Hysteresis and the Welfare Costs of Business Cycles

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Abstract

Lucas (1987, 2003) finds that the welfare costs of business cycles are trivial, 0.008-0.05% of consumption in each period. I analyze the implications of hysteresis for the welfare costs of business cycles by extending the basic New Keynesian model with hysteresis. Hysteresis is defined as the negative effect of the negative, one-percentage point output gap on potential output. The net present value of the welfare cost of a recession in which the deviation of output from the trend is 3% is 0.6% of consumption without hysteresis. If the degree of hysteresis is 0.4, an empirical estimate for OECD countries, the welfare cost increases – by a factor of 121 – to 70%. The study of stabilization policy using New Keynesian models without hysteresis is pointless; the potential benefits of stabilization policy are notable only in the presence of hysteresis.

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1. Introduction

How large are the welfare costs of business cycles? Lucas (1987, 2003) analyzes the welfare effect of eliminating all consumption variability, considering a representative household, which is endowed with a stochastic consumption stream

$$C_t = Ae^{gt}e^{-(0.5)\delta^2}\varepsilon_t,$$

where A is the initial level of consumption, g is the growth rate of consumption, δ is the standard deviation of the natural log of consumption, and ε_t is a log-normally distributed random shock. The preferences are

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\gamma} C_t^{1-\gamma}\right],$$

where E_0 is the expectations operator, $0 < \beta < 1$ is the discount factor, and γ is the relative risk aversion parameter. A risk-averse household prefers a deterministic consumption path to a risky one with the same mean. Lucas measures the utility difference in consumption equivalent terms, denoted by λ, such that the household is indifferent between the deterministic consumption path and the risky path. The welfare gain from eliminating business cycles is simply

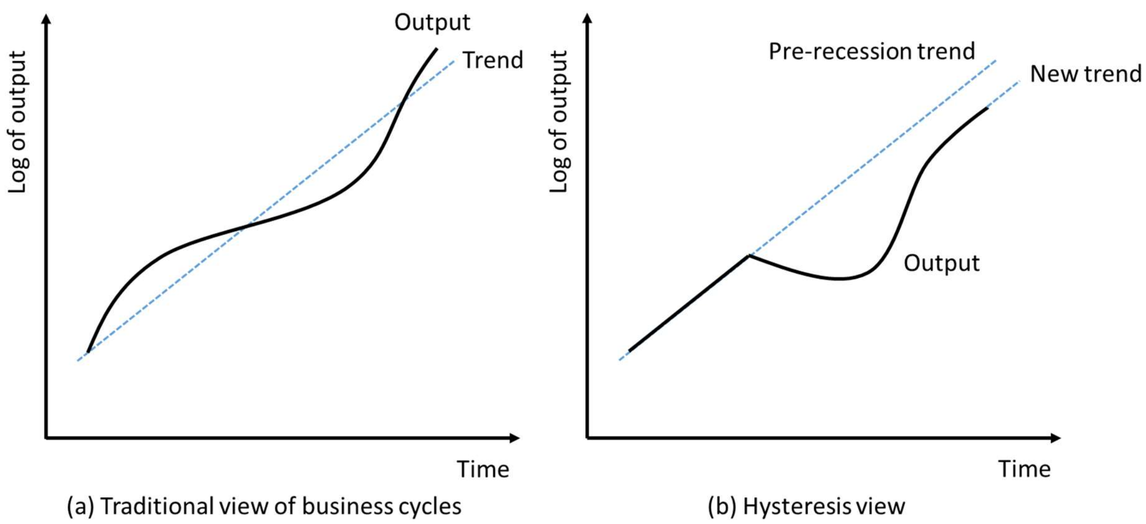
$$\lambda \cong \frac{1}{2}\gamma\delta^2.$$

The welfare loss depends on the size of the consumption risk and the risk aversion for it. Lucas (2003) estimates, using annual U.S. data, that the standard deviation of the log of real per capita consumption about a linear trend is 0.032. In the baseline calculation, he assumes log utility for consumption ($\gamma = 1$). Therefore, Lucas (2003) concludes that the welfare cost of business cycles is only 0.05% of consumption. In Lucas (1987), the welfare loss is 0.008%, because the standard deviation of consumption is set at 0.013. He (1987, 2003) concludes that the welfare costs of business cycles and the potential welfare gains from addition stabilization policy are extremely small and academic economists and policymakers should therefore focus on long-term growth rather than on stabilization policy.

In a survey, Imrohoroglu (2008) writes that many assumptions in the framework of Lucas (1987; 2003) have been challenged and the welfare costs of business cycles may be somewhat higher than Lucas estimated. Imrohoroglu (2008) concludes, however, that: "the weight of the evidence seems to suggest that they may not be too high for the US economy." More recently, Walentin and Westermark (2018a) stress that "[a]lthough most people hold the belief that business cycles are costly, the dominating macroeconomic theories of recent decades – both real business cycle theory and new Keynesian theory – imply that the welfare cost of output fluctuations are negligible.”

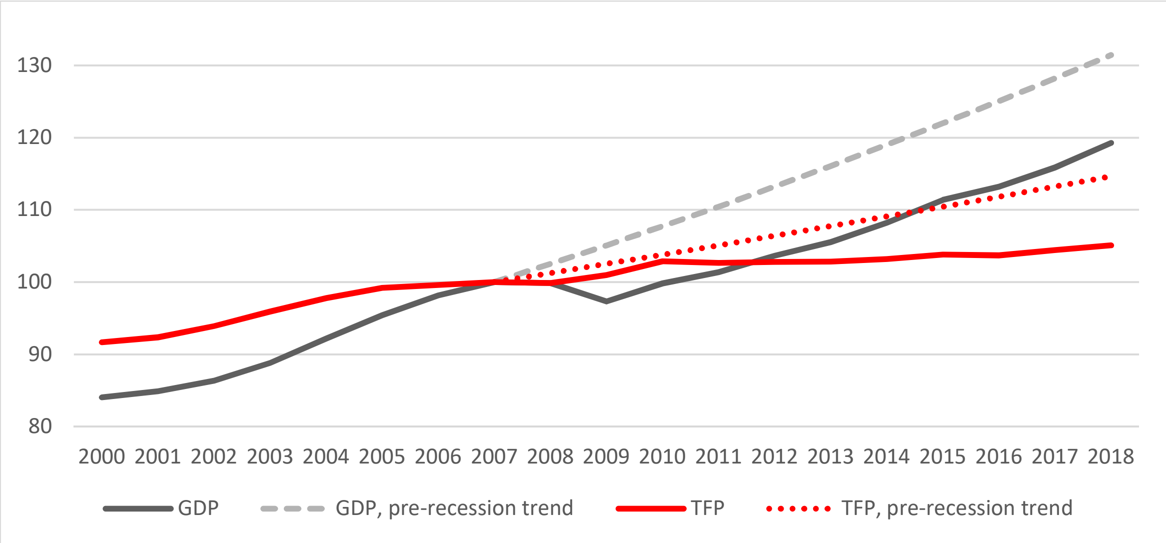
The literature relies on the traditional view of business cycles; Cerra and Saxena (2017) argue that the problem with the view, shown in Figure 1(a), is that data do not support it. They claim that it is based on the assumption that supply-side components bring about a steady upward trend in potential output and demand shocks cause temporary fluctuations around a trend. A recession is a temporary drop in output, which bounces back to its pre-recession trend during the recovery. New studies support the view that recessions have a permanent effect on the level of output relative to the pre-recession trend. Ball (2014) finds that the damage to potential output is almost as great as the temporary deviation of actual output from its pre-recession trend in most OECD countries. Rawdanowicz et al. (2014, 8) discover that one percentage point in the negative output gap reduced potential output by an average of 0.4% in OECD countries in the Great Recession. Blanchard et al. (2015) find that some two-thirds of recessions are followed by low output relative to the pre-recession trend even after the recovery phase of the business cycle. Martin et al. (2015) do not find support for the traditional view and emphasize that the hysteresis effect raises questions about how we should model potential output around recessions. The hysteresis view of the present paper, shown in Figure 1(b), is that the new trend is parallel to the pre-recession trend but below it.

Figure 1. Views of Business Cycles



The contribution of this paper is to analyze the implications of hysteresis for the welfare costs of business cycles. I extend the textbook version of the New Keynesian dynamic stochastic general equilibrium (DSGE) model of Gali (2015) with hysteresis. The empirical observations that recessions have permanent economic costs in terms of lost consumption should lead to the conclusion that the welfare cost of business cycles is measured in terms of the welfare value of permanently lost consumption. Barnichon et al. (2018, 4) argue that a financial crisis “can have large costs in terms of societal welfare by causing persistent losses in the level of GDP." Therefore, a first-order Taylor expansion of the utility function is a right way to estimate the welfare loss of recessions. The volatility of consumption would be a good way to measure the welfare costs of business cycles, if business cycles were just temporary fluctuations around a trend. The welfare cost is measured as the percentage of initial consumption that the household in the case without a recession is willing to pay in order to avoid the recession and be as well off in the recession case as in the case without the recession. My welfare measure is based on the net present value, since the welfare effects of business cycles do not stay constant over time in a New Keynesian DSGE model.

Figure 2. U.S. GDP and TFP (indexes 2007=100) and pre-recession trends, data source: OECD (2019)



Cerra and Saxena (2017) state that "[a] new paradigm of the business cycle needs to account for shifts in trend output." Figure 2 shows U.S. GDP and total factor productivity (TFP) in 2000–2018 and their pre-recession trends based on their growth rates on 2000–2007. It shows persistent drops in the levels of GDP and TFP. Output hysteresis can be induced by a permanent fall in employment, capital accumulation or TFP. Empirical studies suggest that a decline in TFP is the most important factor in hysteresis. Martin et al. (2015) find that total hours worked, labor force participation and employment rate return to their pre-recession level trends after normal recessions, while only deep recessions induce hysteresis in the labor market. They also find that investment falls during recessions and remains below the pre-recession trend. However, the effects are strong only during deep recessions. Adler et al. (2017) emphasize that a fall in TFP growth after the Great Recession has been widespread and persistent across countries and that this fall has been the main contributor to significant output losses relative to pre-recession trends. They discover that not only the Great Recession but also previous deep recessions have been followed by TFP hysteresis, a persistent drop in the level of TFP. Anzoategui et al. (2019) find that a significant fraction of the post-Great Recession TFP slowdown was an endogenous response to the fall in demand that caused the recession. I follow the work of Engler and Tervala (2018), where negative demand shocks can induce TFP hysteresis via learning-by-doing.

In this paper, I show that the welfare cost of a recession in which the deviation of output from the trend is 3% is only 0.6% of consumption in the absence of hysteresis. The size of the recession is based on Martin et al. (2015), who find that the average deviation of output from the pre-recession trend one year after the start of a recession is roughly 3%. A recession causes a very short-lived decline in consumption. Consequently, the welfare loss is negligible. My finding is consistent with Walentin and Westermark (2018a), who point out that in New Keynesian models the welfare costs of inflation variability are "a fraction of a percent of average utility."

The main finding of the paper is that hysteresis has drastic consequences for the welfare costs of business cycles. Rawdanowicz et al. (2014) find the hysteresis parameter of 0.1 for the U.S. In this paper, I show that this small degree of hysteresis increases the welfare cost of a recession – by a factor of 47 – to 27.3% of consumption in a New Keynesian model. This result may underestimate the welfare costs of recessions, because Rawdanowicz et al. (2014) find that the average degree of hysteresis in OECD countries is 0.4. In this paper, I show that this extent of hysteresis implies that the welfare cost of a recession increases to 70%. Hence, a realistic extent of output hysteresis raises the welfare loss by a factor of 121. The reason for the massive welfare loss is a permanent fall in consumption. Walentin and Westermark (2018b), the most directly related paper, find that *employment* hysteresis raises the welfare costs of business cycles by a factor of six in their basic case. My findings show that *TFP* hysteresis, which creates a realistic extent of *output* hysteresis, increases the welfare loss considerably more.

I conclude that the welfare costs of recessions – in the presence of hysteresis – are massive and stabilization policy should be a high priority for academic economists and policymakers. The New Keynesian framework has been used extensively to examine business cycles and stabilization policy. An important feature of this framework is that the economy's response to economic shocks is typically inefficient. This makes potentially welfare-improving stabilization policy possible. The argument, however, seems highly overrated, because the welfare costs of business cycles and, consequently, the potential benefits of stabilization policy are negligible in the basic framework. The study of stabilization policy using New Keynesian DSGE models without hysteresis is virtually pointless; the potential benefits of stabilization policy are notable only in the presence of hysteresis.

The rest of the paper is structured as follows: Section 2 introduces the model. Section 3 discusses the parameterization. Section 4 analyzes the implications of hysteresis for the welfare costs of recessions. Section 5 concludes the paper.

2. Model

Gali (2015, Chapter 3) offers an overview of the New Keynesian framework that has been used extensively to understand business cycles and economic policy. I extend it with hysteresis. The model's features and notation follow Gali (2015) as closely as possible. The size of the economy is normalized to one. There is a continuum of firms and households indexed by $i \in [0,1]$.

2.1 Demand Side: Households

The representative household seeks to maximize the utility function

$$U_t = E_0 \sum_{s=t}^{\infty} \beta^{s-t} \left[lnC_s - \frac{N_t^{1+\varphi}}{1+\varphi} \right], \quad (1)$$

where C_t is a consumption index, N_t is the household's employment (hours worked), and $1/\varphi$ is the Frisch elasticity of labor supply. The consumption index is

$$C_t = [\int_0^1 (C_t(i))^{\frac{\varepsilon-1}{\varepsilon}} di]^{\frac{\varepsilon}{\varepsilon-1}},$$

where $C_t\ (i)$ denotes the consumption of good i and ε is the elasticity of substitution between goods. The demand for good i is given by

$$C_t(i) = \left[\frac{P_t\ (i)}{P_t} \right]^{-\varepsilon} C_t. \quad (2)$$

$P_t(i)$ denotes the price of good i and P_t is an aggregate price index defined as

$$P_t = \left[\int_0^1 (P_t(i))^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}}.$$

The period budget constraint of the household is given by

$$P_t C_t + Q_t B_t = B_{t-1} + W_t N_t + D_t. \quad (3)$$

B_t is the holding of one-period nominal discount bonds held at the end of period t. Bonds pay one currency when maturing in period $t+1$. The price of the bond is $Q_t = 1/(1+i_t)$, where

i_t is the nominal interest rate. W_t denotes the nominal wage, and D_t is nominal dividends of the firms that the household own.

The household's optimality conditions for consumption and employment are

$$Q_t = \frac{\beta P_t C_t}{P_{t+1} C_{t+1}}, \tag{4}$$

$$N_t = \left(\frac{W_t}{C_t P_t}\right)^{\frac{1}{\varphi}}. \tag{5}$$

2.2 Supply Side: Firms and Productivity

All firms produce differentiated goods with the production function

$$Y(i) = A_t(i) N_t(i)^{1-\alpha}, \tag{6}$$

where $Y_t(i)$ is the output of the firm i, A_t is the level of TFP, and $1-\alpha$ is the output elasticity of employment. As in Gali (2015), private capital is omitted from the production function. Following the work of Chang et al. (2002), Tervala (2013), and Engler and Tervala (2018), a change in the level of TFP is determined by the following log-linear equation:

$$\hat{A}_t(i) = \rho_A \hat{A}_{t-1}(i) + \mu \widehat{N}_{t-1}(i). \tag{7}$$

$0 \leq \rho_A \leq 1$ is the persistence of the changes in TFP, μ is the elasticity of TFP with respect to employment and percentage changes from the initial steady state are denoted by hats (e.g., $\hat{A}_t(i) = dA_t(i)/A_0\,(i)$ where the zero subscript zero indicates the initial steady state). Equation (7) creates a link between recessions and potential output: A fall in employment today reduces TFP tomorrow, with an elasticity of μ. TFP depreciates at the rate of $1-\rho_A$. Strictly speaking, hysteresis requires that $\rho_A = 1$. Then a fall in employment reduces the level of TFP permanently. For computational reasons, however, ρ_A is set at 0.999999. Therefore, recessions have a quasi-permanent effect on TFP and output, but they eventually return to the initial steady state.

The firm seeks to maximize its profits

$$\Pi_t(i) = P_t\ \ (i) Y_t(i) - W_t N_t(i), \tag{8}$$

taking into account the production function (6) and the demand for its goods (2).

The optimal price under flexible prices is

$$P_t\ (i) = \frac{\varepsilon}{\varepsilon-1}\frac{W_t}{A_t(i)(1-\alpha)N_t\ (i)}. \tag{9}$$

Under flexible prices, the price is a constant mark-up over the marginal cost, which is

$$MC_t(i) = \frac{W_t}{A_t(i)(1-\alpha)N_t\ (i)}.$$

As in Calvo (1983), each firm can set new prices with the probability of $1-\theta$ in any given period, independently of other firms and the time since the last adjustment. The firm seeks to maximize

$$\max_{P_t\ (i)} V_t(i) = \sum_{s=t}^{\infty} \theta^{s-t} \Lambda_{t,s} \pi_s(i),$$

where$\Lambda_{t,s}$ is the stochastic discount factor between periods t and s. The result is

$$P_t\ (i) = \left(\frac{\theta}{\theta-1}\right)\frac{\sum_{s=t}^{\infty}\theta^{s-t}\Lambda_{t,s}C_s\left(\frac{1}{P_s}\right)^{-\varepsilon}MC_s}{\sum_{s=t}^{\infty}\theta^{s-t}\Lambda_{t,s}C_s\left(\frac{1}{P_s}\right)^{-\varepsilon}}.$$

A log-linearized version of it is

$$\hat{P}_t\ (z) = \beta\gamma\hat{P}_{t+1}(i) + (1-\beta\gamma)\left(\widehat{W}_t - \hat{A}_t\ (i) + \alpha\widehat{N}_t(i)\right).$$

The change in the optimal price is a weighted average of the changes in current and future marginal costs. A reduction in TFP increases the optimal price.

2.3 Monetary Policy

In the basic New Keynesian framework, including Gali (2015), monetary policy is characterized by the Taylor rule (see Taylor 1993). The central bank adjusts the interest rate based on the deviations of inflation and output from their targets. In this paper, I take a demand-driven source for a recession. I assume that a monetary shock drives the economy into a recession and causes a negative output gap. This then brings about a reduction in employment, which then reduces the level of TFP, and thus potential output. In this type of analysis, it makes little sense to have the output gap in the monetary policy rule. I assume that the central bank follows a log-linear Taylor rule with interest rate smoothing

$$\hat{\imath}_t = (1-\rho_i)\phi_\pi \Delta\hat{P}_t + \rho_i\hat{\imath}_{t-1} + \omega_t. \tag{10}$$

Coefficient ρ_i measures the degree of interest rate smoothing, ϕ_π is the coefficient for inflation in the monetary policy, Δ is the first-difference operator, and ω_t represents unexpected monetary shocks. I wish to emphasize that I do not argue that monetary policy shocks are the main cause of recessions; a positive monetary policy shock is just a practical source for a recession in the model.

2.4 Initial Steady State

All firms are identical and every firm that sets a price, in any given period, chooses the same price and output. Equilibrium is a sequence of variables that clears the labor and goods markets every period, while satisfying pricing rules. The initial level of employment, which is needed in welfare analysis, can be solved using equations (5), (6) and (9)

$$N_0 = \left[\frac{(\varepsilon-1)(1-\alpha)}{\varepsilon}\right]^{\frac{1}{1+\varphi}}. \tag{11}$$

3. Parameterization

The baseline parameterization of the model, shown in Table 1, follows Gali (2015) as much as possible. Periods represent quarters and the discount factor (β) is set at 0.99. This implies a 2% steady state annual real interest rate. The elasticity of substitution of goods (ε) is set at 9. This implies a 12.5% price markup over the marginal cost in the steady state. The Calvo parameter (θ) is set at 0.75, implying that the average price duration is one year. α is set at 0.25, which implies that the elasticity of output with respect to employment is 0.75. The coefficient for inflation (ϕ_π) in the monetary policy rule is set at 1.5.

The monetary policy rule differs from Gali (2015) because of interest rate smoothing. The smoothing parameter (ρ_i) is set at 0.8. This is a common value in the New Keynesian literature and consistent with Clarida et al. (2000).

The right size of the Frisch elasticity of labor supply is debated, partly because micro and macro elasticities differ greatly. The micro elasticity typically refers to the Frisch elasticity of individuals' hours of work and it is estimated using micro data. The macro elasticity refers to the elasticity of the aggregate hours worked in the economy and it is estimated using macro data. In a review, Whalen and Reichling (2017) argue that estimates of the Frisch elasticity based on macro data are considerably larger. They find that estimates of the micro elasticity for the intensive margin range from zero to more than one. Keane and Rogersson (2012) find that small estimates for the micro elasticity are fully consistent with the large macro elasticities. They (2012, 475) conclude that the macro elasticity exists in the range of 1 to 2. Gali (2015) sets it at 0.2, which may be too small a value at the macro level. I set φ at one, so the Frisch elasticity is one. Gali et al. (2007), for example, use this value in analyzing the welfare costs of business cycles.

The persistence of the changes in TFP (ρ_A) is set at 0.999999. Consequently, recessions have quasi-permanent effect on the level of TFP and thus output. A crucial parameter is the elasticity of TFP with respect to employment (μ), since it determines the extent of hysteresis. Chang et al. (2002) estimate that it is 0.11, which is chosen as the baseline value. The welfare costs of business cycle, however, are very sensitive to it. Therefore, we study in detail how the main results depend on it.

Table 1. Baseline Parameterization of the Model

	Baseline value	Description	Reference
β	0.99	Discount factor	Gali (2015)
ε	9	Elasticity of substitutability	Gali (2015)
α	0.25	$1-\alpha$ is the output elasticity of labor	Gali (2015)
θ	0.75	Calvo parameter	Gali (2015)
ϕ_π	1.5	Coefficient for inflation in the monetary policy rule	Gali (2015)
ρ_i	0.8	Interest rate smoothing	Clarida et al. (2000)
φ	1	Inverse of the Frisch elasticity	Gali et al. (2007)
ρ_A	0.999999	Persistence of the changes in TFP	Assumption
μ	0.11	Elasticity of TFP with respect to employment	Chang et al. (2002)

DeLong and Summers (2012) define hysteresis as a proportional decrease in potential output from a temporary recession. They claim that the plausible degree of hysteresis is between 0 and 0.2. Rawdanowicz et al. (2014, 8) define the hysteresis parameter as “the impact of one percentage point of the negative output gap on reducing potential output”. They find that 25 out of 32 OECD countries suffered from hysteresis in the Great Recession. They discover the hysteresis parameter of 0.1 for the U.S. and 0.3 for the euro area. The average degree of hysteresis, including countries without hysteresis, is 0.4. The median value is 0.35. In the present model, the degree of hysteresis is measured as the ratio of the fall in output in the 20th period, when prices have adjusted, to the fall in first-period output. Under the baseline parameterization, the degree of hysteresis is 0.21. I vary the elasticity of TFP with respect to employment within the range of 0 to 0.29 so that the degree of hysteresis is in the range of 0 to 0.4.

The size of a monetary shock is set such that the depth of a recession matches the empirical estimates on the effects of recessions on the deviation of output from a trend. Martin et al. (2015) study the consequences of recessions on the long-term level of output using data on 23 advanced economies over the past 40 years. They find that the average deviation of GDP from the pre-recession trend one year after the beginning of a recession is roughly 3%. Therefore, I set the size of a positive monetary shock such that it brings about a 3% deviation of output. Under the baseline parameterization and the presence of hysteresis, the size of the monetary shock is 325 basis points.

4. Welfare Costs of Recessions

4.1 Method of Welfare Analysis

I measure the welfare cost of business cycles as a percentage of initial consumption that the household in the case without business cycles is willing to pay to avoid business cycles and thus to be as well off in the business cycle case as in the case without business cycles.[1] Let $\{C_s^{NBS},\ N_s^{NBS}\}_{s=t}^{\infty}$ be the consumption and employment paths with no business cycles (NBS). The associated net present value (NPV) of welfare is given by

$$U_{NPV}^{NBS} = \sum_{s=t}^{\infty} \beta^{s-t} \left[\ln(C_s^{NBS}) - \frac{(N_s^{NBS})^{1+\varphi}}{1+\varphi} \right].$$

I define λ^f as the NPV of the welfare cost of business cycles (BS) relative to a case without business cycles. For now, I measure it as a *fraction* of initial consumption. Let U_{NPV}^{BS} denote the NPV of welfare in case with business cycles. Then

$$U_{NPV}^{BS} = \sum_{s=t}^{\infty} \beta^{s-t} \left[\ln\left((1-\lambda^f)\, C_s^{NBS} \right) - \frac{(N_s^{NBS}(z))^{1+\varphi}}{1+\varphi} \right]$$

$$U_{NPV}^{BS} = \frac{1}{1-\beta} \ln(1-\lambda^f) + U_{NPV}^{NBS}\ .$$

The next step is to solve for λ^f. In addition, the welfare cost of business cycles is now expressed as the *percentage* of consumption (denoted by λ).

$$\lambda = -100 \times [\exp(1-\beta)\,(U_{NPV}^{BS} - U_{NPV}^{NBS}) - 1]. \quad (12)$$

[1] This follows the idea of Lucas (1987, 2003) and Schmitt-Grohe and Uribe (2007).

A first-order Taylor expansion of the utility function is

$$dU_{NPV} = U_{NPV}^{BS} - U_0 = \sum_{s=t}^{\infty} \beta^{s-t} dU_s^{BS} = \sum_{s=t}^{\infty} \beta^{s-t} (\hat{C}_s^{BS} - (N_0)^{1+\varphi} \widehat{N}_s^{BS}.$$

Welfare in the case without business cycles is obviously the same as in the initial steady state. Therefore, the equation above can be substituted into equation (13) to obtain the welfare costs of business cycles

$$\lambda = -100 \times \left[\exp(1-\beta)\left(\sum_{s=t}^{\infty} \beta^{s-t} (\hat{C}_s^{BS} - (N_0)^{1+\varphi} \widehat{N}_s^{BS}\right) - 1\right]. \quad (13)$$

In a figure, I depict the welfare cost of business cycles in one period

$$\lambda_t \;= 100 \times \left[\exp(1-\beta)\left(\hat{C}_s^{BS} - (N_0)^{1+\varphi} \widehat{N}_s^{\mathrm{BS}}\right) - 1\right].$$

However, the welfare cost of business cycles typically refers to equation (13), which measures the NPV.

4.2 Degree of Hysteresis and the Costs of Recessions

Figure 3 shows the impulse responses of the key variables to a monetary shock. The horizontal axis shows time and the vertical axis typically displays percentage deviations from the initial steady state. However, interest rate and inflation are expressed as percentage point deviations in annual terms and welfare cost is denoted in the percentage of initial consumption. The solid lines represent the case without hysteresis; the dashed lines represent the case with hysteresis. As discussed in Section 3, the size of the monetary shock is always set such that it causes a three percent fall in output.

In the absence of hysteresis, the model is virtually identical to Gali (2015, Chapter 3) and the effects of a monetary policy shock are identical to those in it, just that the size of the shock is different (340 basis points). A rise in the real interest rate causes a fall in consumption demand. Consequently, output and employment fall. In the long term, prices adjust and the economy returns to the initial equilibrium. In an imperfectly competitive economy, identical declines in consumption and employment cause a fall in welfare. Figure 3(d) shows a very short-lived fall in welfare. Table 2 shows that the welfare cost of a recession is only 0.6% of consumption.

In the presence of hysteresis, the size of the monetary shock is reduced to 325 basis points so that the initial drop in output remains at 3%. A fall in employment causes a fall in TFP, shown in Figure 3(c). Moran and Queralto (2018) find empirical evidence that an expansionary monetary policy shock has a positive effect on TFP and the effect is stronger in the medium term than in the short term. Moreover, the effect is long-lived. The behavior of TFP in this model is in line with this evidence. TFP hysteresis brings about a permanent fall in aggregate supply, causing output hysteresis and a permanent fall in consumption (Figure 3(a)). However, employment reverts to its initial level. In the medium and long term, the economy experiences a fall in welfare (Figure 3(d)), due to a reduction in consumption and unchanged employment. Table 2 shows that the welfare cost of a recession increases from 0.6% to 47.1%.

Figure 3. Dynamic responses of key variables without and with hysteresis

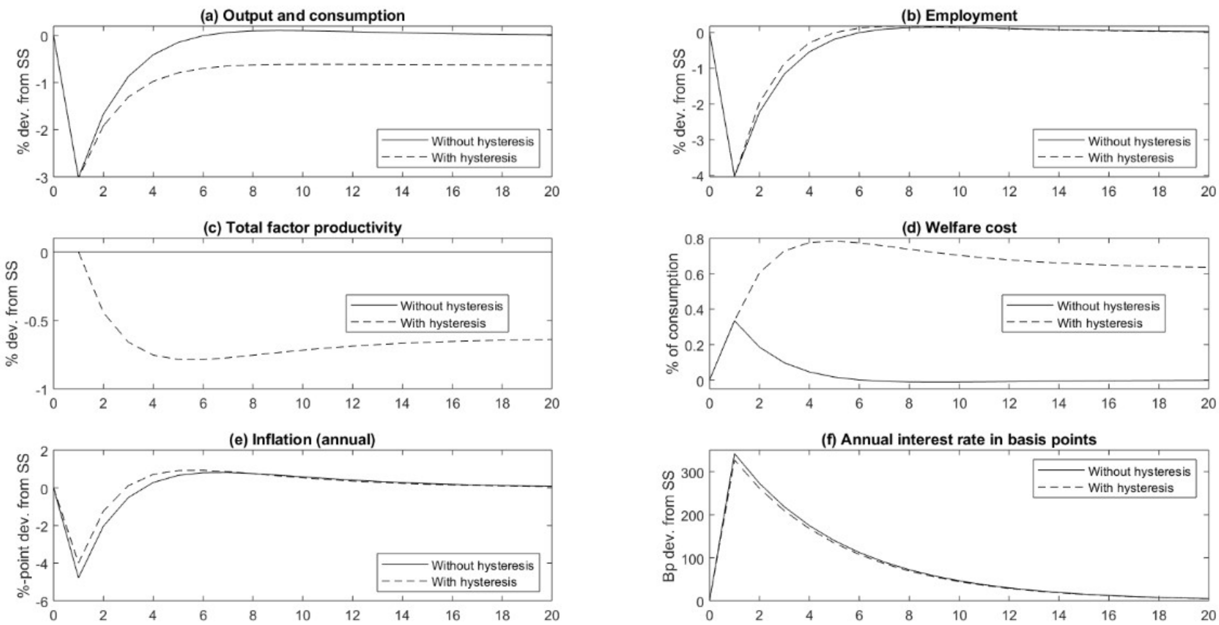


Table 3 and Figure 4 show the dependence of the welfare loss of a recession on the degree of hysteresis. The elasticity of TFP with respect to employment is varied such that the degree of hysteresis is at the desired level. At the same time, the size of the monetary policy shock is changed such that the fall in output remains at 3% (the higher the degree of hysteresis, the smaller the monetary shock). As previously mentioned, Rawdanowicz et al. (2014) discover the hysteresis parameter of 0.1 for the U.S. and 0.3 for the euro area. In Figure 4, the solid lines represent the case where hysteresis is 0.1, the dashed lines represent the baseline case where hysteresis is 0.21, and the dashed lines with a star represent the case where hysteresis is 0.3. Table 2 highlights that the welfare loss of a recession is highly sensitive to changes in the degree of hysteresis.

Figure 4(a) shows that the higher the degree of hysteresis, the larger the fall in consumption. Even a small degree of hysteresis (0.05) has a drastic consequence, as the welfare cost of a recession is increased by a factor of 27. The hysteresis estimate of Rawdanowicz et al. (2014) for the U.S. (0.1) implies that the welfare cost of a recession increases to 27.3% of consumption. This is 47 times the welfare cost without hysteresis. This may underestimate the welfare cost of some recessions greatly, since Rawdanowicz et al. (2014) estimate that the average degree of hysteresis in OECD countries during the Great Recession was 0.4. This degree of hysteresis implies that the welfare cost of a recession is no less than 70% of consumption, 121 times the welfare cost in the absence of hysteresis.

Table 2. Hysteresis and the Welfare Costs of Recessions

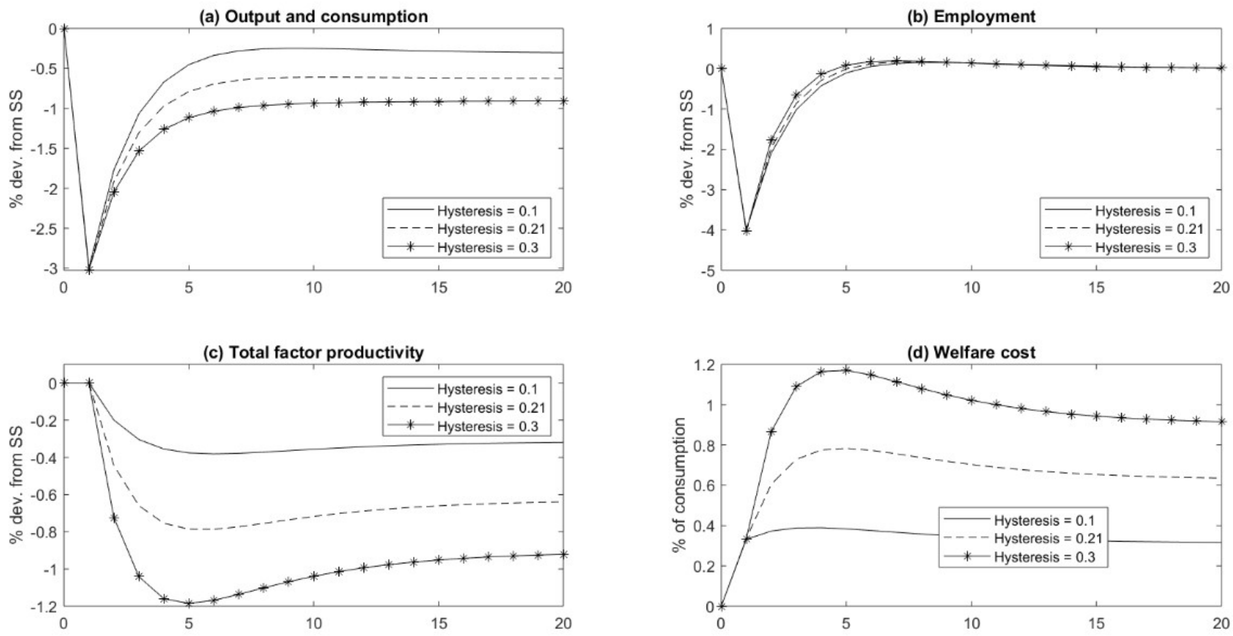
Elasticity of TFP with respect to employment	Hysteresis	Welfare cost of a recession
0	0	0.578
0.025	0.050	15.6
0.05	0.10	27.3
0.076	0.15	37.0
0.11 (baseline)	0.21	47.1
0.14	0.25	53.6
0.18	0.30	60.1
0.227	0.35	66.7
0.29	0.40	70.2

Lucas (2003) estimates that the welfare gain from eliminating all consumption variability is 0.05% of consumption in each period, when the standard deviation of consumption is set at 3.2%. The numbers of the present paper are not fully comparable with his numbers since I focus on analyzing the NPV of the welfare cost of a 3% drop in consumption. Figure 4(d), however, shows the welfare cost of a recession in each period. When the extent of hysteresis is in the range to 0.1 to 0.3, the welfare cost ranges from 0.32% to 0.92% of initial consumption in the 20th period. When the extent of hysteresis is 0.4, the welfare cost is 1.2% in each period.

Since the publication of Lucas (1987), several studies have challenged its main findings. Barlevy (2005) classify these studies according to the features of Lucas' model that they modify. The first group has modified preferences or the persistence of shocks (including Dolmas 1998, Pemberton 1996, Obstfeld 1994, Otrok 2001, Tallarini 2000). For example, a higher degree of risk aversion increases the welfare costs of business cycles. Barlevy (2005) argues that these studies, however, find that the costs of business cycles are small, although they may be higher than in Lucas (1987). On the other hand, Dolmas (1998) finds that the welfare costs can be up to 20% of consumption in each period, if the shocks affect the long-term growth rate of GDP. It is, however, questionable to interpret this as the welfare costs of business cycles; the result actually supports Lucas' claim (1987) that the welfare costs of reduced growth are much higher that the welfare costs of business cycles. The present paper shows that the welfare costs of business cycles are substantial even without a change in the growth rate of output, as long as business cycles affect the level of output permanently.

The second group of studies (including Imrohoroglu 1989 and Storesletten et al. 2001) has calibrated consumption risk to match household data rather than aggregate data, since the consumption of some individuals decline much more during recessions than aggregate consumption (Barlevy 2005). Some of these studies suggest that the costs of business cycles are somewhat higher than Lucas (1987, 2003) estimated.

Figure 4: Dynamic responses of key variables with hysteresis



The third group of studies, including Epaulard and Pommeret (2003) and Barlevy (2004a), assumes that stabilization policy affects long-run growth through investment. This channel increases the welfare loss of business cycles, but it is still less than 0.5% in each period. Figure 4(d) shows that, under the baseline parameterization, the welfare cost in the 20th period is somewhat higher even without growth effects. In a growth model of Barlevy (2004b), however, the welfare loss can be 7.5-8% in each period. In his model, an increase in investment increases economic growth less than an identical fall in investment decreases it. Therefore, eliminating business cycles increases the growth rate. On one hand, the finding of this paper and those of Epaulard and Pommeret (2003) and Barlevy (2004a) suggest that the welfare costs of business cycles can be higher than the welfare costs of reduced growth. On the other hand, Barlevy (2004b) provides support for Lucas' view (1987) that the welfare costs of reduced growth are much higher although the welfare costs of business cycles can be substantial.

The fourth group of studies assumes that stabilization policy affects the level of consumption, whereas in Lucas (1987, 2003) business cycles are deviations from a trend that leave the long-run level of consumption unchanged. Ramey and Ramey (1991) assume that firms must make technology commitments in advance and each technology corresponds to a different level of output at which costs are minimized. In the absence of business cycles, firms choose their technology such that a minimum efficient scale is in line with the equilibrium level of output. Business cycles imply that the equilibrium level of output departs from minimum efficient scale and thus they lead to a lower mean level of output. They find that all business cycles lower the level of output on average by 1.7%. Figure 4(a) shows that a single recession lowers the level of output permanent slightly less than 1% when the degree of hysteresis is 0.3.

Cohen (2000) criticizes the work of Lucas (1987), where the aim of stabilization policy is to eliminate both above-trend and below-trend fluctuations in consumption. DeLong and Summer (1988, 434) emphasize that the Keynesian idea is that "successful macroeconomic policies fill in troughs without shaving off peaks." Cohen (2000) considers that stabilization policy aims at eliminating only below-trend movements, thus allowing an increase in the mean level of consumption. The welfare benefit of eliminating all below-trend movements is 1% of consumption in each period. In the present model, when the extent of hysteresis is in the range to 0.3 to 0.4, the welfare cost of a recession ranges from 0.92% to 1.2% of initial consumption in the 20^{th} period. Therefore, my results are consistent with Cohen (2000).

Walentin and Westermark (2018a) stress that the welfare cost of business cycles is negligible both in real business cycle theory and New Keynesian theory. Gali et al. (2007) investigate the welfare costs in a New Keynesian model. Under their baseline parameterization (log utility for consumption and Frisch elasticity of one), the welfare cost of postwar U.S. business cycles is only 0.01% of consumption. The results of the present paper are not fully comparable with Gali et al. (2007) since they take into account the welfare gains of booms. Both results, however, indicate that the welfare costs of business cycles in a New Keynesian model are negligible. More importantly, they analyze the welfare costs by measuring the cumulative welfare losses over the recession. This welfare measure is comparable with the NPV of the welfare cost of a recession. Under their baseline parameterization, the welfare cost of the U.S. recession in the beginning of the 1990s was 2.3% of consumption. In the present model, the welfare cost in the absence of hysteresis (0.6%) is smaller than in Gali et al. (2007), mostly because of the milder and shorter downturn.

The most directly related paper is Walentin and Westermark (2018b). They study the welfare costs of business cycles using a labor market search and matching framework with human capital dynamics (learning on-the-job and skill losses during unemployment). A recession cuts the number of new jobs, and thus employment. The learning on-the-job feature implies that a fall in employment diminishes human capital and this lowers incentives to post vacancies, further reducing employment. Human capital dynamics create hysteresis in employment and eliminating business cycles increases the long-term level of output. The welfare cost of business cycles in the absence of human capital dynamics is 0.26% in each period. Human capital dynamics increase it to 1.52%. Hence, hysteresis increases the welfare costs of business cycles by a factor of six. My result is in line with Walentin and Westermark (2018b). However, modelling the influence of recessions on aggregate supply through TFP increases the welfare costs of recessions considerably more. Even a small degree of hysteresis (0.05) increases welfare loss by a factor of 27 and the average degree of hysteresis in OECD countries during the Great Recession (0.4) increases it by a factor of 121.

4.3 Sensitivity Analysis

The next step is to explore whether the welfare costs of business cycles are sensitive to changes in parameter values. Table 3 shows the results of the sensitivity analysis. Row 1 shows the baseline result. In the present model, periods represent quarters. Strictly speaking, the baseline result is that the welfare cost of a recession is 47.1% of quarterly consumption. Lucas (1987) sets the discount factor at 0.95 so his analysis measures the welfare cost of business cycles as a percentage of annual consumption. In row 2, I use the same value. The welfare cost measured as a percentage of annual consumption is almost the same (46.2%).

A difference from Lucas (1987, 2003) is the endogeneity of labor supply, and this feature may affect the welfare costs of consumption risks. The elasticity of substitution of goods affects the level of initial employment (equation (11)) and this in turn affects the welfare cost of business cycles (see equation (13)). In row 3 it is reduced to 6, a common value in New Keynesian literature, and in row 4 it is increased to 21. Table 3 shows that the main finding is robust to change in it.

Gali et al. (2007) find that the welfare loss can be sensitive to the Frisch elasticity of labor supply. Row 5 shows the welfare loss when it is set at 0.2, following Gali (2015). I need to emphasize that the row shows the consequences of varying the Frisch elasticity while I increase the size of the shock such that the fall in output remains at 3%. If I decrease the Frisch elasticity and keep the size of the shock constant, then the recession is smaller. In this case, the welfare loss of a recession would be smaller. Row 5 illustrates that a smaller Frisch elasticity reduces the degree of hysteresis and consequently the welfare costs of business cycles. Row 6 shows that doubling the Frisch elasticity from the baseline value of 1 to 2 has a small effect on the welfare costs.

The output elasticity of labor is $1-\alpha$. In row 7, α is set at 0.33, which is commonly used in macroeconomics, while the baseline parameterization followed Gali (2015). It shows that the welfare cost increases mildly to 49.6%. In row 8, α is set at zero and output is linear in labor. Gali et al (2007) argue that this assumption is line with the view that changes in the capital stock are negligible at business cycle frequencies, and that the capital utilization rate is proportional to employment. Row 8 shows that the welfare cost decreases to 41%.

The parameters that govern the damage caused to potential output by a recession are the elasticity of TFP with respect to employment and the persistence of the level of TFP, which affects the duration of the damage. In rows 9-11, the persistence is reduced to from 0.999999 to 0.99, 0.96 and 0.86. They show that the persistence of TFP has a significant effect on the welfare cost of business cycles. When the persistence is 0.96, the negative effect of a recession on TFP fades away quite quickly and the reduction in consumption is relatively short-lived. This implies that the welfare cost is drastically reduced to 12.5%. In this case, it is somewhat misleading to talk about hysteresis because the level of output returns to the initial level quite rapidly, while the empirical studies find that recessions have a permanent or highly persistent effect on output. When the persistence of TFP is set at 0.86, output returns very rapidly to the initial level and the welfare cost decreases to 4.8%. This is, however, still much higher than the baseline number without hysteresis (0.6%).

Table 3. Sensitivity Analysis

Row	Parameter	Hysteresis	Welfare cost of a recession
1	Baseline	0.21	47.1
2	$\beta = 0.95$ ($\beta = 0.99$)	0.19	46.2
3	$\varepsilon = 6$ ($\varepsilon = 9$)	0.21	47.3
4	$\varepsilon = 21$ ($\varepsilon = 9$)	0.21	47.0
5	$\varphi = 5$ ($\varphi = 1$)	0.17	41.3
6	$\varphi = 0.5$ ($\varphi = 1$)	0.21	48.1
7	$\alpha = 0.33$ ($\alpha = 0.25$)	0.22	49.6
8	$\alpha = 0$ ($\alpha = 0.25$)	0.17	40.8
9	$\rho_A = 0.99$ ($\rho_A = 0.999999$)	0.17	27.6
10	$\rho_A = 0.96$ ($\rho_A = 0.999999$)	0.091	12.5
11	$\rho_A = 0.86$ ($\rho_A = 0.999999$)	0	4.8

In summary, the welfare costs of business cycles are not, in general, sensitive to changes in parameter values. The main results are sensitive to the elasticity of TFP with respect to employment and the persistence of TFP. If the elasticity of TFP with respect to employment is low, then the damage of a recession to potential output is weak. Consequently, the welfare cost of a recession is smaller. If the persistence of TFP is not high, then the damage to potential output is relatively short-lived. Hence, the welfare cost of a recession is small. On the other hand, when recessions affect TFP quasi-permanently, the welfare cost of a recession can be significant. The welfare cost of a recession obviously depends crucially on its size. The next step should be to analyze the sensitivity of the main results of the paper, extending the model in several dimensions.

5. Conclusions

Yellen (2016) says that deep recessions often challenge prevailing views about how the economy works and expose flaws in economists' knowledge. One of her main points was that the recent experience suggests that changes in aggregate demand may have a persistent effect on potential output. She highlighted that addressing this topic is vital to the work of central bankers and other economic policymakers. In this paper, I have argued that hysteresis has not been taken properly into account in the study of the welfare effects of business cycles. I show that hysteresis has very important implications for the welfare costs of business cycles. In the basic New Keynesian framework, the welfare costs of recessions are negligible and the study of stabilization policy using it seems pointless. On the other hand, a small extent of hysteresis, 0.1, raises the welfare cost by a factor of 47 from 0.6% to 27.3% of consumption. A higher degree of hysteresis, 0.4, increases the welfare loss by a factor of 121 to 70%.

My findings suggest that the welfare costs of recessions are massive in the presence of hysteresis, with the implication being that stabilization policy should be a high priority for researchers and policymakers. Yellen (2016) emphasizes that hysteresis seems to make it very important for policymakers to respond quickly and aggressively to a recession, since this reduces the depth and persistence of the recession, and thus limits the damage to potential output. Reifschneider et al. (2015) show that hysteresis provides a strong motivation for a vigorous monetary policy response to a recession. Moran and Queralto (2018) stress that the dependence of aggregate supply on demand raises the stakes over the conduct of monetary policy, compared to the traditional view, which treats the evolution of TFP as exogenous. Engler and Tervala (2018) find that a fiscal expansion becomes desirable in recessions with hysteresis effects, while it is not desirable in the absence of hysteresis. However, much more research is needed to better understand the implications of hysteresis for the welfare costs of business cycles and the conduct of stabilization policy.

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