

Hysteresis and Business Cycles

Valerie Cerra, IMF

Antonio Fatás, INSEAD

Sweta C. Saxena, IMF and UNESCAP

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 motivate this paradigm shift. The renewed interest in hysteresis has been sparked by the persistence of the Global Financial Crisis, as GDP in advanced economies remains far below the pre-crisis trends. 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.

JEL Classification Numbers: E32, E60, O47

Keywords: business cycles; growth; hysteresis; economic model; macroeconomic policy; persistence; stabilization policy; macroeconomy; booms; crises; recovery

Authors' E-Mail Addresses: vcerra@imf.org; antonio.fatas@insead.edu; sweta.saxena@un.org

The views expressed in this Paper are those of the author(s) and do not necessarily represent the views of the IMF, its Executive Board, or IMF management or carry the endorsement of the United Nations.

Contents

Abstract.....	1
I. Introduction.....	3
II. Cycle and Trend.....	4
A. The cycle in the business cycle.....	4
B. Modeling the trend and the cycle.....	5
C. The cycle and trend when growth is endogenous.....	7
III. Empirical Evidence.....	9
A. Persistence a key feature of business cycles.....	9
B. Early evidence on persistence and unit roots.....	9
C. Persistent or permanent?.....	10
D. Cross-country evidence on persistence of fluctuations.....	11
E. Persistence after financial crises and deep recessions.....	12
F. Persistence, sources of shocks and mechanisms.....	14
G. Scars in the labor market.....	14
H. Scars in capital accumulation, R&D and innovation.....	16
I. The role of economic policy.....	18
IV. Theory.....	20
A. Traditional theory of business cycles without hysteresis.....	20
B. Endogenous growth models and hysteresis.....	21
C. Expectations-driven multiple equilibria and non-linearities.....	28
V. Policy Implications.....	32
A. Stabilization policy and the costs of business cycles.....	32
B. Optimal stabilization policy in the presence of hysteresis.....	33
C. Measuring the output gap in the presence of hysteresis.....	36
VI. Conclusions.....	37
References.....	38

I. INTRODUCTION

More than 10 years have passed since the Global Financial Crisis started and there is still a perception that many advanced economies have not properly recovered from this event. The crisis has left scars on investors, firms, workers, and consumers' memories who suffered its negative consequences. These perceptions are 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), Fatás and Mihov (2013), among many others, have shown). This slow recovery means that GDP, or GDP per capita, today is clearly below its pre-crisis trend.

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 (shocks) are persistent, that their effects are still with us years after the shock takes place.

The persistent and possibly permanent effects of recessions imply that what we refer to as cyclical events are not simply movements along a trend. They, themselves, affect the trend. The possibility that exogenous technology shocks could drive both the trend and cycle was a cornerstone of the Real Business Cycle Theory. Its models and the empirical evidence that supported them led to the view that permanent technology shocks were a fundamental driver of fluctuations. But there is an alternative view related to the persistence of cyclical fluctuations, one that postulates that the dynamics of the trend react to the cycle and persistence can then be seen as the scars left by recessions. In this alternative view, the state of the economy and the level of GDP are history dependent, what it is known as hysteresis.¹

Hysteresis has implications for the way we think about the drivers of both business cycles and long-run growth, as well as 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. 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.

¹ One of the earlier explicit references to the word hysteresis in the macroeconomic literature was 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. The definition of hysteresis used was that of path dependence in steady states "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".

This paper reviews the literature on hysteresis. 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.

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.² Two decades before, Mitchell (1923) had described economic cycles as a succession of crises that followed periods of prosperity. He saw crisis 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*

² 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.

market and natural rates of interest, will not help because we cannot observe normal state 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.

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 impossible a long-term tradeoff between inflation and unemployment. 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).³ 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.⁴

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:

³ Kydland and Prescott (1990) build on the earlier criticism that Koopmans (1947) had made of the Burns and Mitchell (1946) methodology as “measurement without theory”.

⁴ There are alternative view of the cycles such as those proposed by Zarnowitz and summarized in Zarnowitz and Ozyildirim (2006).

“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 given 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. Fatás (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 in the academic literature 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 endogenous growth allowed these early intuitions to be later 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 emphasize 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 sections, we have described the importance for our understanding of economic fluctuations of the separation of trend and cycle. The original notion that trends were slow-moving and possibly deterministic while fluctuations from temporary, cyclical events was challenged first by the RBC literature and later by models with hysteresis effects. In these two strands of the literature a key feature was the role played by 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. 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.^{5,6}

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

⁵ 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.

⁶ 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.

growth component. Moreover, to impose the trend specification is to assume away long-run uncertainty in these variables and to remove much of their variation a priori.

These results also challenged theories in which output fluctuations are primarily caused by temporary shocks to aggregate demand. Traditional Keynesian models based on nominal rigidities such as that of Fischer (1977) or models based on misperceptions, such as that of Lucas (1973), imply that the deviations from trend caused by demand shocks are transitory in nature. 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 1.⁷

Cochrane (1991) showed 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.⁸ 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, he shows that GDP growth is positively autocorrelated at short lags, but there are many small negative autocorrelations at long lags.

In contrast, using fractionally integrated ARMA models that introduce persistence, Diebold and Rudebusch (1989) found evidence of long memory, which induces persistence, though this long memory need not be associated with a unit root.⁹ Likewise, introducing a new approach to hypothesis testing in time series regression with a unit root, Perron (1988)

⁷ See Darné (2009) for the literature on biases in unit root tests due to structural break.

⁸ 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.

⁹ 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.

confirmed the conclusions reached by Nelson and Plosser (1982). It appears, indeed, that the nonstationarity of most macroeconomic variables is best construed as stochastic rather than deterministic.

This debate on trend and difference stationarity was important in the context of several debates. For instance, unlike Nelson and Plosser (1982), 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). Similarly, Diebold and Senhadji (1996) pointed out that the distinction between trend stationarity might not be critical if one wants a broad gauge of the persistence in aggregate output dynamics, although the distinction becomes potentially important in other contexts, such as economic forecasting. Trend- and difference stationary models may imply very different dynamics and hence different point forecasts, as also argued by Stock and Watson (1988) and Campbell and Perron (1991).

Taking a more pragmatic approach to the debate, Christiano and Eichenbaum (1990), argued that the data simply do not discriminate between the trend stationary and the difference stationary views of U.S. real GDP. Given the nature of the difference between these two types of stochastic processes, any argument in favor of one or the other necessarily relies on strong identifying restrictions about which economic theory has nothing to say. This led them to say that “we don’t know” if there is a unit root and “we don’t care.” Diebold and Senhadji (1996) disagreed with this conclusion. Their view was that U.S. aggregate output was not likely to be difference-stationary: the dominant autoregressive root was likely close to, but less than, unity. They argued that “even for the famously recalcitrant aggregate output series, unit-root tests over long spans can be informative, and they may be important for point forecasting, among other things.” Hence, they find the “uncritical repetition of the ‘we don't know, and we don't care’ mantra is just as scientifically irresponsible as blind adoption of the view that ‘all macroeconomic series are difference-stationary,’ or the view that ‘all macroeconomic series are trend-stationary.’” Similarly, but more recently, Cushman (2016) argues that testing for unit roots matters. His view is that the hypothesis of a unit root in U.S. real GDP after World War II cannot be rejected, once the issues of individual and multiple-test size distortion are dealt with. Since interest in unit root models and forecasting has often centered on whether or not recoveries from recessions would be robust, involving rebounds, he finds that models with unit roots forecast better over the postwar period than trend stationary models. This is particularly true for forecasts of recoveries from seven postwar recessions.

D. Cross-country evidence on persistence of fluctuations

Most of the literature discussed above was tested on data from the United States and focused on the debate on whether or not there is a unit root. Many papers also produced results from other countries that 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 US (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 large 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.

Blanchard, Cerutti and Summers (2015) found that a high proportion of recessions (roughly two-thirds) have been followed by lower output (hysteresis) or even lower growth (super-hysteresis).¹⁰ They found a high incidence of hysteresis (at around 63 percent) even for recessions plausibly induced by intentional disinflations, indicating that even demand shocks could affect output permanently.

Haltmaier (2013) studied both advanced and emerging markets to explicitly show 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.¹¹

E. Persistence after financial crises and deep recessions

A strand of the literature focused on the analysis of persistence in large crises, in particular those that involved significant financial disruption. The advantage of this analysis is that identification of both the shocks and their dynamics can be sharper given the large magnitude of output loss associated with crisis events. In addition, results are not as dependent on long-horizon or asymptotic assumptions as with the earlier literature on the property of US GDP dynamics.

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

¹⁰ 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.

¹¹ 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.

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) likewise find the persistent loss in output from both financial and political crises. 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.¹²

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 (2012) 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.¹³

Reinhart and Rogoff (2014) examine 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.

¹² 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.

¹³ This is at odds with Claessens, Kose and Terrones (2012) who find that length and duration of recessions are not affected by credit.

F. Persistence, sources of shocks and mechanisms

The analysis of the source of shocks has been a recurrent theme in the empirical business cycle literature. Not only is it relevant for understanding the forces driving economic fluctuations but, in addition, the identification of sources of shocks is needed to inform the optimal policy response. Under the conventional framework, temporary demand-driven cyclical fluctuations required expansionary policies while supply-driven fluctuations required structural reforms.

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.¹⁴

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. Because of this, the focus on the empirical literature on hysteresis has been on identifying and measuring the mechanisms through which recessions persistently reduce output or even lower long-term GDP growth. Are the long-term scars coming from the labor market or via lower capital accumulation or TFP? We now delve into the evidence for each of these potential channels.

G. Scars in the labor market

The label hysteresis was possibly used for the first time 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

¹⁴ 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.

degree of economic slack and unemployment rates were the most obvious indicator of that slack, as formalized by the Phillips curve.¹⁵

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.¹⁶ 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 not quite permanent changes in unemployment.¹⁷ The years that followed their work provided support for this view of high 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 (2000), Bluedorn and Leigh (2019) or Bluedorn and Leigh (2018).

¹⁵ 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)).

¹⁶ Similar observations about the persistence of labor market outcomes had been made earlier by, among others, Clark and Summers (1982) or Ellwood (1982).

¹⁷ 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.”

Why is unemployment so persistent? Blanchard and Summers (1986) 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. Because of this interaction, early expansionary macroeconomic policies could have reduced European unemployment in those years.

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), Ruhm (1991), Von Wachter and Bender (2006), Davis and Von Wachter (2011), Kahn (2010) all present evidence of persistent effects of job losses or the timing of entry into the labor market on earnings or unemployment spells. Yagan (2018), Rinz (2019) also discuss similar evidence in the context of the great recession. Saez et al. (2019) present evidence of persistent effects of changes in tax policies that affect labor demand. While many of these papers discuss the negative effects of job losses, there is also evidence of positive effects of a tight labor market as in Hotchkiss and Moore (2018).

H. 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 effect would become permanent.

There was a variety of endogenous growth models, each of them relying on a different set of variables in order to understand 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 Fatás (2000b)), or maybe learning by doing, human capital, R&D or knowledge accumulation (Stadler (1986) and Stadler (1990) Stiglitz (1993) or Fatás (2000a)). In all these papers the key factor is the procyclicality of the long-term source of growth.

Fatás (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 Fatás (2000a), Barlevy (2007) or Anzoategui et al. (2019).

In a similar vein, Haltmaier (2013) and Reifschneider et al. (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 et al. (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 (2019) 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.¹⁸

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 et al. (2012) find that the developments in housing markets are also important in shaping the length and magnitude of cyclical outcomes.

¹⁸ Although Sedgley, Burger and Tan (2019) results suggest that the cyclicity of R&D expenditures is fairly symmetric and cannot fully be explained by financial constraints or conditions.

More recently, Bianchi, Comin, 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.

I. The role of economic policy

The evidence we have presented so far supports the view that fluctuations are persistent. In addition, we have provided empirical insights on the mechanisms through which persistence happens. But what are the sources of shocks that are causing this persistence? And how do we distinguish between the hypothesis that the shocks themselves are persistent (as in RBC models) from the existence of hysteresis coming from a variety of sources?

If hysteresis is relevant, we should see any shock, even those that are temporary in nature, producing persistent or permanent effects. To provide supporting evidence on this hypothesis there are two avenues. One is to study specific episodes of large fluctuations (such as the Great Recession or financial and banking crisis). We have already reviewed the empirical evidence on these events and showed that, indeed, they have generated very persistent changes in output. But deep recessions associated with financial crises do not span the full range of output fluctuations or shocks.

The second approach is to identify specific shocks, in particular demand shocks that are supposed to be temporary in nature. The natural candidates are policy shocks, in particular monetary and fiscal policy. Using a non-parametric approach, Blanchard et al. (2015) identified 122 recessions for 23 advanced economies and measured their persistence as deviations from pre-crisis trends. Between 70 and 80 percent of these recessions display an “unambiguous” persistent gap relative to those trends. Each of these recessions was then characterized by whether or not “demand” shocks 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.

Fatás 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. Today, a strong expansion could push employment and potential output back toward their pre-crisis paths. Failing that, the expansion might at least reverse declines in the growth rate of potential, so the damage from the Great Recession does not continue to grow.

Some researchers are less optimistic about the reversibility of hysteresis effects. For example, Reifschneider et al. (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.¹⁹

IV. THEORY

As described in Section II, the view of the economic cycle as distinct from the long-term trend was underpinned by two main types of theoretical models: real business cycle models set in a neoclassical growth framework of Solow (1956) and Swan (1956), and New Keynesian models with sticky prices. Neither of these theoretical frameworks incorporated 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 the shift in theoretical paradigm 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 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 technology that follows an exogenous stochastic process summarized by

$$A_{t+1} = c + \rho A_t + e_{t+1}.$$

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 (forthcoming)). The only source of growth in the steady state derives from exogenous technological advancement.

¹⁹Jaimovich and Siu (2012) show evidence for jobless recoveries driven by job polarization, i.e., shrinking concentration of employment in occupations in the middle of the skill distribution.

When the parameter ρ is set well below one, these models cannot explain the persistent behavior of output during and after economic crises because technology shocks are temporary with short-term dynamics, and output returns to its pre-crisis trend. RBC models that set the parameter ρ at 1 allow for permanent shifts in trend GDP via permanent shocks to the exogenous productivity process.²⁰

Conceptually, the idea of permanent technology shocks remains controversial. While it is natural for some, for others this logic merely assumes rather than explains the behavior of output. 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. And, 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.

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. This allows scope for demand policies (e.g. monetary and fiscal policy) to impact output as prices and/or wages do not fully adjust on impact. 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.

These New Keynesian models abstract from the determination of the long-run level of output, so they do not, in isolation of other theoretical components, produce hysteresis. It is true that demand, either shocks or policy responses, affect output, but only temporarily. Fluctuations are seen as short-run deviations of output from its long-term exogenous trend.

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. These models incorporate endogenous productivity mechanisms into real and/or monetary models in line with the empirical evidence that productivity creation and adoption are strongly correlated with economic

²⁰ An alternative to generate persistence, at least for some large shocks is to allow for an arbitrary large structural break.

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

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

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):

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

This model displays increasing returns if $\alpha + \eta > 1$. In the special case that $\alpha + \eta = 1$ 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) incorporate endogenous growth to an otherwise standard real business cycle model. They follow Rebelo (1991), 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.

$$Y_t = f(K_t^\alpha H_t^{1-\alpha}, \dots)$$

$$H_{t+1} = g(K_t^\nu H_t^{1-\nu}, \dots)$$

Adding endogenous growth has profound implications for the cycle-trend decomposition in these models. 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 trends.

Stadler (1990) goes beyond the standard RBC model in order to compare the properties of real and monetary business cycle models with and without endogenous technological change. He presents 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. Aggregate demand is given by the quantity theory of money, $Y = M/P$, and the money supply evolves as a random walk with drift. 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 that depends on aggregate employment and labor productivity. Using our notation

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

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

In the general model, output depends on the level of technical knowledge, temporary and permanent shocks to the exogenous technology, and the unanticipated component of money supply. This general model nests several sub-models: (1) In a pure RBC model with exogenous technology (no learning) and constant money (and constant H): output and the price level are impacted only by the exogenous shocks. Output can be non-stationary only if there are permanent shocks to exogenous technology, as in the typical RBC model. (2) In a hybrid monetary and real model without endogenous technology: the impact on output of any temporary monetary or real shock dies out. Money is neutral in the long-run and only permanent technology shocks can impact output permanently.²¹ (3) In a pure monetary model with endogenous learning but no exogenous technology shocks: an unexpected money supply shock raises output, which then leads to learning by doing and permanently higher output. In fact, the endogenous learning acts as a propagation mechanism that amplifies the impact of the money shock over time. Monetary policy now displays hysteresis. (4) In a model with learning but also exogenous shocks: a temporary shock to exogenous technology can also have a permanent effect on output because the temporary rise in output leads to higher growth in knowledge, as in King, Plosser, and Rebelo (1988). In other words, the learning-by-doing mechanism generates permanent impacts of both temporary demand and temporary supply shocks.

A wave of recent theoretical work builds on the endogenous growth framework to incorporate roles for demand shocks that can generate hysteresis. We describe the features and findings of key contributions to this recent literature, which spans analysis of endogenous R&D, macroeconomic policy, and financial frictions. Although the papers include rich modeling of 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 and productivity accumulation that depends on cyclical or demand-side factors.

Comin and Gertler (2006) 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

²¹ However, if technology depreciates, then even permanent exogenous technology shocks would dissipate and lead to stationary output processes.

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)). However, the paper finds that the speed of technological diffusion is strongly correlated with the medium-term business cycle.

Motivated by these empirical findings, Comin and Gertler (2006) and Comin (2009) 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} .

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

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

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 influence 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.

Anzoategui et al. (2019) find that a significant fraction of the post-Great Recession fall in productivity was an endogenous response to the liquidity demand shock. Using 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), they find that liquidity demand shocks are the most important factor driving cyclical behavior, including during the Great Recession. 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.

Turning to macroeconomic policies, Vinci and Licandro (2019) include monetary policy in an AK endogenous growth model and show that the model reproduces economic data from the Great Recession well. The model features price markups, risk 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 shock to capital can move the economy to a lower trend. Monetary policy may be able to counteract the shock if the weight on output gap in the policy rule is high enough. However, a very deep recession could lead to a significant downward revision in potential output, prompting less monetary policy stimulus under the policy rule and therefore a weak recovery.

Jordà, Singh, and Taylor (2020) find 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 show that endogenous TFP growth can deliver this result in a theoretical model. 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, but 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 the section above on the empirical literature, financial crises have been associated with many of the most severe and prolonged recessions. 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.

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 US. 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 (8½ 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 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 a LBD model in which the effectiveness of labor increases as a by-product of employment, and can spur ongoing growth if $\varphi=1$. 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

A second category of models that can generate hysteresis are those that involve multiple equilibria due to expectations. The models can take the form of self-fulfilling prophecies that

lead the economy to be stuck in a low output or low growth state. Some recent papers include the endogenous productivity mechanisms of the previous section while also linking current economic decisions with expectations of future economic outcomes.

The third category of models in which the economy can be stuck at a low level of output or aggregate demand are those that feature 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. In macro, 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. Many of the papers that feature a zero lower bound restriction also include self-fulfilling expectations as an element of the story, so this section jointly discusses these two themes.

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 produce 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 induce 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) features expectations-driven investment (returns to innovation depend on future aggregate demand) that can generate multiple equilibria. The model consists of 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. When the model is extended to allow for a temporary liquidity trap, the economy can go back to full employment after emerging from the pessimistic state, but does not make up for low growth during the period stuck in the trap. Thus, the trap leads to a permanent loss in output. The model demonstrates that a liquidity trap, like financial market distress, can generate a temporary disruption to the growth process. This temporary disruption can lead to a permanent loss of output. In some of the other models, endogenous growth depends on the current state of the economy. In this model, it depends on expectations of future state of the economy since that is what drives the incentive to invest in innovation to gain future monopoly power.

There are models with multiple equilibria where stagnation traps can be associated with higher unemployment. If the economy moves from one equilibrium to the other it can display hysteresis as well. For example, Weitzman (1982) and Farmer (2012) both develop a model with increasing returns to scale and multiple equilibria. As the economy gets stuck in a high unemployment equilibrium, the economy exhibits hysteresis. Farmer (2012) also generates multiple equilibria in growth rates in the context of an endogenous model. So high unemployment equilibria correspond to low-growth states. The connection between unemployment and growth takes place through a standard endogenous growth model of innovation.

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. In their model, unemployment can return to its natural rate after a recession even while output remains below trend. They explore the use of monetary policy to offset the permanent impact of temporary demand shocks on the level of GDP. They find that if monetary policy is affected by the zero-lower bound, then both strict inflation-targeting and a Taylor rule could lead to output hysteresis. While, in principle, the central bank could offset output hysteresis by committing to running a *high-pressure economy* in the future, this would not be time consistent. Thus, there is a “hysteresis bias” in monetary policy. In other words, the nonlinearity of the zero-lower bound creates a constraint on the use of stabilization policy.

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 in unemployment. 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) and Schmitt-Grohé and Uribe (2017) relate to a body of literature that debate 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) revives 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 et al. (2019) differs 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. In models of endogenous growth with capital accumulation and productivity advancement, 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 et al. (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 (2004b)).²²

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. Typically these models suggest that replicating the flexible price equilibrium is the welfare-maximizing objective for monetary policy. As a result, minimization of output gaps (defined as deviations from such a flexible price equilibrium) characterize well optimal 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.²³ 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. This means that the GDP trend is history dependent and the longer recessions are, the larger the permanent scars will be. Shocks to economic policies also 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.

In the context of optimal policy this means that taking early and aggressive policy action can minimize the effects of other shocks and therefore help offset the permanent damage they cause. This applies to both monetary and fiscal policy (Blanchard et al. (2015), Fatás and Summers (2018)). The ability to affect the supply side via early intervention minimizes any fear of generating inflation.

²² For a good summary of this literature see Barlevy (2004a).

²³ 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.

While optimal policy is still trying to replicate the flexible price equilibrium, this cannot be simply implemented by attempting to close a static measure of the output gap. Potential output is itself reacting to the policy actions and if monetary or fiscal policy are late responding to the shocks, not only we will incur the costs of larger temporary deviations from potential but we will also suffer the consequences of a permanently lower potential.

To illustrate this intuition but also some of the challenges of designing optimal policy in models of hysteresis, we can think of a typical model of hysteresis that postulates that “effective productivity” (Z_t) follows a law of motion (in logs) of the type

$$\log Z_{t+1} = g_t + \log Z_t + \eta f(y_t)$$

where g_t is the long-term growth rate of effective productivity, y_t is a measure of aggregate demand or a cyclical component of GDP, η is the hysteresis parameter and we assume that $f'(y_t) > 0$. This reduced form summarizes the dynamics of most of the models discussed in Section IV. In some of the models, Z_t represents technological innovations that are developed endogenously in a R&D sector, such as new varieties of intermediate goods. In AK models, Z_t is the aggregate stock of physical capital; in models of learning by doing, it is the stock of human capital. For endogenous growth, this production function for effective productivity accumulation needs to be linear homogeneous in Z_t . However, in line with the empirical literature debating the relevance of a strict unit root, if instead there are diminishing returns in the evolution of effective productivity, $\psi \log Z_t$, where ψ is less than but close to unity, then shocks will have highly persistence, albeit not permanent, impacts on output. The policy implications will be fairly similar.

The cyclical component, y_t , can take different forms reflecting the state of economic activity or one of its components. Earlier models of hysteresis typically relied on endogenous growth models that displayed scale effects (Jones (1999)). As a result, the cyclical state (y_t) was associated to a “scale” variable such as employment. Shocks had permanent effects via learning by doing (Martin and Rogers (1997) or innovation, whose incentives also depended on economic activity (Fatás (2000a)). Optimal policy in these models was about maximizing employment but under the assumption that the labor supply was fixed this could also be interpreted as minimizing unemployment (or the output gap). In the presence of growing population and labor force, the interpretation of the model mechanism was more difficult given that a larger scale (higher employment via population growth) generated a higher level of steady-state growth.

In more recent models (Garga and Singh (2016), Moran and Queralto (2018) or Jordà, Singh, and Taylor (2020)), y_t is the gap between output and its flexible price level equilibrium. Optimal policy then becomes the same as in models without endogenous growth or

hysteresis: to minimize deviations from the flexible price equilibrium.²⁴ But there is a difference, the costs of inaction are now much larger because of the supply effects of low demand. In our notation, the cyclical state, y_t , is a function of policy, \mathbb{p}_t , and other non-policy factors, \mathbb{x}_t .

$$y_t = y_t(\mathbb{p}_t, \mathbb{x}_t)$$

Policy interventions feed into the supply potential of the economy indirectly through their impact on aggregate demand.

$$\log Z_{t+1} = g_t + \log Z_t + \eta f(y_t(\mathbb{p}_t, \mathbb{x}_t))$$

Stabilization policy should try to offset the damaging impact of an adverse shock as fast as possible during a recession. And the larger the hysteresis parameter, the larger are the costs of inaction during recessions. For the same reason, the costs of hitting the ZLB is now much larger than previously assumed because the inability to reproduce the efficient equilibrium now has permanent consequences on the supply side (Moran and Queralto (2018) and Garga and Singh (2016)). Garga and Singh (2018) provide quantitative estimates of the benefits of monetary policy in the presence of hysteresis.

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 et al. (2015), Fatás and Summers (2018), Gechert et al. (2019), Bianchi, Comin, et al. (2019), Jordà et al. (2019), Moran and Queralto (2018), International Monetary Fund (2009) or 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

²⁴ Benigno and Fornaro (2018) reach similar conclusions in a model where 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.

(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 current 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, getting potential output right is more challenging. We discuss this issue next.

C. Measuring the output gap in the presence of hysteresis

In order for policy to ensure that we maintain a high-pressure economy, we need to have a measure of slack. Traditionally this has been done through the use of the output gap, a measure that makes use of estimates of potential output or through estimates of some version of the natural rate of unemployment. These estimates have traditionally relied on standard macroeconomic models that separate the cyclical dynamics from long-term trends. In this traditional framework, policy makers are supposed to react only to the temporary cyclical component. Errors in how the cyclical and structural components are estimated can generate the wrong stabilization policy. If the trend is exogenous, these errors will be destabilizing and add volatility (or not reduce enough the volatility caused by shocks). But in the presence of hysteresis these errors propagate to the supply side and can generate permanent scars on GDP.

Because of the reliance on traditional business cycle models that ignore hysteresis and the use of filters to separate the cyclical and structural component of GDP changes, potential output estimates are procyclical. 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 (Fatás (2019), Dovern and Zuber (2019), Claeys, Darvas and Leandro (2016), Coibion, Gorodnichenko and Ulate (2018), Martin, Munyan, and Wilson (2015)).

If policy makers believe that the measured “structural” component of the observed change in GDP reflects exogenous productivity as in the traditional RBC model (as if the hysteresis parameter $\eta=0$ in our framework above), they will be hesitant to use their stabilization tools. They will assume these can only impact the “cyclical” component of GDP, which is independent from the economy’s supply potential. 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 and, via hysteresis effects, will lead to large permanent losses in GDP. In addition, if policy makers ignore the possibility of hysteresis, they could interpret the ex-post negative long-term effects on GDP as a confirmation of their (mistaken) pessimistic views on potential, 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. Fatás (2019)

presents evidence that this behavior characterizes well fiscal policy in the 2010-14 period among European countries.

Realize that to avoid these mistakes is not simply a question of choosing a different filter to estimate potential output. In order to eradicate the possibility of these policy errors, 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.

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.

References

- Aghion, Philippe, Philippe Askenazy, Nicolas Berman, Gilbert Clette, and Laurent Eymard, 2012, “Credit Constraints and the Cyclicalities of R&D Investment: Evidence from France.” *Journal of the European Economic Association* 10(5):1001–1024.
- Aghion, Philippe, and Peter Howitt, 1992, “A Model of Growth Through Creative Destruction.” *Econometrica* 60(2):323–351.
- Aghion, Philippe, and Gilles Saint-Paul, 1991, “On the Virtue of Bad times: An Analysis of the Interaction between Economic Fluctuations and Productivity Growth.” CEPR Discussion Papers 578. Centre for Economic Policy Research, London.
- Anzoategui, Diego, Diego Comin, Mark Gertler, and Joseba Martinez, 2019, “Endogenous Technology Adoption and R&D as Sources of Business Cycle Persistence.” *American Economic Journal: Macroeconomics* 11(3):67–110.
- Arrow, Kenneth J., 1962, “The Economic Implications of Learning by Doing.” *The Review of Economic Studies* 29(3):155–173.
- Ball, Laurence M., 2009, “Hysteresis in Unemployment: Old and New Evidence.” NBER Working Paper No. 14818. National Bureau of Economic Research, Cambridge, MA. Available at: <http://www.nber.org/papers/w14818>.
- Ball, Laurence M., 2014, “Long-Term Damage from the Great Recession in OECD Countries.” NBER Working Paper No. 20185. National Bureau of Economic Research, Cambridge, MA. Available at: <http://www.nber.org/papers/w20185>.
- Ball, Laurence, N. Gregory Mankiw, and William D. Nordhaus, 1999, “Aggregate Demand and Long-Run Unemployment.” *Brookings Papers on Economic Activity* 1999(2):189–251.
- Barlevy, Gadi, 2007, “On the Cyclicalities of Research and Development.” *American Economic Review* 97(4):1131–1164.
- Barlevy, Gadi, 2004a, “The Cost of Business Cycles and the Benefits of Stabilization: A Survey.” *National Bureau of Economic Research*, No. 10926. National Bureau of Economic Research, Cambridge, MA. Available at: <http://www.nber.org/papers/w10926>
- Barlevy, Gadi, 2004b, “The Cost of Business Cycles under Endogenous Growth.” *American Economic Review* 94(4):964–990.
- Bean, Charles R., 1994, “European Unemployment: A Survey.” *Journal of Economic Literature* 32(2):573–619.
- Beaudry, Paul, Dana Galizia, and Franck Portier, 2017, “Reconciling Hayek’s and Keynes’ Views of Recessions.” *The Review of Economic Studies* 85(1):119–156.
- Benhabib, Jess, Stephanie Schmitt-Grohé, and Martin Uribe, 2001, “Monetary Policy and Multiple Equilibria.” *American Economic Review* 91(1):167–186.

Benigno, Gianluca, and Luca Fornaro, 2018, “Stagnation Traps.” *The Review of Economic Studies* 85(3):1425–1470.

Bernanke, Ben S., Mark Gertler, Mark Watson, Christopher A. Sims, and Benjamin M. Friedman, 1997, “Systematic Monetary Policy and the Effects of Oil Price Shocks.” *Brookings Papers on Economic Activity* 1997(1):91–157.

Beveridge, Stephen, and Charles R. Nelson, 1981, “A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the ‘Business Cycle.’” *Journal of Monetary Economics* 7(2):151–174.

Bianchi, Francesco, Diego Comin, Howard Kung, Thilo Kind, and Alexander Matusche, 2019, “Slow Recoveries through Fiscal Austerity: New Insights in the Effects of Fiscal Austerity.” ZEW policy brief.

Bianchi, Francesco, Howard Kung, and Gonzalo Morales, 2019, “Growth, Slowdowns, and Recoveries.” *Journal of Monetary Economics* 101:47–63.

Blanchard, Olivier, Eugenio Cerutti, and Lawrence Summers, 2015, “Inflation and Activity - Two Explorations and their Monetary Policy Implications.” NBER Working Paper No. 21726. National Bureau of Economic Research, Cambridge, MA. Available at: <http://www.nber.org/papers/w21726>.

Blanchard, Olivier, and Jordi Galí, 2007, “Real Wage Rigidities and the New Keynesian Model.” *Journal of Money, Credit and Banking* 39(s1):35–65.

Blanchard, Olivier, and Daniel Leigh, 2013, “Growth Forecast Errors and Fiscal Multipliers.” *American Economic Review* 103(3):117–20.

Blanchard, Olivier, and Danny Quah, 1989, “The Dynamic Effects of Aggregate Demand and Supply Disturbances.” *American Economic Review* 79(4):655–673.

Blanchard, Olivier, and Lawrence Summers, 1986, “Hysteresis and the European Unemployment Problem.” In *NBER Macroeconomics Annual 1986, Volume 1*. MIT Press, pp. 15–90. Available at: <http://www.nber.org/chapters/c4245.pdf>.

Bluedorn, John, and Daniel Leigh, 2019, “Hysteresis in Labor Markets? Evidence from Professional Long-Term Forecasts.” IMF Working Paper 19/114. International Monetary Fund, Washington, DC.

Bluedorn, John, and Daniel Leigh, 2018, "Is the Cycle the Trend? Evidence from the Views of International Forecasters." IMF Working Paper 18/163. International Monetary Fund, Washington, DC.

Burns, Arthur F., and Wesley C. Mitchell, 1946, *Measuring Business Cycles*. National Bureau of Economic Research. Available at: <http://ideas.repec.org/b/nbr/nberbk/burn46-1.html>.

Caballero, Ricardo, and Mohamad L. Hammour, 1994, “The Cleansing Effect of Recessions.” *American Economic Review* 84(5):1350–68.

Calvo, Guillermo A., 1983, "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12(3):383–398.

Campbell, John Y., and N. Gregory Mankiw, 1987, "Are Output Fluctuations Transitory?" *The Quarterly Journal of Economics* 102(4):857–880.

Campbell, John Y., and Pierre Perron, 1991, "Pitfalls and Opportunities: What Macroeconomists Should Know about Unit Roots." *NBER Macroeconomics Annual* 6:141–201.

Cerra, Valerie, Mai Hakamada, and Ruy Lama, forthcoming, "Financial Frictions, Investment Dynamics, and the Lost Recovery."

Cerra, Valerie, and Sweta C. Saxena, 2000, "Alternative Methods of Estimating Potential Output and the Output Gap: An Application to Sweden." IMF Working Paper 00/59. International Monetary Fund, Washington, DC.

Cerra, Valerie, and Sweta C. Saxena, 2005a, "Growth Dynamics: The Myth of Economic Recovery." IMF Working Paper 05/147. International Monetary Fund, Washington, DC.

Cerra, Valerie, and Sweta C. Saxena, 2005b, "Did Output Recover from the Asian Crisis." *IMF Staff Papers*, 52(1): 1-23.

Cerra, Valerie, and Sweta C. Saxena, 2005c. "Eurosclerosis or Financial Collapse: Why Did Swedish Incomes Fall Behind?" IMF Working Paper 05/29. International Monetary Fund, Washington, DC.

Cerra, Valerie, and Sweta C. Saxena, 2008, "Growth Dynamics: the Myth of Economic Recovery." *The American Economic Review* 98(1): 439–457.

Cerra, Valerie, Sweta C. Saxena, and Ugo Panizza, 2013, "International Evidence on Recovery from Recessions." *Contemporary Economic Policy*, 31(2): 424-439.

Cerra, Valerie, and Sweta C. Saxena, 2017, "Booms, Crises, and Recoveries: A New Paradigm of the Business Cycle and its Policy Implications." IMF Working Paper 17/250. International Monetary Fund, Washington, DC.

Christiano, Lawrence J., Martin S. Eichenbaum, and Benjamin K. Johansson, 2018, "Does the New Keynesian Model Have a Uniqueness Problem?" NBER Working Paper No. 24612. Available at: <http://www.nber.org/papers/w24612>.

Christiano, Lawrence J., and Martin S. Eichenbaum, 1990, "Unit Roots in Real GNP: Do We Know, and Do we Care?" In *Carnegie-Rochester Conference Series on Public Policy*. Elsevier, pp. 7–61.

Claessens, Stijn, M. Ayhan Kose, and Marco E. Terrones, 2012, "How do business and financial cycles interact?" *Journal of International Economics* 87(1):178-90.

Claeys, Grégory, Zsolt M. Darvas, and Alvaro Leandro, 2016, "A Proposal to Revive the European Fiscal Framework." Bruegel Policy Contribution 2016(07).

Clark, Kim B., and Lawrence H. Summers, 1982, "Labour Force Participation: Timing and Persistence." *The Review of Economic Studies* 49(5):825–844.

Cochrane, John H., 1991, "A Critique of the Application of Unit Root Tests." *Journal of Economic Dynamics and Control* 15(2):275–284.

Cochrane, John H., 1988, "How Big is the Random Walk in GNP?" *Journal of Political Economy* 96(5):893–920.

Cochrane, John H., 1994, "Shocks." In *Carnegie-Rochester Conference series on Public Policy*. Elsevier, pp. 295–364.

Cochrane, John H., 2017, "The new-Keynesian liquidity trap." *Journal of Monetary Economics* 92:47–63.

Cogley, Timothy, 1990, "International Evidence on the Size of the Random Walk in Output." *Journal of Political Economy* 98(3):501–518.

Cohen, Darrel S., 2000, "A Quantitative Defense of Stabilization Policy." Finance and Economics Discussion Series 2000-34, Board of Governors of the Federal Reserve System (U.S.), revised 2000.

Coibion, Olivier, Yuriy Gorodnichenko, and Mauricio Ulate, 2018, "Real-Time Estimates of Potential GDP: Should the Fed Really be Biting the Brakes?" *Policy Futures* No. 23580, *Center on Budget and Policy Priorities*.

Comin, Diego, 2009, "On the Integration of Growth and Business Cycles." *Empirica* 36(2):165–176.

Comin, Diego, and Mark Gertler, 2006, "Medium-Term Business Cycles." *American Economic Review* 96(3):523–551.

Cushman, David O, 2016, "A Unit Root in Postwar US Real GDP Still Cannot Be Rejected, and Yes, it Matters." *Econ Journal Watch* 13(1):5–45.

Darné, Olivier, 2009, "The Uncertain Unit Root in Real GNP: A Re-Examination." *Journal of Macroeconomics* 31(1):153–166.

Davis, Steven J., and Till Von Wachter, 2011, "Recessions and the Costs of Job Loss/Comments and Discussion." *Brookings Papers on Economic Activity*: 2011, 1-72.

Di Tella, Rafael, and Robert MacCulloch, 2006, "Europe vs America: Institutional hysteresis in a Simple Normative Model." *Journal of Public Economics* 90(12):2161–2186.

Diebold, Francis X., and Glenn D. Rudebusch, 1989, "Long Memory and Persistence in Aggregate Output." *Journal of Monetary Economics* 24(2):189–209.

Diebold, Francis X., and Abdelhak S. Senhadji, 1996, "The Uncertain Unit Root in Real GNP: Comment." *The American Economic Review* 86(5):1291–1298.

- Dosi, Giovanni, Marcelo C. Pereira, Andrea Roventini, and Maria Enrica Virgillito, 2018, "Causes and Consequences of Hysteresis: Aggregate Demand, Productivity, and Employment." *Industrial and Corporate Change* 27(6):1015–1044.
- Dovern, Jonas, and Christopher Zuber, 2019, "Recessions and Potential Output: Disentangling Measurement Errors, Supply Shocks, and Hysteresis Effects." *The Scandinavian Journal of Economics*.
- Dupraz, Stéphane, Emi Nakamura, and Jón Steinsson, 2019, "A Plucking Model of Business Cycles." NBER Working Paper No. 26351. National Bureau of Economic Research, Cambridge, MA. Available at: <http://www.nber.org/papers/w26351>.
- Eggertsson, Gauti B., Neil R. Mehrotra, and Jacob A. Robbins, 2019, "A Model of Secular Stagnation: Theory and Quantitative Evaluation." *American Economic Journal: Macroeconomics* 11(1):1–48.
- Eggertsson, Gauti B., and Michael Woodford, 2004, "Policy Options in a Liquidity Trap." *American Economic Review* 94(2):76–79.
- Ellwood, David T., 1982, "Teenage Unemployment: Permanent Scars or Temporary Blemishes?" In *The youth labor market problem: Its nature, causes, and consequences*. University of Chicago Press, pp. 349–390.
- Engler, Philipp, and Juha Tervala, 2018, "Hysteresis and Fiscal Policy." *Journal of Economic Dynamics and Control* 93(C):39–53.
- Farmer, Roger E. A., 2012, "Confidence, Crashes and Animal Spirits." *The Economic Journal* 122(559):155–172.
- Farmer, Roger E.A., and Michael Woodford, 1997, "Self-fulfilling Prophecies and the Business Cycle." *Macroeconomic Dynamics* 1(4):740–769.
- Fatás, Antonio, 2000a, "Do Business Cycles Cast Long Shadows? Short-run Persistence and Economic Growth." *Journal of Economic Growth* 5(2):147–162.
- Fatás, Antonio, 2000b, "Endogenous Growth and Stochastic Trends." *Journal of Monetary Economics* 45(1):107–128.
- Fatás, Antonio and Mihov, Ilian, 2013, "Recoveries." CEPR Discussion Paper No. DP9551. Available at SSRN: <https://ssrn.com/abstract=2294810>
- Fatás, Antonio, 2019, "Fiscal Policy, Potential Output, and the Shifting Goalposts." *IMF Economic Review* 67(3):684–702.
- Fatás, Antonio, and Lawrence H. Summers, 2018, "The Permanent Effects of Fiscal Consolidations." *Journal of International Economics* 112(C):238–250.
- Fernald, John G., Robert E. Hall, James H. Stock, and Mark W. Watson, 2017, "The Disappointing Recovery of Output After 2009." *Brookings Papers on Economic Activity*:1–59.

Fischer, Stanley, 1977, "Long-term Contracts, Rational Expectations, and the Optimal Money Supply Rule." *Journal of Political Economy* 85(1):191–205.

Friedman, M., 1993, "The Plucking Model of Business Fluctuations Revisited." *Economic Inquiry* 31(2):171–177.

Friedman, Milton, 1964, "Monetary Studies of the National Bureau." *The National Bureau Enters Its 45th Year* 44:7–25.

Friedman, Milton, 1968, "The Role of Monetary Policy." *The American Economic Review* 58(1):1–17.

Gali, Jordi, and J. L. Hammour, 1992, "Long Run Effects of Business Cycles." Columbia - Graduate School of Business Papers 92-96.

Garga, Vaishali, and Sanjay Singh, 2018, "Output Hysteresis and Optimal Monetary Policy." *Society for Economic Dynamics* 2018:554 Available at: <https://www.ssrn.com/abstract=3244088>.

Garga, Vaishali, and Sanjay R. Singh, 2016, "Output Hysteresis and Optimal Monetary Policy." Mimeo. Brown University.

Gechert, Sebastian, Gustav Horn, and Christoph Paetz, 2019, "Long-term Effects of Fiscal Stimulus and Austerity in Europe." *Oxford Bulletin of Economics and Statistics* 81(3):647–666.

Grossman, Gene M, and Elhanan Helpman, 1991, "Quality Ladders and Product Cycles." *The Quarterly Journal of Economics* 106(2):557–586.

Guerron-Quintana, Pablo, and Ryo Jinnai, 2014, "Liquidity, Trends, and the Great Recession." FRB of Philadelphia Working Paper No. 14–24.

Gunn, Christopher M., and Alok Johri, 2011, "News and Knowledge Capital." *Review of Economic Dynamics* 14(1):92–101.

Hall, Robert E., 1991, "Recessions as Reorganizations." *NBER Macroeconomics Annual*:17–47.

Haltiwanger, John, Ron S. Jarmin, and Javier Miranda, 2013, "Who Creates Jobs? Small versus Large versus Young." *Review of Economics and Statistics* 95(2):347–361.

Haltmaier, Jane, 2013, "Do Recessions Affect Potential Output?" FRB International Finance Discussion Paper 1066. Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2251879.

Hicks, John, 1933, "Equilibrium and the Cycle." *Reprinted in Hicks (1980)*.

Hotchkiss, Julie L., and Robert Elijah Moore, 2018, "Some Like it Hot: Assessing Longer-term Labor Market Benefits from a High-pressure Economy." *Andrew Young School of Policy Studies Research Paper Series* (18–01).

International Monetary Fund, 2009, “What’s the Damage? Medium-Term Output Dynamics after Financial Crises.” *World Economic Outlook*, Chapter 4.

Jaimovich, Nir, and Henry E. Siu, 2012, “The Trend is the Cycle: Job Polarization and Jobless Recoveries.” NBER Working Paper No.18334. Available at: <http://www.nber.org/papers/w18334>.

Johnson, Paul, and Chris Papageorgiou, “What Remains of Cross-Country Convergence?” *Journal of Economic Literature* (forthcoming).

Jones, Charles I., 1999, “Growth: With or Without Scale Effects?” *American Economic Review* 89(2):139–144.

Jordà, Òscar, Moritz H.P. Schularick, and Alan M. Taylor, 2011, “When Credit Bites Back: Leverage, Business Cycles, and Crises.” NBER Working Paper No. 17621. Available at: <http://www.nber.org/papers/w17621>.

Jordà, Òscar and Singh, Sanjay R. and Taylor, Alan M., "The Long-Run Effects of Monetary Policy." (January 2020). NBER Working Paper No. 26666. Available at SSRN: <https://ssrn.com/abstract=3522315>.

Kahn, Lisa B., 2010, “The Long-term Labor Market Consequences of Graduating from College in a Bad Economy.” *Labour Economics* 17(2):303–316.

Keynes, John Maynard, 1936, “The General Theory of Employment, Interest and Money.” London: Macmillan.

King, Robert G., Charles I. Plosser, and Sergio T. Rebelo, 1988, “Production, Growth and Business Cycles: II. New Directions.” *Journal of Monetary Economics* 21(2–3):309–341.

King, Robert, Charles I. Plosser, James H. Stock, and Mark W. Watson, 1987, *Stochastic Trends and Economic Fluctuations*. National Bureau of Economic Research Cambridge, Mass., USA.

King, Robert, and Sergio Rebelo, 1988, “Business Cycles with Endogenous Growth.” University of Rochester Working Paper.

Kiyotaki, Nobuhiro, and John Moore, 2012, “Liquidity, Business Cycles, and Monetary Policy.” NBER Working Paper No.17934. National Bureau of Economic Research, Cambridge, MA. Available at: <http://www.nber.org/papers/w17934>.

Klein, Lawrence Robert, and Arthur Stanley Goldberger, 1955, *Econometric Model of the United States, 1929-1952*. North-Holland Publishing Company.

Koopmans, Tjalling C., 1947, “Measurement Without Theory.” *The Review of Economic Statistics*:161–172.

Krugman, Paul R., 1998, “It’s Baaack: Japan’s Slump and the Return of the Liquidity Trap.” *Brookings Papers on Economic Activity* (2):137.

Kydland, Finn E., and Edward C. Prescott, 1990, “Business Cycles: Real Facts and a Monetary Myth.” *Real Business Cycles: A Reader* 383.

- Kydland, Finn E., and Edward C. Prescott, 1982, "Time to Build and Aggregate Fluctuations." *Econometrica: Journal of the Econometric Society*:1345–1370.
- Lucas, Robert E., 1988, "On the Mechanics of Economic Development." *Journal of Monetary Economics* 22: 3–42.
- Lucas, Robert E., 1972, "Expectations and the Neutrality of Money." *Journal of Economic Theory* 4(2):103–124.
- Lucas, Robert E., 1987, *Models of Business Cycles*. Wiley Publications.
- Lucas, Robert E., 1973, "Some International Evidence on Output-Inflation Tradeoffs." *The American Economic Review* 63(3):326–334.
- Lucas, Robert E., 1977, "Understanding Business Cycles." *Carnegie-Rochester Series on Public Policy* 5:7–29.
- Martin, Philippe, and Carol Ann Rogers, 1997, "Stabilization Policy, Learning-by-doing, and Economic Growth." *Oxford Economic Papers* 49(2):152–166.
- Martin, Robert, Teyanna Munyan, and Beth Anne Wilson, 2015, "Potential Output and Recessions: Are We Fooling Ourselves?" FRB International Finance Discussion Paper No. 1145. Available at SSRN: <https://ssrn.com/abstract=2665116>.
- Mertens, Karel, and Morten O. Ravn, 2014, "Fiscal Policy in an Expectations-driven Liquidity Trap." *The Review of Economic Studies* 81(4):1637–1667.
- Mitchell, Wesley C., 1923, *Business Cycles and Unemployment*. Chapter in NBER book.
- Mitchell, Wesley C., 1927, *Business Cycles: The Problem and Its Setting*. NBER book.
- Moran, Patrick, and Albert Queralto, 2018, "Innovation, Productivity, and Monetary Policy." *Journal of Monetary Economics* 93:24–41.
- Murphy, Kevin M., and Robert Topel, 1997, "Unemployment and Nonemployment." *The American Economic Review* 87(2):295–300.
- Nelson, Charles R., and Charles R. Plosser, 1982, "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications." *Journal of Monetary Economics* 10(2):139–162.
- Nickell, Stephen, 1997, "Unemployment and Labor Market Rigidities: Europe versus North America." *Journal of Economic Perspectives* 11(3):55–74.
- Okun, Arthur M., 1973, "Upward Mobility in a High-pressure Economy." *Brookings Papers on Economic Activity* 1973(1):207–261.
- O'Shaughnessy, Terry, 2011, "Hysteresis in Unemployment." *Oxford Review of Economic Policy* 27(2):312–337.
- Ouyang, Min, 2011, "On the Cyclicalities of R&D." *Review of Economics and Statistics* 93(2):542–553.

- Perron, Pierre, 1988, "Trends and Random Walks in Macroeconomic Time Series: Further Evidence from a New Approach." *Journal of Economic Dynamics and Control* 12(2–3):297–332.
- Phelps, Edmund S., 1968, "Money-wage Dynamics and Labor-market Equilibrium." *Journal of Political Economy* 76(4, Part 2):678–711.
- Queralto, Albert, 2019, "A Model of Slow Recoveries from Financial Crises." *Journal of Monetary Economics*. Available at: <https://doi.org/10.1016/j.jmoneco.2019.03.008>.
- Rawdanowicz, Lukasz, Romain Bouis, Kei-Ichiro Inaba, and Ane Kathrine Christensen, 2014, "Secular Stagnation: Evidence and Implications for Economic Policy." OECD Economics Department Working Paper, No. 1169. Available at: http://www.oecd-ilibrary.org/economics/secular-stagnation-evidence-and-implications-for-economic-policy_5jxvvgg6q27vd-en.
- Rebelo, Sergio, 1991, "Long-run Policy Analysis and Long-run Growth." *Journal of Political Economy* 99(3):500–521.
- Reifschneider, Dave, William Wascher, and David Wilcox, 2015, "Aggregate Supply in the United States: Recent Developments and Implications for the Conduct of Monetary Policy." *IMF Economic Review* 63(1):71–109.
- Reinhart, Carmen M., and Kenneth S. Rogoff, 2014, "Recovery from Financial Crises: Evidence from 100 Episodes." *American Economic Review* 104(5):50–55.
- Rinz, Kevin, 2019, "Did Timing Matter? Life Cycle Differences in Effects of Exposure to the Great Recession." Washington Center for Equitable Growth Working Paper. Available at: <https://equitablegrowth.org/working-papers/did-timing-matter-life-cycle-differences-in-effects-of-exposure-to-the-great-recession/>.
- Romer, Paul M., 1990, "Endogenous Technological Change." *Journal of Political Economy* 98(5):S71-102.
- Romer, Paul M., 1986, "Increasing Returns and Long-run Growth." *The Journal of Political Economy*, 94(5):1002–1037.
- Rotemberg, Julio J., 2003, "Stochastic Technical Progress, Smooth Trends, and Nearly Distinct Business Cycles." *American Economic Review* 93(5):1543–1559.
- Ruhm, Christopher J., 1991, "Are Workers Permanently Scarred by Job Displacements?" *The American Economic Review* 81(1):319–324.
- Saez, Emmanuel, Benjamin Schoefer, and David Seim, 2019, "Hysteresis from Employer Subsidies." NBER Working Paper No.26391. National Bureau of Economic Research, Cambridge, MA. Available at: <http://www.nber.org/papers/w26391>.
- Schmitt-Grohé, Stephanie, and Martín Uribe, 2017, "Liquidity Traps and Jobless Recoveries." *American Economic Journal: Macroeconomics* 9(1):165–204.

Sedgley, Norman H., John D. Burger, and Kerry M. Tan, 2019, "The Symmetry and Cyclicalities of R&D Spending in Advanced Economies." *Empirical Economics* 57(5):1811–1828.

Shimer, Robert, 2012, "Wage Rigidities and Jobless Recoveries." *Journal of Monetary Economics* 59:S65–S77.

Solow, Robert M., 1956, "A Contribution to the Theory of Economic Growth." *The Quarterly Journal of Economics*, 70(1):65–94.

Stadler, George W., 1990, "Business Cycle Models with Endogenous Technology." *The American Economic Review*:763–778.

Stadler, George W., 1986, "Real versus Monetary Business Cycle Theory and the Statistical Characteristics of Output Fluctuations." *Economics Letters* 22(1):51–54.

Stiglitz, Joseph E., 1993, "Endogenous Growth and Cycles." NBER Working Paper No. 4286. National Bureau of Economic Research, Cambridge, MA. Available at: <http://www.nber.org/papers/w4286>.

Stock, James H., and Mark W. Watson, 1988, "Variable Trends in Economic Time Series." *Journal of Economic Perspectives* 2(3):147–174.

Summers, Lawrence H., 2015, "Demand Side Secular Stagnation." *The American Economic Review* 105(5):60–65.

Summers, Lawrence H., 2014, "U.S. Economic Prospects: Secular Stagnation, Hysteresis, and the Zero Lower Bound." *Business Economics* 49(2):65–73.

Swan, Trevor W., 1956, "Economic Growth and Capital Accumulation." *Economic Record* 32(2):334–361.

Taylor, John B., 2000, "Reassessing Discretionary Fiscal Policy." *Journal of Economic Perspectives* 14(3):21–36.

Tobin, James, 1980, "Stabilization Policy Ten Years After." *Brookings Papers on Economic Activity* 1(1980):19–71.

Topel, Robert, 1990, "Specific Capital and Unemployment: Measuring the Costs and Consequences of Job Loss." In *Carnegie-Rochester Conference Series on Public Policy*. Elsevier, 33(1990):181–214.

Uzawa, Hirofumi, 1965, "Optimum Technical Change in an Aggregative Model of Economic Growth." *International Economic Review* 6(1):18–31.

Vinci, Francesca, and Omar Licandro, 2020, "Switching-track after the Great Recession." CFCM, University of Nottingham Working Paper 20/02.

Von Wachter, Till, and Stefan Bender, 2006, "In the Right Place at the Wrong Time: The Role of Firms and Luck in Young Workers' Careers." *American Economic Review* 96(5):1679–1705.

Weitzman, Martin L., 1982, "Increasing Returns and the Foundations of Unemployment Theory." *The Economic Journal* 92(368):787–804.

Woodford, Michael, 2012, "Methods of Policy Accommodation at the Interest-rate Lower Bound." In *Proceedings-Economic Policy Symposium-Jackson Hole. Federal Reserve Bank of Kansas City*, pp 185–288.

Yagan, Danny, 2019, "Employment Hysteresis from the Great Recession." *Journal of Political Economy*, 127(5):2505–2558.

Yellen, Janet L., 2016, "Macroeconomic Research After the Crisis" : a speech at "\"The Elusive 'Great' Recovery: Causes and Implications for Future Business Cycle Dynamics\"" 60th annual economic conference sponsored," Speech 915, Board of Governors of the Federal Reserve System (U.S.).

Zarnowitz, Victor, and Ataman Ozyildirim, 2006, "Time Series Decomposition and Measurement of Business Cycles, Trends and Growth Cycles." *Journal of Monetary Economics* 53(7):1717–1739.