process.[28] The trend inherits the properties of the exogenous technology shocks.[29]

$$\tau_t = g + \tau_{t-1} + \epsilon_t$$

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[27] We will refer to these shocks as demand shocks for simplicity and they can include changes in preferences or fiscal and monetary policy shocks.

[28] An alternative to generate persistence, at least for some large shocks, is to allow for an arbitrarily large structural break.

[29] For the trend to be stochastic we need to assume permanent technology shocks driving the business cycle, a concept that remains controversial. For example, the idea that the large persistent decline in output associated with the Great Recession is due to a coincidental exogenous decline in technological knowledge does not sound plausible to some. While there is evidence of a decline in productivity starting well before 2007 (at least in the US economy, see Fernald et al. (2017)), there is no observable sudden lapse in aggregate knowledge or innovation during that time. In addition, the fact that we observe a similar pattern in all advanced countries and that, in those countries, larger financial or sovereign-debt crisis are associated with stronger permanent effects on GDP, supports the view of persistence caused by hysteresis. Finally, as we have discussed in Section III, there is abundant evidence about the effects that financial stress has had on variables that drive growth (such as investment) and therefore can be responsible for the severe output loss in the Great Recession and other similar episodes.

In these models, the permanent technology shock also creates cyclical dynamics through temporary changes in capital and labor. And, as before, we can include a variety of other purely transitory shocks (v_t).

$$c_t = \phi(L)\,\epsilon_t + \varphi(L)\,v_t$$

New Keynesian models, unless we add the same permanent technology shocks, cannot produce hysteresis or permanent scars as the effects of demand shocks on output are only temporary. The persistence of GDP depends on the persistence of shocks but also on the transmission mechanism. In New Keynesian models with price rigidities as the mechanism of propagation of shocks, it is very difficult to generate significant persistence with reasonable assumptions for price rigidities.

One way to generate higher persistence in this type of models is to assume other rigidities. Rigidities in labor markets is a possibility, motivated by the observed slow response of unemployment towards its equilibrium level. We discussed earlier the evidence on unemployment persistence in Europe in the 1970s (Blanchard and Summers (1986)).

Why is unemployment so persistent? Blanchard and Summers (1986) or Galí (2020) emphasized theories based on an insider-outsider model of the labor market. These theories can generate structural unemployment, but they can also interact with a succession of adverse shocks to generate the observed persistence.

There are several other alternative mechanisms suggested in the literature to generate hysteresis in labor markets. For example, unemployment can interact with the design of institutions which then provides a mechanism for unemployment to stay higher (Di Tella and MacCulloch (2006)). And there are also many models and evidence in the microeconomics labor literature supporting the view that either employment levels, skill levels, or wages can react persistently to the business cycle. Topel (1990) presents evidence of persistence of labor market outcomes after recessions, evidence that is supportive of the hysteresis hypothesis. The potential channel highlighted in the paper is the loss of specific human capital by displaced marginal workers in the presence of shocks that induce reallocation to new activities. Davis and von Wachter (2011) interpret similar evidence in the context of the Morten-Pissarides search model. In order to get large effects of job separations in labor market outcomes, the standard model needs to be complemented with rigidity of wages to be able to create additional variability in unemployment (Hall and Milgrom (2008), Hagedorn and Manovskii (2008)). Finally, the findings of Kahn (2010) about the persistence effects of cohorts that join the labor market in recessionary times find support in models where the quality of the search decreases during times where the market is thin and this will lead to underinvestment in human capital by the firm or by the worker (Jovanovic (1979), Gibbons and Waldman (2004)).

Persistence in labor markets is unlikely to translate into permanent effects on the aggregate employment level as workers that have seen their skills affected by the recession or those who have been discouraged by lack of opportunities will eventually be replaced with other workers as new generations enter the labor market.[30] In other words, $\varphi(L)$ will not have a unit root. But over reasonably long horizons, a very persistent process might resemble one with a unit-root, and that's why this literature referred to these dynamics as hysteresis in labor markets.

B. Endogenous growth models and hysteresis

Starting in the 1980s, a series of papers developed models in which economic growth is determined by endogenous economic forces. Endogenous growth was then imported into real and/or monetary models of the business cycle to establish a link between capital accumulation, innovation or productivity growth and economic activity. This literature creates linkages between cyclical conditions and growth, thereby generating channels for hysteresis. Temporary shocks, including from demand-side policies, can permanently impact the level of output.

The endogenous growth literature can be broadly grouped into versions of (1) learning by doing (LBD) models, (2) Romer (1986) "AK" models, and (3) R&D models (mostly of expanding varieties).

Lucas (1988), drawing on Uzawa (1965) and the empirical evidence from Arrow (1962), added the accumulation of human capital, H, as a factor supporting economic growth

$$Y_t = A_t K_t^{\alpha} \, (H_t L_t)^{1-\alpha}$$

Learning by doing happens as a by-product of the production process or, alternatively, through investment in education where

$$H_{t+1} = g(H_t).$$

The production and learning functions exhibit constant returns to scale in the factors, K and H, that can be accumulated. This linear homogeneous property is essential for endogenous growth.

Romer (1986) assumed that the stock of knowledge is related to increases in physical capital, with a spillover of technical knowledge at the industry level. While an individual firm faces diminishing returns to its own capital (k_i) its production level benefits from the aggregate stock of knowledge (K):

$$Y_i = A k_i^{\alpha} L_i^{1-\alpha} K^{\eta}$$

[30] The impact on the individual affected worker could still be permanent, even if aggregate employment does not have a unit root.

This model displays increasing returns if α+η>1. In the special case that α+η=1 and normalizing aggregate labor L=1, aggregate output depends linearly on total physical capital:

$$Y = AK$$

giving rise to the nomenclature "AK" model.

A third category of endogenous growth models derives from consideration of an R&D sector devoted to innovation, based on seminal contributions from Romer (1990), Aghion and Howitt (1992), and Grossman and Helpman (1991). Firms in the R&D sector make explicit business decisions to invest in producing new varieties of intermediate goods:

$$Z_{t+1} = Z_t g(J_t)$$

where Z_t is the stock of endogenous technologies and J_t is the R&D investment flow in time t. Firms that successfully innovate a new intermediate product are assumed to obtain monopoly rights for some time, with the expected return of monopoly rights covering the investment cost in equilibrium. Final output is produced by labor and a continuum of intermediate products:

$$Y = L^{1-\alpha} \int_0^Z x(j)^\alpha dj$$

where $x(j)$ is the input of intermediate product j.

The vast majority of hysteresis-generating models fall into one of these endogenous growth categories and feature various types of demand shocks (e.g., liquidity demand, debt financing, equity financing, monetary and fiscal policy) rather than technology shocks. In order to generate hysteresis, they need to establish a link between the endogenous growth engine (R&D, learning by doing or capital accumulation) and the cyclical state of the economy (e.g. output, employment, output gap, credit availability).

We now review some of the models that establish this connection. To highlight similarities across all these models, we convert the notation in the original literature to the following consistent set of notation: exogenous technology (A); human capital or knowledge capital (H); physical capital (K); the stock of endogenous technologies that have been innovated (Z); adopted technologies (X); intermediate goods (M); labor supply (L); final output (Y); investment flow in physical capital (I); investment flow in R&D (J); and capital utilization (U).

King, Plosser, and Rebelo (1988) is one of the first papers to incorporate endogenous growth to an otherwise standard real business cycle model. They follow King and Rebelo (1988), which extends Lucas (1988) to include both physical and human capital. The production functions of final goods and human capital both have linear homogeneous technologies in physical and human capital, permitting ongoing growth.

$$Y_t = A_t (V_t K_t)^{1-\alpha} \, (H_t L_t)^{\alpha}$$

$$H_{t+1} - H_t = A_t^* \, ((1 - V_t) K_t \,)^{1-\nu} (E_t H_t)^{\nu} - \delta \, H_t$$

Where E_t is the fraction of time dedicated to human capital formation and V_t represents the fraction of physical capital used to produce output (the rest is used in the production of human capital). Human capital depreciates at a rate of δ. The two production functions above, for output and human capital, have constant returns to scale in H and K, a requirement for endogenous growth.

Adding endogenous growth has profound implications for the cycle-trend decomposition in these models. The trend component in this model is driven by the long-term dynamics of physical and human capital. Shocks to either production technology now lead to permanent effects on the levels of variables such as output and consumption. By endogenizing growth, temporary macroeconomic events can generate shifts in the trend of output. In this model, temporary productivity shocks to the production of output (shocks to A_t, ϵ_t^y) or human capital (shocks to A_t^*, ϵ_t^h) lead to unit roots in the logs of both capital stocks, k and h.

$$k_t = k_{t-1} + \beta(L) \, \epsilon_t^y + \theta(L) \, \epsilon_t^h$$
$$h_t = h_{t-1} + \varphi(L) \, \epsilon_t^y + \psi(L) \, \epsilon_t^h$$

Stadler (1986) and Stadler (1990) go beyond the standard RBC model in order to compare the properties of real and monetary business cycle models with and without endogenous technological change. They present a general framework that includes endogenous and exogenous technology on the production side, and one-period sticky wages with a stochastic money growth rule on the nominal side of the economy.

In Stadler (1986) the supply side is characterized by endogenous accumulated technical knowledge, labor, and both temporary and permanent shocks to exogenous technology. Learning is a by-product of the output process. Using our notation

$$Y_t = A_t L_t^{\alpha} \, {H_t}^{1-\alpha}$$
$$H_{t+1} = H_t \, Y_t^{\gamma}$$

Aggregate demand is given by the quantity theory of money, $Y = M/P$, and the money supply is itself stochastic. If we assume that the money supply is a random walk

$$m_t = m_{t-1} + v_t$$

We can obtain an expression for output as a nonstationary stochastic process, i.e. with a unit root

$$y_t = (1 + \gamma)\, y_{t-1} + \kappa\, (v_t - v_{t-1})$$

We have a pure monetary model with endogenous learning and monetary policy shocks can generate permanent effects on output (when $\gamma \geq 0$). This model captures well the hysteresis properties of endogenous growth models. Temporary disturbances, regardless of their origin, can cause permanent scars on output.[31]

A wave of theoretical work builds on the intuition of these two papers and incorporate roles for a variety of demand shocks that can generate hysteresis through several potential channels. Rather than going into the details of each of the theoretical economic structures, we focus our mathematical description on the modeling components that drive hysteresis: namely, production functions that are linear homogenous in factors that can be accumulated or productivity accumulation that depends on cyclical or demand-side factors.

Comin and Gertler (2006) and Comin (2009) model the volatility and persistence of high- and medium frequency variation in economic data. They emphasize that conventional detrending methods used in business cycle analysis sweep longer-term oscillations into the trend, thereby removing them from analysis. Their analysis finds that TFP, including both disembodied and embodied technological change, is strongly procyclical over the medium term, demonstrating that the supply and demand sides of the economy are correlated. Likewise, Comin (2009) notes that standard RBC models match the persistence of economic activity by imposing persistence in exogenous technological shocks or through exogenous diffusion of technology (Rotemberg (2003)). The paper finds that the speed of technological diffusion is strongly correlated with the medium-term business cycle.

Motivated by these results, the papers modify the conventional business cycle framework to integrate growth and business cycles through endogenous productivity growth, similar to Romer (1990). Procyclical entry or exit of final goods producers induce countercyclical movements in their markups. Meanwhile, endogenous technology development and adoption modeled through the entry/exit of intermediate goods producers induce long procyclical swings in both embodied and disembodied productivity. Their model features an expanding variety of final goods producers and intermediate producers. Each differentiated final good producer uses capital, labor, variable capital utilization U_{it}, and an intermediate good composite M_{it}, where the composite aggregates the total stock of differentiated intermediate goods Z_{t+1}.

$$Y_{it} = f(U_{it}, K_{it}, L_{it}, M_{it})$$

[31] These models can also include technology shocks. And as in King, Plosser, and Rebelo (1988), temporary technology shocks also produce permanent effects.

$$M_{it} = \left(\int_0^{X_t} M_{it}(j)^{1/\nu} dj \right)^{\nu}$$

The stock of differentiated intermediate goods increases through R&D (J_t) and a productivity parameter that reflects aggregate conditions on the value of capital.

$$Z_{t+1} = Z_t f(J_t, P_t^I K_t)$$

A fraction of created innovations is adopted.

$$X_{t+1} = X_t g(L_t, Z_t - X_t)$$

The model permits high frequency nontechnological disturbances to have sustained effects on productivity over the medium term. The variation in mark-ups generates volatility in output, but also influences the pace of R&D and technological adoption. A recession compresses the demand for intermediate R&D goods and the value of firms conducting R&D. The value of adopted and non-adopted technologies declines and the return to R&D falls, leading to less R&D. Thus, technological advancement is endogenous and also procyclical.

Jordà, Singh, and Taylor (2020) show in a model with endogenous TFP growth that monetary policy shocks have long-lasting effects on capital accumulation, TFP, and output, contrary to the tenet of long-run neutrality of money. They use a reduced form specification in which the output gap is positively correlated with the rate of TFP growth, where potential output (Y_t^P) is the flexible price level of output.

$$Z_{t+1} = Z_t f(A_t, Y_t / Y_t^P)$$

The model is embedded in a New Keynesian model with sticky prices. An interest rate increase lowers current output, and the slowdown/recession reduces productivity growth (which is linked to the economic cycle) and thereby decreases the trend in output permanently.

Engler and Tervala (2018) examine fiscal multipliers in a New Keynesian DSGE model with endogenous TFP through learning by doing. Their production function relies on productivity and labor. Skills increase because of learning by doing. In our notation

$$Y_{it} = H_{it} L_{it}$$

$$H_{it+1} = H_{it}^{\phi} f(L_{it})$$

A higher level of employment leads to higher productivity growth through learning. If $\phi = 1$, employment permanently shifts labor productivity. In the model, fiscal policy-driven changes in employment generate permanent increases in productivity and output. Hysteresis substantially increases the NPV fiscal output multipliers to 4.5 in the benchmark parameterization case from a value of 0.8 in the absence of hysteresis. Likewise, hysteresis leads to a positive welfare multiplier of fiscal policy. That is, even if fiscal spending has no direct utility value to consumers, a fiscal expansion leads to a permanent expansion of output. Each dollar of public spending leads to a welfare gain equivalent to 2.2 dollars of private consumption.

The Global Financial Crisis, as well as other episodes of crises leading to severe recessions, demonstrate that the financial system contributes to economic fluctuations. In some cases, it constitutes a source of shocks. Financial frictions also affect the transmission of domestic and external shocks and may amplify them or impede a recovery. Indeed, as discussed in Section III.E., the empirical literature demonstrated that financial crises have been associated with many of the most severe and prolonged recessions, with persistent scars on output. Therefore, a strand of recent literature builds financial frictions into models with endogenous growth and productivity and uses the models to analyze economic behavior during the Great Recession and other financial crises.

Anzoategui et al. (2019), motivated by the empirical finding that a significant fraction of the post-Great Recession fall in productivity was an endogenous response to the liquidity demand shock, build a model with endogenous R&D creation through expanding varieties and a procyclical adoption of technology as in Comin and Gertler (2006) and Comin (2009). The slowdown in productivity following the onset of the Great Recession mainly reflected an endogenous decline in the rate that technologies are incorporated in production, which was a result of the recession. They find a limited role for exogenous technology. Furthermore, the endogenous decline in TFP increased production costs (relative to trend), which partly counteracted the negative effect of the recession on inflation as in a traditional Phillips-curve effect. They argue that their model and analysis demonstrate the important impact that demand shocks have on the supply side over the medium term.

Bianchi, Kung, and Morales (2019) examine the implications of debt versus equity financing frictions in an endogenous growth framework with R&D spillovers and nominal rigidities. The model includes two types of endogenous technologies, an aggregate stock of R&D knowledge capital and a utilization of technology. Each monopolistic intermediate good producer uses physical capital, labor, and total TFP comprised of exogenous technology, R&D knowledge capital, and technology utilization.

$$Y_t = (A_t U_t^n H_t)^{1-a} K_t^a$$

Knowledge capital depends on investment that is subject to convex adjustment costs.

$$H_{t+1} = H_t f(J_t)$$

There are spillovers of both types of endogenous technologies across firms and aggregate production and technology. The paper assumes only physical capital can be pledged as collateral for debt. They use the model to interpret the 2001 and 2008 recessions in the United States. The Great Recession was associated with a sharp drop in the technology utilization rate while R&D knowledge was little affected. This corresponded to a severe financial crisis impacting debt capital markets. In contrast, the 2001 recession was due to the end of the IT boom of high-tech R&D firms that relied on equity financing.

Queralto (2019) presents evidence that banking crises precipitate an enormous persistent drop in R&D of 35 percent in a panel of 36 countries, as well as permanent declines in output (15 percent), hours (7 percent), and productivity (8.5 percent). Relative to pre-crisis trends, the Korean financial crisis of 1997 led to significant declines in GDP, employment, TFP, investment, consumption, and R&D. In his theoretical framework, the process of innovation in R&D sector is endogenous. TFP takes the form of expanding variety of intermediate goods.

$$Z_{t+1} = Z_t f(Y_t, L_t^s)$$

The financial friction consists of a tightening of credit that lowers the pace of innovation. The financial accelerator operates as follows: a decline in bank net worth forces banks to reduce project lending; prices for entrepreneurs' new and outstanding securities fall; this leads to a further decline in bank net worth.

Guerron-Quintana and Jinnai (2014) model endogenous productivity in the form of creation of new intermediate goods and knowledge spillovers (Romer (1990)) and a financial friction in the liquidity of equity finance (Kiyotaki and Moore (2012)). The US financial crisis entails large shocks to financing conditions, but these recovered following the crisis. Their estimated model generates an economic and stock market boom following a favorable liquidity shock, and these temporary shocks shift the trend of output, in line with post-crisis US economic developments. Their counterfactual analysis shows that the US economy would have averted the Great Recession if there had been better financing conditions.

Cerra, Hakamada, and Lama (forthcoming) show that long-term productivity losses following financial crises in a large sample of countries are strongly linked to investment losses and less so to lower R&D spending in the aftermath of the crisis. Based on these findings, they introduce technological improvement embodied in the purchase of new capital, which increases the effective quality of firms' capital.

$$Y_t = A_t (Z_t K_t)^{\alpha} (L_t)^{1-\alpha}$$

$$Z_t = \varphi Z_{t-1} + \lambda I_t$$

Thus, the effectiveness of capital increases as a by-product of investment, analogous to an LBD model in which the effectiveness of labor increases as a by-product of employment, and can spur ongoing growth if φ=1. A temporary adverse financial shock that raises the cost or lowers the volume of borrowing leads to a large decline in investment, which in turn depresses the acquisition of technology embodied in investment goods and thereby persistently lowers effective capital (often measured as a component of TFP) and output.

C. Expectations-driven multiple equilibria and non-linearities

There are two other types of models that can also generate hysteresis but through mechanisms that are different from those in the previous section. In the first type, self-fulfilling prophesies lead the economy to be stuck in a low output or low growth state. Recessions can then be seen as episodes where the economy spends time in the low-growth state. In these models, growth, possibly via the endogenous productivity mechanisms of the previous section, is affected via economic decisions that interact with expectations of future economic outcomes.

In the second type of models, the economy can also be stuck at a low level of output or aggregate demand but now through a non-linearity or boundary restriction. The development literature has discussed poverty traps due to deficiencies in savings at low incomes that create non-linear savings functions in a Solow growth model, giving rise to multiple steady states (Durlauf and Johnson (1995)). In macroeconomics, the most common non-linearity in the recent literature is the zero-lower bound on nominal interest rates, which constrains monetary policy and opens up the possibility of a liquidity trap. Because many of the papers that feature a zero-lower bound restriction also include self-fulfilling expectations as an element of the story, this section jointly discusses these two set of models.

Durlauf (1991) in a model with strong complementarities across sectors shows the possibility of multiple stochastic equilibria that are associated with differences in both the mean and the variance of output. In the absence of a coordination mechanism, the economy can shift from one equilibrium to another and generate persistence fluctuations in GDP. After being hit with a shock, the economy displays path dependence until it gets hit with a future offsetting shock.

Evans, Honkapohja, and Romer (1998) present a similar intuition in a model where capital complementarities generate multiple equilibria in GDP growth rates. If the economy shifts temporarily to a low growth state, it will display hysteresis as the level of GDP does not go back to its pre-crisis trend.

Farmer and Woodford (1997) show that a large set of stationary rational expectations equilibria exist in a business cycle model such as that of Lucas (1972) in which informational asymmetries are proposed as an explanation of the Phillips-curve correlation between inflation and output. The self-fulfilling character of expectations produces multiple equilibria. They also show that the intergenerational burden of alternative forms of government finance may be indeterminate. This gives rise to the possibility that expectations may be influenced by non-economic factors, such as social norms, or "animal spirits" or alternatively, justifies stabilization policy to pin down a unique equilibrium.

Gunn and Johri (2011) show how expectations of future productivity can drive current demand and supply. Production is a function of knowledge capital (H_t), which accumulates as a by-product of employment in production, a form of learning-by-doing.

$$Y_t = A_t f(L_t, K_t, H_t)$$

$$H_{t+1} = g(H_t, L_t)$$

Additional knowledge contributes to current output but also raises the marginal effectiveness of labor in future learning. The value of the firm and its equity price, V, depends on the stock of knowledge: $V_t = q_t H_{t+1}$

News about a future rise in exogenous productivity (A_{t+k}) increases the value of the firm's knowledge and leads to an immediate rise in employment and output, which induces a boom in consumption and investment. If expectations of future productivity do not materialize, there is a bust. Cycles are characterized by a boom in output, consumption, investment, and employment in advance of the expected rise in exogenous TFP.

Benigno and Fornaro (2018) feature expectations-driven investment where returns to innovation depend on future aggregate demand in a way that can generate multiple equilibria. The model includes endogenous growth in the form of vertical innovation. Each innovator of a new quality of intermediate input gains a patent and becomes a monopolist for the next period. The future profit depends on future aggregate demand and thus total employment. The value of innovation is the discounted value of future profits that depend on employment:

$$V_t(Z_t) = E_t f(P_{t+1}, Z_t, L_{t+1})$$

There is a nominal wage rigidity, and a central bank with an interest rate rule aiming at stabilizing output by reducing the interest rate when employment falls. The model gives rise to multiple equilibria, but only when there is endogenous growth and a zero-lower bound on the interest rate. Without both features, equilibrium would be unique. Expectations of future aggregate demand drive innovation (to gain future profits) and growth. If expectations shift to low future aggregate demand, the central bank may not be able to respond if the zero lower bound is binding. The model is extended to allow for a temporary liquidity trap where the economy can ultimately return to full employment after emerging from the pessimistic state. But because there is no way to make up for low growth during that period, the trap leads to a permanent loss in output, displaying hysteresis.

There are models with multiple equilibria where stagnation traps can be associated with getting stuck in a high unemployment equilibrium. If the economy moves from the good equilibrium to the bad one it will display hysteresis as well. For example, Weitzman (1982) and Farmer (2012) develop models with increasing returns to scale and multiple equilibria.

Schmitt-Grohé and Uribe (2017) is another recent contribution in this category of models. They propose a model of a liquidity and growth trap based on key elements of downward nominal wage rigidity and a zero-lower bound on nominal interest rates, extending the framework of Benhabib, Schmitt-Grohé, and Uribe (2001). A confidence shock can push the economy into a low inflation liquidity trap where the zero lower bound restricts monetary policy and real wages are too high to be compatible with full employment. The economy can become chronically stuck with high levels of unemployment. The associated temporary low employment growth and, as a result, GDP growth during the period of increasing unemployment results in permanent effects on GDP levels. In a version of the model that allows for capital accumulation, there can also be an investment slump with a permanently lower level of capital.

Garga and Singh (2018) construct a model of Schumpeterian Growth along the lines of Aghion and Howitt (1992) and Grossman and Helpman (1991) in a New Keynesian setting. A contraction in aggregate demand leads to an endogenous slowdown in TFP growth and persistent gap of output below its pre-crisis trend. While monetary policy could offset the permanent impact of temporary demand shocks on the level of GDP in normal times, it fails to do so in the presence of a the zero-lower bound.

Garga and Singh (2018) and Schmitt-Grohé and Uribe (2017) relate to a body of literature that debates the policy options for reviving the economy from a liquidity trap, such as through commitment to a higher inflation target to raise inflationary expectations (Krugman (1998); Woodford (2012); Eggertsson and Woodford (2004)) or through the active use of fiscal instruments (Mertens and Ravn (2014); Cochrane (2017)). Jobless recoveries can also result from real wage rigidities (Shimer (2012)). Much of this literature on liquidity traps are driven by self-fulfilling expectations, which Christiano, Eichenbaum, and Johannsen (2018) argue are not "learnable" and therefore may be indeterminate.

Summers (2015) and Summers (2014) revive the concept of secular stagnation as a chronic deficiency in demand stemming from secular trends that are likely to maintain a ZLB liquidity trap for the foreseeable future. Eggertsson, Mehrotra, and Robbins (2019) formalize the secular stagnation hypothesis based on the framework of an endowment economy with three-period overlapping generations. Savings by one cohort are lent to another cohort for their consumption. The equilibrium real interest rate depends on factors other than the discount rate—such as population growth, the income profile over a lifetime, the debt limit, inequality, and deleveraging—and may turn out to be negative. Some of these fundamentals reflect long-term secular trends, implying that nothing prevents the equilibrium real interest from remaining negative indefinitely. A deleveraging cycle can permanently depress the natural rate of interest as lower borrowing by the young implies more resources for saving as that cohort reaches middle age, thus increasing the supply of loanable funds. Adding wage or price rigidities introduces a role for monetary policy. If the inflation target is set sufficiently high, the nominal interest rate may be positive if it accommodates the negative natural rate. However, there is another equilibrium in which secular stagnation remains. Fiscal policy via debt, tax, or spending changes can offset the weak aggregate demand, but the fiscal multiplier depends on the how taxes and spending are distributed across generations.

Eggertsson, Mehrotra, and Robbins (2019) differ from some of the other literature in its treatment of savings. In their model, savings serve the function of smoothing consumption across time through borrowing and lending transactions between heterogenous agents, namely different cohorts in the three-period OLG framework. In contrast, other papers (e.g., Gunn and Johri (2011), Garga and Singh (2018), Benigno and Fornaro (2018)) are set in the framework of a representative agent production economy where savings provide resources for investment and endogenous growth.

Heterogenous agent models may incorporate coordination externalities and the endogenous productivity processes described above. Dosi et al. (2018) develop an agent-based model featuring hysteresis. The model includes endogenous technological innovation and adoption and learning by doing, as well as imperfect information. The paper also features alternative labor market institutions and policies, exploring their impact on recoveries and long-term growth.

All the models described in this section display some form of hysteresis although the dynamics are not quite identical to those in the previous section. In models of endogenous growth with capital accumulation and productivity growth, a temporary shock from either demand-side or supply-side sources can disrupt decisions to invest in capital accumulation or innovation. Given the linearity associated with production functions for final output or for innovation and knowledge accumulation, a temporary disruption to the growth process implies a permanent impact on the level of output. In models of self-fulfilling expectations, the economy can get stuck in a bad equilibrium state for prolonged periods even due to a temporary shock. If there is no self-correcting mechanism or policy instrument that can move the economy back to the good equilibrium, the result can be permanently lower output or employment, which is a form of hysteresis. Alternatively, if policy interventions or other shocks shift expectations and the economy back to the good equilibrium, some of the models would imply that the damage to output and employment is reversed. Thus, the relationship between hysteresis and self-fulfilling models of multiple equilibria depend on whether the economy is permanently stuck at the bad equilibrium, as well as whether the model also incorporates features of endogenous growth, as in Benigno and Fornaro (2018). The formulation of secular stagnation in Eggertsson, Mehrotra, and Robbins (2019) provides an example of how fundamentals, such as demographic and secular factors, can indefinitely shift to values that constrain (monetary) policy from overcoming the liquidity trap and potentially lead to some form of hysteresis via effects on growth.

V. POLICY IMPLICATIONS

A. Stabilization policy and the costs of business cycles

In the traditional trend-cycle decomposition, GDP fluctuations are seen as temporary, symmetric deviations from trend. While these fluctuations have an impact on welfare, under certain assumptions the costs of business cycles are very small. The seminal work of Lucas (1987) suggested that the costs of the US business cycle was as small as 0.008 percent of consumption level equivalent. Some challenged these calculations by exploring different utility functions or looking at heterogeneity among individuals and produced larger estimates of these costs. Adding endogenous growth to a typical business cycle can also increase the cost of business cycles as the increased volatility of investment might reduce the average GDP growth (Barlevy (2004a)).[32]

But beyond the specifics of the utility function, there is a key feature of the framework used in Lucas (1987) that makes the costs of fluctuations small. The potential benefits of stabilization policies are limited to the ability of demand management to keep output close to potential and correct from any distortions related to these deviations. In the context of New Keynesian models, potential output can be seen as the level of output consistent with the flexible price equilibrium (Blanchard (2018) and the output gap the difference between actual and potential output. Typically, these models suggest that keeping GDP close to potential, minimizing the output gap, should be the welfare-maximizing objective for monetary policy. In addition, and under certain assumptions, this can be implemented by stabilizing inflation, what Blanchard and Galí (2007) refer to as the divine coincidence. A similar framework has been used for fiscal policy where the goal of countercyclical fiscal policy is to minimize deviations from potential.[33] Given that both economic policy tools had identical objectives and given that one of them, monetary policy, was seen as being more capable of stabilizing output, this led some to argue against the use of any discretionary fiscal policy (Taylor (2000)).

An obvious deviation from this framework that could increase the costs of business cycles is asymmetric fluctuations as in the "plucking model" of Friedman (1964) as it assumes that fluctuations are all deviations from a potential output *ceiling*. The goal of policy makers is still to reduce deviations from potential, but now, by doing so, stabilization policy cannot only reduce the volatility of GDP around its natural levels but can also increase its average level (Cohen (2000), Dupraz, Nakamura, and Steinsson (2019)).

B. Optimal stabilization policy in the presence of hysteresis

In the presence of hysteresis, the state of the cycle feeds into the long-run supply capacity. As discussed in Section IV, the trend in output corresponds to stocks of capital and/or

[32] For a good summary of this literature see Barlevy (2004b).
[33] As an example, the EU fiscal policy framework heavily depends on the measurement of potential output both when assessing when policy is needed and when measuring the stance of fiscal policy.

innovation; it contains a unit root and is driven by technology shocks (ϵ_t) as well as demand shocks (υ_t).[34]

$$\tau_t = \tau_{t-1} + \varphi(L)\,\epsilon_t + \phi(L)\,\upsilon_t$$

This means that the GDP trend is history dependent, a function of the scars left by previous recessions.

Among the potential demand shocks, we can have shocks to economic policies. Those share the same history dependence and therefore can have permanent effects. Martin and Rogers (1997), Engler and Tervala (2018), Garga and Singh (2016), Jordà, Singh, and Taylor (2020) all show how fiscal and monetary policy shocks have permanent effects on the level of GDP via learning by doing or the reaction of R&D.

What about the design of optimal stabilization policy? Garga and Singh (2018) explicitly analyze optimal monetary policy in an endogenous growth model within a New Keynesian setting. Growth is modeled along the lines of Aghion and Howitt (1992) and Grossman and Helpman (1991) where the final good producer faces a production function

$$Y_t = M_t^{1-\alpha}\, L_t^{1-\alpha} \int_0^1 A_{it}^{1-\alpha}\, x_{it}^{\alpha}\, di$$

Where x_{it} is the flow of intermediate product i used at time t and A_{it} represents the quality of that particular intermediate product. M represents an aggregate productivity shock. Entrepreneurs can invest into R&D in order to improve the productivity of the intermediate products and earn profits from their patents. In the presence of nominal rigidities, a decrease in demand for the final good decreases the value of obtaining the patent. As a result, negative demand shocks (υ_t) lead to a slowdown of TFP and hysteresis dynamics.

$$a_t - a_t^e = \psi(L)\,\upsilon_t$$

where a_t represents the (log of) the aggregate productivity index and a_t^e its level in the absence of price rigidities.

What constitutes optimal monetary policy in this setting? The model replicates the results of standard New Keynesian models. Monetary policy should try to replicate the flexible price equilibrium.[35] In a standard New Keynesian model with no hysteresis, Blanchard and Galí

[34] Where we assume a simple linear lagged polynomial relationship and the lagged polynomials $\phi(L)$ and $\psi(L)$ do not contain a unit root.

[35] As it is the case of New Keynesian models without hysteresis, there can be several inefficiencies that could be addressed by monetary and fiscal policies. As in models without hysteresis, Garga and Singh (2018) assume

(continued…)

(2007) distinguished the efficient (first-best) level of output from the natural (flexible price) level of output that arises if real wage rigidities are not offset by policy instruments, and each concept of potential has an associated output gap. Provided that fiscal policy instruments are available to address structural distortions, monetary policy should minimize the deviations of output from the flexible price equilibrium. This intuition carries over to models with hysteresis as shown in Garga and Singh (2016), Moran and Queralto (2018) or Jordà, Singh, and Taylor (2020).[36]

In these models, if monetary policy is unrestricted it can avoid hysteresis effects by targeting the level of output consistent with flexible prices. If successful, actual output will be identical to potential, eliminating the output gap in a way that is similar to models without hysteresis.[37] But if monetary policy is constrained by the zero-lower bound, the central bank cannot restore the flexible price equilibrium and, as a result, the cyclical dynamics of the recession turn permanent via hysteresis effects. The same outcome would happen if the central bank is not setting the interest rate at the right level. If the central bank is not as aggressive as the optimal monetary policy rule dictates, it would create deviations of output from the potential, deviations that will turn into permanent scars via hysteresis.

The main insight is that in the presence of hysteresis monetary policy that is not aggressive enough during a downturn (either because of constraints on monetary policy or because of central bank mistakes) can have much bigger consequences because of the permanent scars on GDP.[38] Garga and Singh (2018) provide quantitative estimates of the benefits of optimal monetary policy in the presence of hysteresis.[39]

Garga and Singh (2018) also discuss the possibility of correcting previous mistakes or compensating for periods where monetary policy had been constrained by the zero-lower bound. In those instances, it may be optimal to commit future policy to generating excess inflation to recoup past output losses. This works in their model because of symmetry: positive shocks generate as much hysteresis as negative ones. However, this stabilization

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sufficient fiscal tax instruments to offset any distortion and externality other than price rigidity and leave stabilization for monetary policy.

[36] Benigno and Fornaro (2018) have a slightly different take on optimal policy because hysteresis is the result of economies getting trapped in a low growth equilibrium. In this case the objective of policy is to avoid such a low-growth equilibrium.

[37] In earlier models of hysteresis, the cyclical variable that triggered hysteresis was simply the level of activity or employment because learning by doing (Martin and Rogers (1997)) or the incentives to innovate (Fatas (2000a)) were directly related to these levels. Under the assumption that the labor supply was fixed this could also be interpreted as minimizing unemployment. A potential issue with these early endogenous growth models was that they displayed scale effects: increases in population will predict increases in long-term growth rates (Jones (1999)).

[38] See also Moran and Queralto (2018) and Garga and Singh (2016) for a similar conclusion.

[39] Ikeda and Kurozumi (2019) also analyze optimal monetary policy in the presence of hysteresis.

strategy is not time-consistent, leading to a hysteresis bias similar to the deflation bias result of Eggertsson (2006) in models without hysteresis.

These results emphasize the need to be aggressive when it comes to stabilization policy in order to minimize the effects of shocks and therefore help offset the permanent damage they cause to output, consumption, capital, and (in some models) employment. This applies to both monetary and fiscal policy (Blanchard, Cerutti, and Summers (2015), Fatas and Summers (2018)). And, in these instances, the ability to raise the economy's supply potential via early intervention minimizes any fear of generating inflation.

As discussed in Section III, there is a variety of empirical evidence supporting the conclusion that policy matters in determining long-term outcomes. For example, Blanchard, Cerutti, and Summers (2015), Fatas and Summers (2018), Gechert, Horn, and Paetz (2019), Bianchi et al. (2019), Oscar Jordà, Singh, and Taylor (2019), Moran and Queralto (2018), International Monetary Fund (2009) and Cerra, Panizza, and Saxena (2013) all provide evidence of the potential long-term benefits of stabilization policy.

What about optimal policy during expansions? On one hand, if we believe that recessions are the outcome of the excesses during expansions, there is a strong role for macroprudential policy and pre-empting excessive credit growth. Macroprudential policy can avoid the future costs of large recessions by emphasizing countercyclical measures that minimize the risk of a future downturn. When economic and credit growth is strong in an upswing, prudential standards should be tightened, and buffers increased to ameliorate any excessive credit growth that might lead to a destabilizing financial crisis.

But, at the same time, if policy makers are too conservative and act too early on the fears that the economy is overheating, they might, via hysteresis effects, negatively affect the supply side and shorten the expansion. Models of hysteresis suggest that running the economy as close to potential as possible can bring large benefits (as in the early intuition of Okun (1973)). This notion has recently been picked up by policy makers by referring to the benefits of running a high-pressure economy (Yellen (2016)). The experience of the US labor market in the post-GFC expansion, where the natural rate of unemployment keeps being revised downwards suggesting that there was more slack than previously anticipated, highlights the potential drawbacks of reacting too early to the fear of excesses and potential financial crisis.

In summary, in the presence of hysteresis, getting an accurate measure of economic slack or the cyclical state becomes even more crucial than in traditional models where the trend is independent of the cycle. But because of the endogeneity of the trend, defining and estimating potential output can be more challenging. We discuss this issue next.

C. Implementing optimal stabilization policy in the presence of hysteresis

The previous section highlighted the importance of countercyclical fiscal and monetary policies in the presence of hysteresis. We concluded that optimal policy requires that policy makers target the level of GDP that would take place in the absence of price rigidities. But such a level cannot be observed, it can only be estimated and this can lead to policy errors. In a non-hysteresis framework, these errors will be destabilizing and add volatility. But in the presence of hysteresis these errors propagate to the supply side and can generate permanent scars on GDP.

Vinci and Licandro (2019) explicitly analyze the impact of errors in monetary policy implementation in the context of an AK endogenous growth model. And they apply their insights to show that the model can reproduce well economic data from the Great Recession, where policy makers ended up targeting a level of GDP that was too pessimistic, leading to policies that were not aggressive enough. Vinci and Licandro (2019) model features price markups, risk and confidence shocks, and a financial accelerator mechanism. An intermediate good is produced with a technology that includes a capital externality, as in Romer (1986):

$$Y_{it} = Ak_{it}^{\alpha} l_{it}^{1-\alpha} K_t^{\eta}.$$

A demand shock combining higher aggregate risk and lower consumer confidence generates a fall in investment and triggers a recession.

Vinci and Licandro (2019) assume that central bankers do not have a complete understanding of the model driving the economy. In their Taylor rule, they target a level of GDP that is estimated with a backward looking moving average of previous GDP observations. For short recessions, policy makers do not change their output target and use monetary policy aggressively in order to return the economy back to pre-crisis levels. The result is that the economy does not display hysteresis effects. But in a long recession, as GDP remains persistently below pre-crisis levels for several periods, policy makers revise down their GDP target. As a result, monetary policy becomes less aggressive and the recovery becomes weaker with the consequence that the economy never returns to its pre-crisis trend because of hysteresis.

The type of error highlighted by Vinci and Licandro (2019) could also be generalized to an economy that is subject to both demand shocks and technology shocks. Policy makers need to separate the two in order to decide on optimal policies. Errors in estimating the origin of the shocks can lead to hysteresis and suboptimal policies.

Several papers have provided evidence supporting this intuition. Because of the reliance on the use of filters to separate the cyclical and structural component of GDP changes, potential output estimates tend to be highly procyclical. For example, a negative surprise of 1 percent of annual GDP leads to immediate revisions to potential GDP of between 0.6-0.8 percent among advanced economies (Fatas (2019), Dovern and Zuber (2019), Claeys, Darvas, and Leandro (2016), Coibion, Gorodnichenko, and Ulate (2018), Martin, Munyan, and Wilson (2015)). This is seen as an overreaction to what could simply be a standard cyclical recession. In this environment, policy makers overestimate the measured "structural" component of the observed change in GDP, so they will be hesitant to use stabilization tools. Monetary and fiscal policy will not be aggressive enough and, as a result, policy makers will make the recession deeper and longer than what is necessary. Because of hysteresis effects, this will lead to large permanent losses in GDP.

In addition, if policy makers ignore the possibility of hysteresis in their models, they could interpret the ex-post negative long-term effects on GDP as a confirmation of their (mistaken) pessimistic views on potential output, rather than as the effects of their policies. The outcome is that policy makers might not learn from their mistakes and repeat them in future recessions. Fatas (2019) presents evidence that this behavior characterizes well fiscal policy in the 2010-14 period among European countries.

Avoiding these mistakes and correcting previous errors is not simply a question of choosing a different filter to estimate potential output. Policy makers need to design stabilization policy using economic models that allow for the presence of hysteresis. These models will have to incorporate the potential endogenous reaction of the supply side to any demand shock.

VI. Conclusions

In the last 25 years we have seen the development of an alternative model of business cycle that emphasizes the effects that business cycles can have on the drivers of long-term economic growth. In these models GDP is history dependent and all shocks can have permanent effects on output, what we refer to as hysteresis. This represents a change from the traditional cycle-trend decomposition that defined cycles as deviations from a trend that was independent of any of the traditional demand shocks that could be responsible for economic fluctuations.

Our review of the theoretical literature has highlighted that in the presence of endogenous growth, hysteresis is a natural outcome of many business cycle models. And the empirical literature has by now produced a strong set of empirical results that emphasizes the persistent nature of fluctuations and that identifies how much of this persistence can be associated with shocks that are related to demand, which in the traditional framework had been assumed to be temporary.

In the traditional framework, policy makers had to assess how much of the observed change in GDP was cyclical and how much was structural. Stabilization policy would only react to the cyclical component. Errors in reacting to cyclical events could be costly but only in the form of additional GDP volatility. In the presence of hysteresis, the costs of cyclical shocks or the lack of action of policy makers are much larger because of the permanent scars they can leave on GDP through their interactions with the endogenous forces that drive long-term growth or the dynamics of labor markets. Aggressive and fast action during recessions becomes optimal policy. And during expansions, the cost of acting too early on fears of inflationary pressure can also be very costly as it can either reduce the potential growth of the economy or hinder positive developments in the labor market. In this new framework, policy makers should understand the likely large supply costs of not being as close as possible to potential output by running a "high-pressure" economy.

VII. References

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