

Preferences, Nominal Rigidities, and Monetary  
Policy

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## PUBLICATION OVERVIEW

The main body of this thesis comprises the following publications:

**Chapter 2** of this dissertation comprises two related works.

**Sections 2.1 - 2.6** are a joint paper with Professor Dennis J. Snower, Ph.D. entitled “Envy, Guilt, and the Phillips curve.” This paper has been published in the *Journal of Economic Behavior & Organization*, volume 99, March 2014, pages 69-84. My contribution to this paper has been the literature review, the formulation of the theoretical model and the simulation exercises, including writing the source codes. The editorial work as well as the intuitions for the result stem from joint efforts. The journal article is available at: <http://dx.doi.org/10.1016/j.jebo.2013.12.015>.

**Sections 2.8 and 2.9** is based on my single-authored working paper “Inequality Aversion and the Long-Run Effectiveness of Monetary Policy: Bilateral versus Group Comparison,” which is provided by the Kiel Institute for the World Economy in its series Kiel Working Papers with number 1802. The permanent download to the original working paper is available at: <http://ideas.repec.org/p/kie/kieliw/1802.html>.

For this thesis, I have extended Chapter 2 by **subsection 2.7**, which elaborates on footnote 21 in “Envy, Guilt, and the Phillips curve” and footnote 10 in “Inequality Aversion and the Long-Run Effectiveness of Monetary Policy: Bilateral versus Group Comparison.”

**Chapter 3** is based on the working paper entitled “Loss Averse Consumers: An Alternative Theory of Price Adjustment,” which is joint with Diplom Volks-

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wirtin Inske Pirschel and Professor Dennis J. Snower, Ph.D. The original paper is provided by Verein für Socialpolitik / German Economic Association in its series Annual Conference 2013 (Duesseldorf): Competition Policy and Regulation in a Global Economic Order with number 79793. My personal contribution to this project includes the simulation exercise, including writing the source codes and running the simulations. Furthermore, I generally contributed to the literature review, the mathematical formulation of the theoretical model, and the intuition of the results. The original working paper is available at: <http://ideas.repec.org/p/zbw/vfsc13/79793.html>.

**Chapter 4** is derived from the paper “Estimating a high-frequency New-Keynesian Phillips curve,” which is joint work with Dr. Stephen Sacht. This paper has been published in *Empirical Economics*, volume 46, issue 2, March 2014, pages 607-628. My contribution to this project lies primarily in providing the initial idea and the empirical part of the paper. The latter comprises, e.g., collecting and processing the data, performing the estimations, and computing the various test statistics. The theoretical part has to be attributed to my co-author. All remaining parts (i.e. editorial work, result discussion, and conclusions) have been joint efforts. The journal article is available at: <http://link.springer.com/article/10.1007/s00181-013-0684-7>.

**Chapter 5** is joint work with Dr. Matthias Hartmann from Heidelberg University. The paper is entitled “State-dependence vs. Time-dependence: An Empirical Multi-Country Investigation of Price Sluggishness” and it is provided by the Kiel Institute for the World Economy in its series Kiel Working Papers with number 1802. While the estimation and testing procedures have been performed by Dr. Hartmann, my contribution to this project has been the underlying intuition, which includes providing the initial idea and the model framework, as well as providing substantial parts of the macroeconomic discussion. Furthermore, I provided the data work (collecting and

processing the data) for this project. The editorial work has been a joint effort. The permanent download to the original working paper is available at: <http://ideas.repec.org/p/kie/kieliw/1907.html>.

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## LIST OF ACRONYMS

AR	Anderson-Rubin
ARCH	autoregressive conditional heteroskedasticity
LM	lagrangian multiplier
AT	Australia
BE	Belgium
CA	Canada
CES	constant elasticity of substitution
CPI	consumer price index
DSGE	dynamic stochastic general equilibrium model
ES	Spain
FN	Finland
FR	France
GDP	gross domestic product
GMM	generalized method of moments
IU	inflation uncertainty
IT	Italy
IV	instrumental variable
JP	Japan
MIT	Massachusetts Institute of Technology
NKM	New Keynesian model
NKPC	New Keynesian Phillips curve
NL	The Netherlands
NZ	New Zealand
OECD	Organisation for Economic Co-operation and Development

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PT .....	Portugal
RBC .....	Real Business Cycle model
SW .....	Sweden
TV .....	television
UK .....	United Kingdom
US .....	United States

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This thesis was written during my employment as research and teaching assistant to Professor Dennis J. Snower, Ph.D. at the chair of Economic Theory at Kiel University from May 2008 to April 2013. Completion of this thesis took place while being research associate at the Technische Universität Berlin.

Above all, I am indebted to my first supervisor Professor Dennis J. Snower, Ph.D. I am very grateful for his passion and dedication towards this dissertation project and for his excellent guidance throughout my complete training as economic researcher. Without his patience, experience, and honesty, this thesis could have never been finished. I am also indebted to my second supervisor Professor Dr. Maik Wolters, who has also closely supervised my progress during the most crucial phases of this dissertation project.

I would like to give special thanks my co-authors Diplom Volkswirtin Inske Pirschel, Dr. Stephen Sacht, and Dr. Mathhias Hartmann and to my many colleagues at Kiel University and the Kiel Institute for the World Economy for fruitful discussions of my works throughout several seminars. Especially to mention are Wolfgang Lechthaler, Ph.D., Christopher Reicher, Ph.D., Dr. Henning Weber, Mewael Tesfaselassi, Ph.D., and Dr. Sebastian Braun, who have always shown special interest in my research projects and who have actively supported me during my entire time as a doctoral student.

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Keynesian Economics, while I was still an economics student at Kiel University, and therewith, to a big part, is responsible for this dissertation project to come to life in the first place. Professor Dr. Ulrich Schmidt has given me the opportunity to widen my academic horizon towards experimental economics, which I very thankful for. I am truly thankful for their support.

Last but not least, I would like to thank my family and my friends for their invaluable emotional support. For better or for worse, they have always stood by my side. Without their patience and imperturbable believe in me this thesis could not have been written.

## 1. INTRODUCTION

This thesis is concerned with preferences, nominal rigidities, and their interaction with monetary policy. Monetary policy is one of the most extensively studied topics in contemporary macroeconomics. At the core of this research area lies the instrumental use of monetary policy to influence macroeconomic activity. This question comprises two dimensions: First, monetary policy as an instrument to stabilize business cycle fluctuations in the short run and, second, monetary policy as an instrument to permanently foster real macroeconomic activity in the long run. As we will show in this thesis, the way preferences and nominal rigidities are modeled, can highly influence the effectiveness of monetary policy both, in the short- and in the long-run.

The workhorse model for monetary policy analysis is the New Keynesian model (henceforth: NKM). The textbook version of the NKM (see, e.g., Woodford, 2003; Galí, 2008; Walsh, 2010) places rational, self-centered, self-interested agents into an economic environment of monopolistic competition. Agents derive their decisions from maximizing forward-looking objective-functions which focus on materialistic values, i.e. firms maximize their current and future expected profits, while households maximize their current and future expected utilities which they derive from consumption and leisure. Monetary authorities conduct monetary policy either by interest rate or money supply management. What makes this model “Keynesian” is that agents are restricted in their price and wage setting decisions and therefore prices and wages do not react flexibly and instantly to every change in the economic environment. As a consequence of these nominal rigidities monetary policy exhibits some influence on the real sector of the economy. If nominal prices and wages were to adjust immediately

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and fully to changes in monetary policy instruments, the classical dichotomy (by which monetary policy is neutral with respect to real variables) would be restored. Against this background, this thesis takes an alternative view on preferences and nominal rigidities and studies their implications for monetary policy. While the alternative view on preferences provides rationales for long-run effects of monetary policy and endogenous price stickiness, the alternative view on nominal rigidities challenges the time-dependent pricing paradigm and questions the high degree of nominal inertia estimated from quarterly data. As will be shown, each of these results has far reaching implications for the conduct of monetary policy analysis. The analysis in this thesis consists of two parts: a theoretical part and an empirical part.

The theoretical part of this thesis breaks with the traditional preference structure. The notion of homo-economicus has been refuted by a massive empirical literature. Inspired by the tremendous success in the field of behavioral and experimental economics, we assume that some market participants follow an alternative behavioral paradigm, namely reference-dependent preferences. With reference-dependent preferences, agents evaluate outcomes relative to a reference point, rather than by its face value. Reference-dependent preferences help explain “anomalistic” behavior such as the equity premium puzzle, the disposition effect, downward-sloping labor supply curves, asymmetric price elasticities in consumer goods, status-quo bias, or endowment effects, which still remain puzzles for homo-economicus (Camerer, 2000; Ho et al., 2006). In this thesis, we show that reference-dependent preferences can also be used to provide novel rationales for the long-run non-neutrality of monetary policy and for microfounded nominal rigidities.

We model reference-dependent preferences along two different lines, differing by the notion of their reference point. In Chapter 2 we substitute selfish preferences with fairness preferences. As a consequence, agents are no longer purely self-interested but other-regarding, i.e. an agent’s well-being depends on the outcomes of others. The notion of fairness that we apply in Chapter 2 is based



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on inequality aversion, a phenomenon covering both envy and guilt. We model inequality aversion along the lines of Fehr and Schmidt (1999) and Bolton and Ockenfels (2000) and incorporate it into an otherwise standard NKM with temporarily fixed nominal wage contracts and positive inflation. This approach has far reaching implications for the conduct of monetary policy. These implications are in conflict with monetary policy recommendations from standard economic theory, according to which monetary policy is (almost) neutral with respect to aggregate employment and output in the long run for low inflation rates.<sup>1</sup>

This changes dramatically under reference-dependent preferences. In the presence of temporarily fixed nominal wage contracts, positive inflation implies that real wages decline over the contract period. Since different workers write nominal wage contracts at different times, this leads to real wage dispersion and thus dispersion of real incomes. In the presence of inequality aversion, workers with relatively low incomes experience envy, whereas those with relatively high incomes experience guilt. The former seek to raise their income and the latter seek to reduce it. The greater the inflation rate, the greater the degree of wage dispersion under nominal wage contracts, and thus the greater the degree of envy and guilt experienced by the workers. Since the envy effect is stronger than the guilt effect, according to the available empirical evidence, a rise in the inflation rate leads workers to supply more labor over the contract period, generating a significant positive long-run relation between inflation and output (and employment), for low inflation rates. This adds a theoretically novel transmission channel to the standard model, by which monetary policy positively influences macroeconomic activity in the long run. As we show, this transmission channel dominates all inefficiencies, which arise from real wage dispersion, for inflation rates up to 4% (given standard calibrations). Consequently, the Phillips curve is backward-bending, so that increases in money growth lead to

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<sup>1</sup>While standard economic theory follows the conventional wisdom that the classical dichotomy holds, this is true only approximately for the standard NKM. While the NKM, qualitatively, implies a non-neutrality of monetary policy due to time discounting and inefficiencies due to relative price instability, quantitatively, these effects are negligibly small for reasonable values of the interest rate and low inflation rates (Ascari, 1998; Graham and Snower, 2004; Levin and Yun, 2007).

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higher employment and output at low inflation, but to lower employment and output at high inflation. Provided that wage adjustments are costly, this trade-off remains significant even once the degree of wage stickiness adjusts to the inflation rate. This Phillips curve relation, together with an inefficient zero-inflation steady state, provides a rationale for a positive long-run inflation rate. Given standard calibrations, optimal monetary policy is associated with a long-run inflation rate around 2 percent. This policy recommendation is particularly noteworthy, since it helps bridge the gap between monetary theory and central banking practice. In contrast to much of the recent literature on monetary policy, according to which the optimal inflation target of the central bank ranges between zero and the Friedman rule (i.e. the inflation rate is minus the real interest rate), we provide a rationale for targeting inflation at a low, positive rate. Therefore, Chapter 2 shows how the policy implication for the monetary authorities changes dramatically in the light of a decision making process, which is influenced by reference-dependent preferences.

While preferences in Chapter 2 depend on interpersonal comparison of perceived outcomes, preferences in Chapter 3 depend on intrapersonal comparison of perceived outcomes. In particular, Chapter 3 challenges the standard assumption from expected utility theory that preferences do not depend on current “assets” (Samuelson and Zeckhauser, 1988; Tversky and Kahneman, 1991). Numerous empirical evidence supports the notion that utility is determined by gains and losses relative to a reference point rather than by plain levels. For intrapersonal comparisons such reference points often take the form of past, present, or future expected outcomes; or a combination of those. In Chapter 3 of this thesis, we resort to Kahneman and Tversky’s (1979, 1984) concept of loss aversion, which not only includes gains and losses as a means of evaluation, but also asserts that losses loom larger than gains. We incorporate consumer loss aversion in the price dimension into an otherwise standard neoclassical model of monopolistic competition and study the price setting behavior of the monopolistic competitive firm, facing loss averse consumers. Due to loss aversion in

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the price dimension, the consumers' perceived utility losses from price increases are weighted more heavily than the perceived utility gains from price decreases of equal magnitude. Price changes are evaluated relative to an endogenous reference price, which is an agent's rational price expectation from the recent past (Kőszegi and Rabin, 2006). By implication, demand responses are more elastic for price increases than for price decreases and thus firms face a downward-sloping demand curve that is kinked at the consumers' reference price. The resulting theory of price adjustment is starkly at variance with past neoclassical and Keynesian theories. First, although the firm is generally capable to flexibly change prices at no costs, full price flexibility is no optimal behavior. Under all circumstances considered in Chapter 3, prices react less pronounced to demand shocks relative to the standard neoclassical model of monopolistic competition. Therefore, the assumption of loss averse consumers generates an endogenous mechanism of state-dependent price sluggishness derived completely from microfoundations. Second, and in contrast to the Keynesian theories of price rigidity, our theory captures empirically observed asymmetric price reactions to positive and negative shocks, which can be reconciled with the standard theories of price adjustment only under restrictive ad-hoc assumptions.

The theoretical part of this thesis concludes that changes of the preference structure taken from recent advances in the behavioral economics literature can have major effects for decision making. These effects are of importance not only for the individualistic behavior but also for macroeconomic policy makers.

While the theoretical part of this thesis looks at adjustments on the household side of the economy, the empirical part analyzes solely the firm side of the economy. In the focus of the second part of this thesis lies the estimation of the structural short-run New Keynesian Phillips curve (henceforth: NKPC), derived from Calvo (1983) price setting. In the short run, the NKPC is upward-sloping in the inflation-employment space, giving rise to a tradeoff between inflation and the real side of the economy. To quantitatively assess this tradeoff from a macroeconomic perspective, Galí and Gertler (1999) estimate the slope of the

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short-run NKPC from quarterly time series data by means of the generalized method of moments (henceforth: GMM). This procedure allows immediate inference on the degree of nominal inertia, measured by the Calvo parameter. Following their pathbreaking contribution, NKPCs have been estimated for the majority of the industrialized and emerging economies. The resulting macroeconomic estimates are, however, often way out of line with microeconomic evidence on price stickiness (Eichenbaum and Fisher, 2007; Kuester et al., 2009). In Chapters 4 and 5 of this thesis, two deviations from the standard estimation procedure in the literature are considered, which help realign the macroeconomic estimates with microeconomic evidence.

The first deviation is concerned with the extend of nominal inertia, found in the data. While microeconomic evidence predicts prices to be fixed on average around half a year in the United States (Bils and Klenow, 2004; Klenow and Kryvtsov, 2008), macroeconomic evidence often finds average durations of sticky prices of well above one year (Galí and Gertler, 1999; Galí et al., 2001, 2003; Nason and Smith, 2008). Consequently, Phillips curves estimated from macroeconomic data seem to be too flat, which entails the risk of overstating the effectiveness of monetary policy. This divergence may be brought about by the different frequencies of analysis. While micro-price studies are generally performed on a daily to monthly basis, the estimation of NKPCs via GMM is generally conducted in a quarterly setting. Chapter 4 intends to realign the frequencies of observation by estimating the NKPC allowing for higher-than-quarterly frequencies. In order to do so, we suitably adjust the frequency-dependent parameters of the model according to the rules described in Franke and Sacht (forthcoming). A higher observation frequency not only strongly mitigates the well known problems of small-sample bias (see, e.g., Fuhrer et al., 1995; Lindé, 2005) and structural breaks (see, e.g., D'Amato et al., 2007), but also avoids the overstatement of the true price stickiness, which arises from employing lower frequency price aggregates (Ellis, 2009; Abe and Tonogi, 2010). Applying a daily frequency allows us to obtain estimates for the Calvo param-

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eter of nominal rigidity over a very short period, for instance, for the recent financial and economic crisis. These daily estimates can then be easily transformed into their low-frequency equivalences, to be used for the calibration of macroeconomic models. With Argentine data from the end of 2007 to the beginning of 2011 we estimate the daily Calvo parameter and find that on average prices remain fixed for approximately two to three months which is exactly in line with recent microeconomic evidence for Argentina from Cavallo (2012). Our results have strong implications for the conduct of monetary policy analysis. If the average frequency of fixed prices is calibrated according to high-frequency evidence (may it be micro- or macroeconometric) rather than evidence stemming from quarterly data, nominal rigidities are much less pronounced and with it also the power of monetary policy to influence economic fluctuations. On the other hand, our results imply that - for the case of Argentina - a quarterly model would need to be calibrated as a Real Business Cycle (henceforth: RBC) flexible price model, instead of a New Keynesian sticky price model. In a RBC model, however, the analysis of monetary policy is redundant. Therefore, in order to analyze monetary policy in a sticky price framework, the NKM model must be at most on a monthly frequency.

While the first deviation is concerned with the value of the Calvo parameter, the second deviation is concerned with the interpretation of the Calvo parameter. In general, economists estimate the slope of the Phillips curve, given that we interpret the Calvo parameter as deep parameter in the sense that it is constant over the full horizon of the analysis. This assumption clearly falls short to the Lucas critique, as economic agents have an incentive to change prices or wages more often in times of high inflation compared to times of low inflation, leading to state-dependent rather than time-dependent pricing behavior. Therefore, the slope of the short-run NKPC might be non-linear in inflation, as also proposed by Gertler and Leahy (2008). In Chapter 5 we empirically investigate the time- and state-dependent behavior of aggregate price setting. We implement a testing procedure by means of a nonparametric representation

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of the structural form NKPC. By means of the so-called functional coefficient regression we allow for potential dependence of the Calvo parameter on inflation and inflation uncertainty. Thus, we can test for state-dependence of the Calvo parameter in a straightforward way. To address residual heteroscedasticity in the inference process regarding functional dependence, we make use of the factor-based bootstrap. We confirm that the Calvo scheme is a rather restrictive model of aggregate price setting, since it deploys state-dependence, especially, with respect to inflation. Quantitatively, the influence of inflation on the Calvo parameter is small but statistically significant. Further, it is documented that a number of shortcomings of empirical NKPC representations in explaining inflation data may be addressed by means of a state-dependent pricing rule. In particular, problems of insignificant or even implausibly negative estimates of the relation between inflation and marginal costs are considerably reduced in the framework of our more general NKPC specification.

Summarizing the empirical part of the thesis calls for some cautionary notes on the way we think about nominal rigidities with clear implications for the analysis in the theoretical part of this thesis. First, with standard macroeconomic applications, we tend to overstate the true nominal rigidity in the economy. Therefore, estimates of structural NKPCs from quarterly data might not be suitable means to calibrate NKMs for simulation. Relying on traditional estimates, economists run the risk of overstating the power of monetary policy. With respect to the NKM from Chapter 2 we present a robustness analysis that takes account of this fact and allows for varying degrees of nominal rigidity. As the Chapter shows, the degree of nominal rigidity not only influences the extend to which monetary policy influences the real sector, but also changes the optimal inflation target. The overall effects are by no means negligible and should be suitably accounted for. Chapter 4, in this sense, offers a novel way to obtain estimates for the Calvo parameter, which seem closer to the true degree of price stickiness in the economy considered.

Second, thinking about firms price setting in terms of a strict time-dependent

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pricing rule is a much too restrictive assumption. As Chapter 5 shows, price setting is described by a state-dependent process rather than a time-dependent one. Inspired by this evidence, state-dependent price and wage setting is given special attention in this thesis. Additionally to time-dependent pricing à la Calvo (1983), Chapter 2 analyzes the influence of inequality aversion on the long-run effectiveness of monetary policy under state-dependent wage setting, by means of a standard ad-hoc adjustment cost model. Even though the influence of inflation on the average frequency of nominal changes in our model is somewhat small, which is in line with the empirical results for state-dependent pricing from Chapter 5, this does not mean that time-dependent pricing is a suitable approximation for state-dependent price and wage setting. Especially for higher inflation rates, say above 5%, the quantitative difference from the state-dependent approach to the time-dependent approach increase. Unfortunately, time-dependent price setting mechanisms still dominate the literature on monetary policy. These time-dependent pricing rules are, like most of the standard state-dependent pricing rules, derived from ad-hoc assumptions about the price setting process. Chapter 3, by contrast, offers a novel price setting mechanism, which is derived completely from optimal microeconomic decision making based on our alternative view on preferences. In accordance with the evidence found in Chapter 4, prices are far from flexible in this alternative approach and, in accordance with our finding in Chapter 5, price setting is state-dependent. Therefore, Chapter 3 suggests a new rationale for the empirical findings on price sluggishness from Chapters 4 and 5, which are much in line with the empirical literature on pricing in general.

Finally, the thesis ends with a summary of the most important results and contributions and gives a brief outlook for future research.

## 2. INEQUALITY AVERSION AND THE PHILLIPS CURVE

**Sections 2.1 - 2.6** are joint efforts with Professor Dennis J. Snower, Ph.D. and have been published in the paper “Envy, Guilt, and the Phillips Curve” in the *Journal of Economic Behavior & Organization*, volume 99, March 2014, pages 69-84. The journal article is available at:

<http://dx.doi.org/10.1016/j.jebo.2013.12.015>.

### *2.7 How Useful is the Calvo Nominal Contracts Scheme?*

In this section we discuss the validity of the Calvo nominal contracts scheme for our analysis. As indicated in Section 2.4, the Calvo nominal contracts scheme implies an upper bound on the steady state inflation rate, up to which the model is defined. For this reason, we have so far restricted our analysis to steady state inflation rates equal to and below 5 percent. As Ascari (2004) and Bakhshi et al. (2007a) point out, for the optimal reset wage to be defined in the steady state, all effective discount factors in equations (2.8) and (2.9) must be smaller than unity for the infinite summations over these effective discount factors to converge to a finite value. Convergence is granted if the following condition is satisfied:<sup>34</sup>

$$\max \left\{ \alpha\beta(1 + \pi)^{2(\theta-1)}; \alpha\beta(1 + \pi)^{\theta(1+\eta)} \right\} < 1. \quad (2.17)$$

<sup>34</sup>The condition stated in equation (2.17) can be directly seen from equations (2.46) and (2.47) in the appendix.



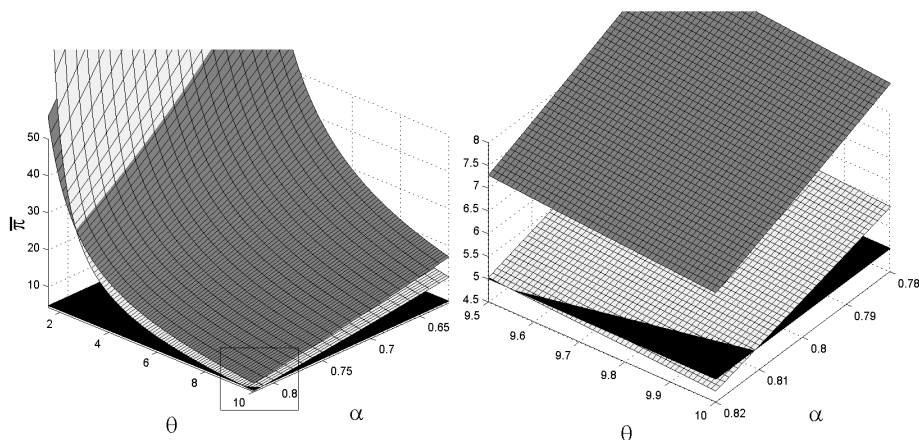


Fig. 2.7: Admissible parameter space for steady state inflation

From condition (2.17) it follows that the maximum inflation rate  $\bar{\pi}$ , for which the model is defined under the Calvo nominal contracts scheme, is given by

$$\bar{\pi} = \min \left\{ \left( \left( \left( \frac{1}{\alpha\beta} \right)^{\frac{1}{2(\theta-1)}} \right)^4 - 1 \right) 100; \left( \left( \left( \frac{1}{\alpha\beta} \right)^{\frac{1}{\theta(1+\eta)}} \right)^4 - 1 \right) 100 \right\}. \quad (2.18)$$

The criterion in (2.18) depends on the parameters  $\alpha$ ,  $\beta$ ,  $\theta$ , and  $\eta$ . The influence of  $\beta$  and  $\eta$  is quantitatively negligible over the range of values considered for these parameters. This is different for  $\alpha$  and  $\theta$ . The larger either the substitutability among the worker types  $\theta$  or the Calvo probability  $\alpha$ , the closer to unity the effective discount factors, even for low rates of steady state inflation. A visual representation for admissible steady state inflation rates, given the range of values for the parameters  $\alpha$  and  $\theta$  from the robustness exercise, is displayed in Figure 2.7.<sup>35</sup> The black shaded surface denotes our threshold of 5 percent steady state inflation. The light shaded surface and the dark shaded surface are the first and the second term in equation (2.18), respectively.

The left panel of Figure 2.7 shows that with the exception of very low substitutability among the different labor types (i.e. a very low value for  $\theta$ ) the first expression in (2.18) is binding. The right panel of Figure 2.7 shows a magnifi-

<sup>35</sup>Figure 2.7 stems from the base calibration. All results reported in this section carry through for alternative values of  $\eta \in (0.11; 0.25; 0.66)$  and in the absence of discounting, i.e.  $\beta = 1$ .

cation of the southern tip of the left panel, i.e. for very sticky wages combined with highly substitutable labor types. As is apparent, if  $\alpha > 0.81$  and  $\theta > 9.5$  hold joint, the maximum steady state inflation rate is slightly below our threshold value of 5 percent.<sup>36</sup> This extreme parameter combination, however, has not been applied in this chapter and therefore, in each application above, our model under the Calvo nominal contracts scheme is defined, given our choice for a maximum steady state inflation rate of 5 percent.

The literature provides two straightforward ways to address this technical constraint. A first solution is to endogenize the frequency of wage adjustment, as seen in the previous section. The argument goes along the following line: With higher inflation workers update their wage contracts more frequently, i.e. they shorten the average contract period. Consequently, while the effective discount factor increases in steady state inflation, it decreases through a declining Calvo probability  $\alpha$ .<sup>37</sup> A second alternative to circumvent the technical constraint is to apply the nominal contract scheme by Taylor (1979) instead of the nominal contract scheme by Calvo (1983). Since the Taylor nominal contract scheme has finite wage contracts, each contract period by definition has a finite present value. Convergence of infinite sums is no issue in this approach. We explore this alternative in the next section.

## 2.8 *Taylor Nominal Contracts Scheme*

In this section we compare the Calvo nominal contracts scheme to the Taylor nominal contracts scheme. The former is characterized by a random duration of each single wage contract, whereas in the latter wage contracts are rewritten in a certain predetermined interval, say each year, in a uniformly staggered manner. This comparison is of interest, since much of the literature on the long-run New Keynesian Philips curve resorts to the Taylor nominal contracts

<sup>36</sup>In the absence of discounting ( $\beta = 1$ ) the joint threshold is given by  $\alpha > 0.8$  and  $\theta > 9.1$ .

<sup>37</sup>The relative quantitative importance of each of the two effects on the effective discount factor depends on the inflation elasticity of the Calvo probability.

scheme.<sup>38</sup> Additionally, the Taylor nominal contracts scheme is not subject to the technical constraint from the previous section. For this reason, we are able to explore the Phillips curves for steady state inflation rates higher than 5 percent. In the following we briefly lay out the model under Taylor nominal wage contracts and juxtapose the long-run Phillips curves associated with each of the two wage setting regimes.

### 2.8.1 Workers with Taylor nominal Wage Contracts

Under the Taylor (1979) nominal contracts scheme workers are grouped into  $N$  different wage setting cohorts  $h$ , for  $h = 1 \dots N$  and  $N < \infty$ . Each period a different cohort  $h$  writes a new wage contract and each wage contract is fixed for  $N$  periods. Thus, wage contracts are uniformly staggered. The number of periods  $N$  is chosen such that wage contracts are fixed for one year, in accordance with empirical macroeconomic evidence by Taylor (1999). The preferences of a representative worker from cohort  $h$  are represented by a (social) utility function of the form

$$u_t(c_{h,t}, n_{h,t}, \Delta_{h,\bar{k},t}) = c_{h,t} - \zeta \frac{n_{h,t}^{1+\eta}}{1+\eta} - \psi_{h,\bar{k},t} \frac{\Delta_{h,\bar{k},t}^2}{2}, \quad (2.19)$$

where  $c_h$  is consumption of a worker from cohort  $h$  and  $n_h$  is her labor supply. The term  $\Delta_{h,\bar{k}}$  denotes the relative real income position of a worker from cohort  $h$ , which is defined as

$$\Delta_{h,\bar{k},t} = w_{h,t} n_{h,t} - \frac{1}{N-1} \sum_{k \neq h} w_{k,t} n_{k,t}, \quad (2.20)$$

where  $w_{h,t}$  is the period- $t$  value of the nominal contract wage of a worker from cohort  $h$ . Inequality aversion, again, is captured by the third term in the utility function. Workers who fall short of the average real income from all other cohorts feel envy, while workers who exceed it feel guilt. Worker  $h$ 's period- $i$

<sup>38</sup>See, e.g. Ascari (1998, 2004), Graham and Snower (2003, 2004, 2008, 2013), Karanassou et al. (2005, 2008), Vaona (2012, 2013a, b), and Vaona and Snower (2008).

budget constraint is given by

$$c_{h,t} + m_{h,t+1} + b_{h,t+1} = w_{h,t}n_{h,t} + \frac{R_t b_{h,t} + m_{h,t}}{1 + \pi} + \Upsilon_{h,t}, \quad (2.21)$$

with  $m_h$  and  $b_h$  being real money and bond holdings of a worker from cohort  $h$ . Lump sum transfers from the government to workers from cohort  $h$  are given by  $\Upsilon_h$ . Analogously to the model under the Calvo nominal contracts scheme with group comparison, the indicator function  $\psi_{h,\bar{k},t}$  is

$$\psi_{h,\bar{k},t} = \begin{cases} \varepsilon & \text{for } \Delta_{h,\bar{k},t} < 0 \\ \gamma & \text{for } \Delta_{h,\bar{k},t} > 0 \end{cases}. \quad (2.22)$$

At the beginning of a new contract period, a worker from cohort  $h$  sets her reset wage to maximize her expected utility over the finite contract period

$$\max_{w_{h,t}} E_t \sum_{i=0}^{N-1} \beta^i [u_{t+i}(c_{h,t+i}, n_{h,t+i}, \Delta_{h,\bar{k},t+i})], \quad (2.23)$$

subject to her budget constraint (2.21) and her downward-sloping labor demand curve (2.2). The optimal wage is set as a markup over the marginal rate of substitution between the present value of the marginal disutilities of labor (the numerator) and the sum of the present values of the marginal utilities of consumption and income (the denominator):

$$w_{h,t}^* = \mu \frac{\zeta E_t \sum_{i=0}^{N-1} \beta^i n_{h,t+i}^{1+\eta}}{E_t \sum_{i=0}^{N-1} \beta^i \frac{n_{h,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{N-1} \beta^i \psi_{h,\bar{k},t+i} \Delta_{h,\bar{k},t+i} \frac{n_{h,t+i}}{(1+\pi)^i}}, \quad (2.24)$$

which after some simple rearrangements yields the labor supply relation

$$\mu \zeta E_t \sum_{i=0}^{N-1} \beta^i n_{h,t+i}^{1+\eta} = E_t \sum_{i=0}^{N-1} \beta^i (1 - \psi_{h,\bar{k},t+i} \Delta_{h,\bar{k},t+i}) \frac{w_{h,t}^* n_{h,t+i}}{(1+\pi)^i}. \quad (2.25)$$

Since wage contracts are finite, deterministic and fully symmetric under the Taylor nominal contracts scheme the steady state reset wage index differs from

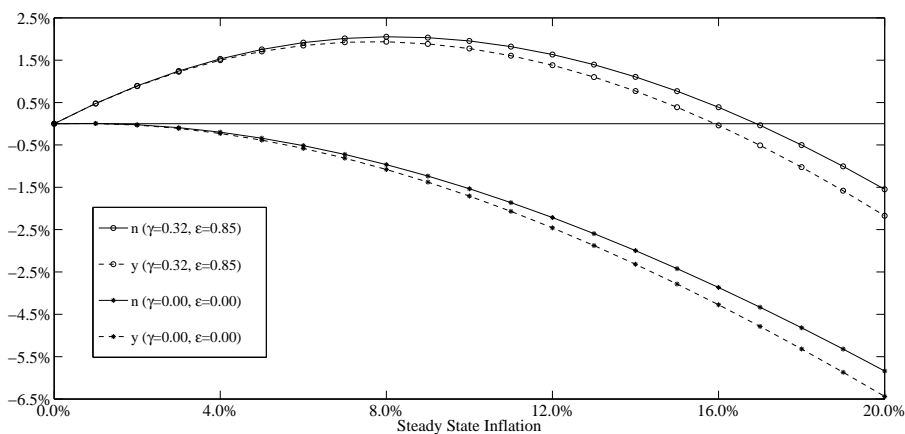


Fig. 2.8: Relation of inflation to real variables under the Taylor nominal contracts scheme

the steady state wage index under the Calvo nominal contracts scheme. Under the Taylor nominal contracts scheme it is given by

$$w^{Taylor} = \left[ \frac{1}{N} \frac{1 - (1 + \pi)^{N(\theta-1)}}{1 - (1 + \pi)^{\theta-1}} \right]^{\frac{1}{\theta-1}}. \quad (2.26)$$

The model under the Taylor nominal contract scheme is fully described by the reset wage (2.26), the labor demand relation (2.2), and the labor supply relation (2.25). Following Taylor (1999), we calibrate  $N = 4$  to match wage contracts which are fixed for one year in a quarterly setting.<sup>39</sup> All remaining parameters are calibrated in accordance with Table 2.1. Finally, we solve the model along the same lines described in Section 2.3.3.

### 2.8.2 Results

Figure 2.8 shows the long-run Phillips curves associated with the Taylor nominal contracts scheme for steady state inflation rates up to 20 percent. The upper two Phillips curves show the long-run tradeoff in the presence of envy and guilt, while the lower two Phillips curves show the long-run tradeoff in the absence of

<sup>39</sup>The results are fully robust to the number of cohorts, given that contracts are fixed for one year.

envy and guilt. Not surprisingly, the figure shows that also for the model with the Taylor nominal contracts scheme the positive long-run tradeoff is substantial, only under the presence of envy and guilt. In the absence of envy and guilt, the standard result in the literature is restored, i.e. the tradeoff is barely positive for very small inflation rates and significantly negative afterwards. Under the Taylor nominal contract scheme, inflation influences macroeconomic activity through the same four channels (i.e. employment cycling, labor smoothing, discounting, and envy and guilt) as in the earlier sections. Therefore, the intuitive analysis for the long-run tradeoff under the Taylor nominal contracts scheme carries over one-to-one from the model under the Calvo nominal contracts scheme (Section 2.4).

While qualitatively, the Taylor nominal contracts scheme and the Calvo nominal contracts scheme, produce the same outcome, quantitatively, they do not. A first indication is already given by Figure 2.8. The typical nonlinear shape of the long-run Phillips curves displayed in the figure arises over a much wider range of steady state inflation (i.e. up to 20 percent). Figure 2.9 strengthens this point. The figure juxtaposes the long-run Phillips curves associated with the Taylor nominal contracts scheme (crossed) and the Calvo nominal contracts scheme (circled). The figure shows that the sensitivity of the long-run tradeoff with respect to the steady state inflation rate differs substantially among the two approaches. While the long-run tradeoff under the Calvo nominal contracts scheme is highly sensitive to trend inflation, turning negative already at moderate inflation rates around four percent, the Phillips curves under the Taylor nominal contracts scheme remain positive over the full range of steady state inflation considered.<sup>40</sup>

The reason for this result is straightforward. As noted, the long-run tradeoff is generated by real wage and income dispersion. With Calvo nominal wage contracts some workers have not reset their nominal wage for a very long time. Consequently, these workers' real wages approach zero, which in turn makes

<sup>40</sup>This result is in line with well established theoretical evidence by Ascari (2004).

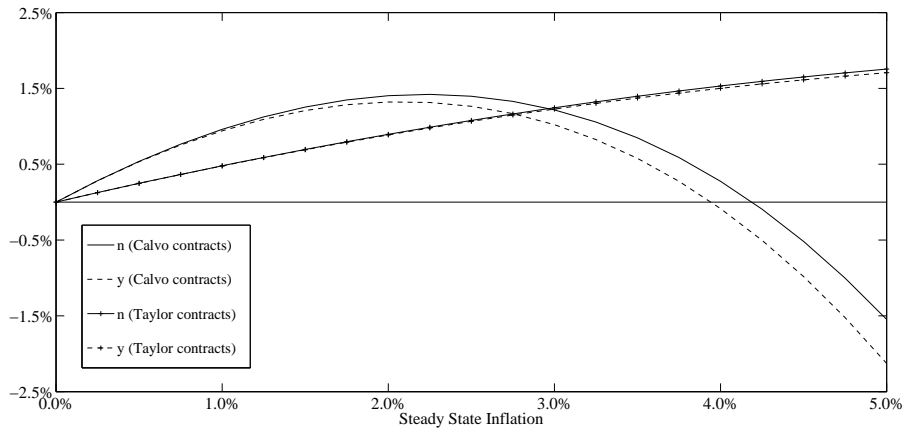


Fig. 2.9: Relation of inflation to real variables under the Calvo nominal contracts scheme and the Taylor nominal contracts scheme

firms want to employ almost exclusively from this worker pool. The inefficiency associated with the resulting excessive use of employment cycling substantially drives down output. Any (even small) positive steady state inflation rate drives a large wedge between the highest and the lowest real wage, making real macroeconomic activity highly sensitive to positive steady state inflation. Under the Taylor nominal contracts scheme, on the other hand, there are only a few different wages. In the case considered above, there are only four different wage setting cohorts and therewith only four different wages. Furthermore, none of these prices is older than one year by definition. Although, also under the Taylor nominal contracts scheme, positive trend inflation drives a wedge into the real wage distribution, this wedge is substantially smaller. Therefore, under the Taylor nominal contracts scheme much higher trend inflation is necessary to generate wage dispersion large enough for the employment cycling and labor smoothing effects to dominate in a quantitative equivalent manner as under the Calvo nominal contracts scheme. Consequently, the long-run tradeoff is much less sensitive to steady state inflation.

Another advantage of the Taylor nominal contracts scheme, is its tractability. This allows us to analyze an alternative model of inequality aversion, namely

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the bilateral comparison by Fehr and Schmidt (1999), which we consider in the next section.

### 2.9 *Bilateral vs. Group Comparison*

Up to this point, following the idea of Bolton and Ockenfels (2000), workers engaged in group comparison, i.e. they have compared their real income to the average real income of all other workers in their reference group.<sup>41</sup> In what follows, we allow for a different approach to inequality aversion. Following the idea of Fehr and Schmidt (1999), workers compare their real income to each other real income in their reference group bilaterally and evaluate the outcome of each comparison individually. We refer to this approach as “bilateral comparison.”<sup>42</sup>

The different treatment of the reference group strongly affects the implications of inequality aversion for utility. Intuitively, under group comparison the middle-income worker does not suffer from any inequality aversion at all, whereas the same worker suffers substantially from both - envy and guilt - under bilateral comparison. Thus, with group comparison workers exclusively care about their relative position to the average income, whereas with bilateral comparison workers care about the income distribution per se.

Against this background, we compare the influence of these two different concepts of inequality aversion on the effectiveness of monetary policy. For simplicity and analytical tractability, we resort to the Taylor nominal contracts scheme from the previous section.

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<sup>41</sup>The reference group was defined as the whole economy.

<sup>42</sup>The articles by Fehr and Schmidt (1999) and Bolton and Ockenfels (2000) are the two predominant contributions in the literature on inequality aversion. Bergh (2008) shows that by May 2007 the combined citation impact of these two articles relative to other significant contributions in the field of other-regarding preferences had been approximately 84 percent. Individually, Fehr and Schmidt (1999) and Bolton and Ockenfels (2000) had accounted for 46 percent and 38 percent, respectively.



## 2.9.1 Workers with Bilateral Comparison

As in the previous section, monopolistic competitive workers write Taylor wage contracts. The preferences of the worker are represented by her (social) utility function

$$u_t(c_{h,t}, n_{h,t}, \Delta_{h,k,t}) = c_{h,t} - \zeta \frac{n_{h,t}^{1+\eta}}{1+\eta} - \frac{1}{N-1} \sum_{k \neq h} \psi_{h,k,t} \frac{\Delta_{h,k,t}^2}{2}, \quad (2.27)$$

where  $\Delta_{h,k,t}$  denotes the bilateral real income deviation between a worker from cohort  $h$  and a worker from cohort  $k$  for  $k = 1, \dots, N-1$ , defined by

$$\Delta_{h,k,t} = w_{h,t}n_{h,t} - w_{k,t}n_{k,t}. \quad (2.28)$$

Inequality aversion is governed by the third term in the utility function (2.27), which implies that a worker from cohort  $h$  bilaterally compares her real income to the real income of each other worker  $k \neq h$  in her reference group. If a worker falls short of another worker's income, she feels envy, whereas she feels guilt, if she exceeds another worker's income. For the special case of only two wage setting cohorts ( $N = 2$ ), group comparison and bilateral comparison coincide. With bilateral comparison, the indicator function  $\psi_{h,k,t}$  is

$$\psi_{h,k,t} = \begin{cases} \varepsilon & \text{for } \Delta_{h,k,t} < 0 \\ \gamma & \text{for } \Delta_{h,k,t} > 0 \end{cases}. \quad (2.29)$$

At the beginning of a new contract period worker  $h$  maximizes her utility function

$$\max_{w_{h,t}} E_t \sum_{i=0}^{N-1} \beta^i u_{t+i}(c_{h,t+i}, n_{h,t+i}, \Delta_{h,k,t+i}) \quad (2.30)$$

subject to her budget constraint (2.21) and her individual labor demand curve (2.2). The optimal wage is again set as a markup over the marginal rate of substitution between the present value of the disutility of labor and the sum of

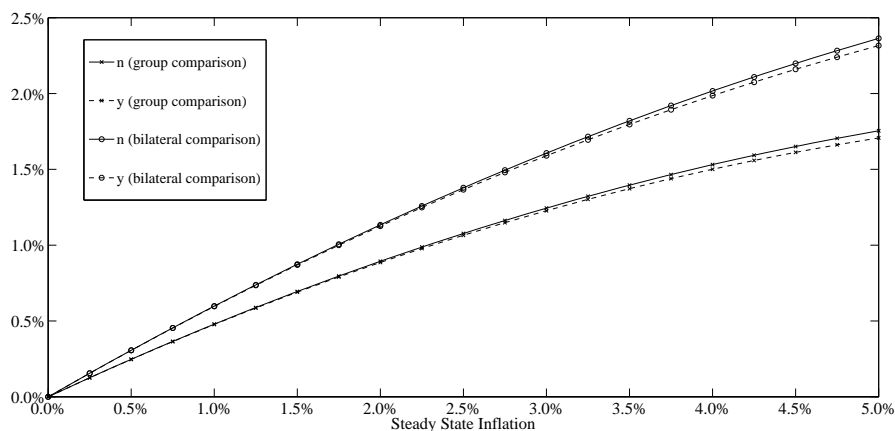


Fig. 2.10: Relation of inflation to real variables for group versus bilateral comparison

the present values of the marginal utility of consumption and income.

$$w_{h,t}^* = \mu \frac{\zeta E_t \sum_{i=0}^{N-1} \beta^i n_{h,t+i}^{1+\eta}}{E_t \sum_{i=0}^{N-1} \beta^i \frac{n_{h,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{N-1} \beta^i n_{h,t+i} \frac{1}{N-1} \sum_{k \neq h} \psi_{h,k,t+i} \Delta_{h,k,t+i}}. \quad (2.31)$$

Rearranging the optimal reset wage yields the labor supply equation under bilateral comparison.

$$\mu \zeta E_t \sum_{i=0}^{N-1} \beta^i n_{h,t+i}^{1+\eta} = E_t \sum_{i=0}^{N-1} \beta^i \frac{w_{h,t}^* n_{h,t+i}}{(1+\pi)^i} \left( 1 - \frac{1}{N-1} \sum_{k \neq h} \psi_{h,k,t+i} \Delta_{h,k,t+i} \right) \quad (2.32)$$

Under bilateral comparison, the model is fully described by the reset wage (2.26), the labor demand relation (2.2), and the labor supply relation (2.32). Once again, we solve the model numerically along the lines described in Section 2.3.3.

## 2.9.2 Results

Figure 2.10 shows the Phillips curves associated with group comparison (circled) and bilateral comparison (crossed), given the base calibration from Table 2.1 and  $N = 4$ . The figure shows that monetary policy has significant long-run real effects under both models of inequality aversion. Interestingly, while the

qualitative result is independent of the choice between bilateral and group comparison, the quantitative result is not. Figure 2.10 clearly indicates that the effectiveness of monetary policy is larger, if the underlying workers evaluate income inequality on a bilateral basis. Expansionary monetary policy, for instance given by an increase in money growth from 0 percent to 2 percent, is associated with a 0.89 percent increase in aggregate employment under group comparison, whereas this figure elevates to 1.13 percent under bilateral comparison. Output increases by 0.88 percent and 1.12 percent, respectively.

This result is not surprising. Under bilateral comparison, steady state inflation generates substantially more envy and guilt than under group comparison. This can be best illustrated by looking at the middle-income worker. Consider first the middle-income worker using group comparison. Intuitively, the middle-income worker has disutility neither from envy nor from guilt, since the worker earns exactly as much as the average of all other workers. The same worker, however, has substantial disutility from both, envy and guilt, when she engages in bilateral comparison. She feels envy towards all workers who exceed her real income and guilt towards all workers who fall short of her real income. Since envy is greater than guilt, however, she will increase her average employment over the contract period. This real effect is not matched by the middle-income worker under group comparison. A similar weighting effects also hold true for non-middle-income workers. In general, under group comparison, workers overrate positive deviations and underrate the role of negative deviations, giving rise to more guilt and less envy. Therefore, this weighing-effect mitigates the dominance of the envy effect over the guilt effect and induces a weakened net reaction of employment to income inequality.

### *2.10 Summary and Concluding Remarks*

This chapter has incorporated inequality aversion into an otherwise standard New Keynesian DSGE model with staggered, monopolistically competitive nominal wage contracts. In this context, the relation between inflation and macroe-

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conomic activity is generated by four phenomena: employment cycling, labor supply variability, discounting, and envy-guilt effects. The first two phenomena imply an inverse relation between inflation and macroeconomic activity, whereas the last two are complementary and imply a positive relation. Furthermore, the last two dominate at low inflation rates, whereas the first two dominate at high inflation rates. Consequently, the Phillips curve is backward-bending, so that increases in money growth lead to higher employment and output at low inflation, but to lower employment and output at high inflation.

What is striking about this tradeoff is that inequality aversion generates a positive tradeoff between inflation and macroeconomic activity over a substantial range of low inflation rates. We show that, along this tradeoff, the optimal inflation rate is significantly positive. For our base calibration, the optimal inflation rate is just under 2 percent.

This result is consonant with central banking practice. By contrast, the mainstream literature on optimal monetary policy places the optimal inflation rate in the range between zero and a negative number (minus the real interest rate, as implied by the Friedman rule).

Endogenizing the probability of wage adjustment does not restore monetary long-run neutrality, as long as wage changes are costly.

Furthermore, we have shown that the positive long-run tradeoff is also generated under the Taylor nominal contracts scheme. Even though the Taylor nominal contracts scheme seems technically preferable to the Calvo nominal contracts scheme, the former lacks ability to create a convincing environment for the presence of envy and guilt. Knowing that one's income cycles in a deterministic sense over the course of only one year, it is questionable that feelings of envy and guilt are generated. In this sense, the Calvo model is much more suited to create an environment in which envy and guilt flourish. Only if workers do not know for how long their income will be higher or lower than their reference income, feelings such as envy and guilt might occur.

Finally, we have shown that the long-run tradeoff even strengthens if workers

compare themselves to each other worker bilaterally instead of comparing to the average of the economy. As we argue, this result is brought about by an additional margin of inequality aversion. Workers do not only care about the average income, but about the income distribution per se. Experimental evidence by Engelmann and Strobel (2004) indicates that agents comply with the predictions of a preference structure characterized by bilateral comparison rather than group comparison. From the macroeconomic perspective, however, group comparison seems more appropriate than bilateral comparison. This is due to the availability of income information. While it seems impossible to gather detailed information on the complete income distribution of an economy, average income data is publicly available. Such information is provided by, e.g. national statistical agencies. For the special case of Germany information on the German average income as well as the average income of several occupational categories in Germany is published annually by popular German newspapers and magazines. However, this does not weaken the importance of the result under bilateral comparison. Even if the model takes place only in a well-defined reference group, e.g. an occupation, a firm, or such alike, the representative agent framework still generates macroeconomic results along New Keynesian lines.

## 2.11 Appendix A

### 2.11.1 A1. The Long-Run Tradeoff Between Inflation and Aggregate Output under the Calvo Nominal Contracts Scheme with Group Comparison

The worker maximizes utility

$$\max_{w_{j,t}} E_t \sum_{i=0}^{\infty} (\alpha\beta)^i [U(c_{j,t+i}) - V(n_{j,t+i}) - Z(\Delta_{j,\bar{k},t+i})], \quad (2.33)$$

subject to her budget constraint (2.6), her downward-sloping labor demand (2.2), and the definition of income inequality given by (2.4). The reference

income is given by the average income in the economy. According to utility function (2.3)

$$U(c_{j,t+i}) = c_{j,t+i}, \quad (2.34)$$

$$V(n_{j,t+i}) = \zeta \frac{n_{j,t}^{1+\eta}}{1+\eta}, \quad (2.35)$$

$$Z(\Delta_{j,\bar{k},t+i}) = \psi_{j,\bar{k},t} \frac{\Delta_{j,\bar{k},t}^2}{2}. \quad (2.36)$$

The first order condition of this maximization problem yields

$$E_t \sum_{i=0}^{\infty} (\alpha\beta)^i \left[ (1-\theta)U_c \frac{n_{j,t+i}}{(1+\pi)^i} + \theta V_n \frac{n_{j,t+i}}{w_{j,t}} - (1-\theta)Z_{\Delta} \frac{n_{j,t+i}}{(1+\pi)^i} \right] = 0, \quad (2.37)$$

where  $U_c$ ,  $V_n$ , and  $Z_{\Delta}$  denote the first derivatives of (2.34), (2.35), and (2.36), respectively. Re-arranging equation (2.37) we get

$$\begin{aligned} E_t \sum_{i=0}^{\infty} (\alpha\beta)^i \theta V_n \frac{n_{j,t+i}}{w_{j,t}} & \quad (2.38) \\ & = (\theta - 1) \left[ E_t \sum_{i=0}^{\infty} (\alpha\beta)^i \frac{U_c n_{j,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{\infty} (\alpha\beta)^i \frac{Z_{\Delta} n_{j,t+i}}{(1+\pi)^i} \right]. \end{aligned}$$

Rearranging equation (2.38) with respect to  $w_{j,t}$  yields

$$w_{j,t} = \frac{\theta}{\theta - 1} \frac{E_t \sum_{i=0}^{\infty} (\alpha\beta)^i V_n n_{j,t+i}}{E_t \sum_{i=0}^{\infty} (\alpha\beta)^i U_c \frac{n_{j,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{\infty} (\alpha\beta)^i Z_{\Delta} \frac{n_{j,t+i}}{(1+\pi)^i}}. \quad (2.39)$$

The first derivatives of  $V_n$ ,  $U_c$ , and  $Z_{\Delta}$  are given by

$$V_n = \zeta n_{j,t+i}^{\eta}, \quad (2.40)$$

$$U_c = 1, \quad (2.41)$$

$$Z_{\Delta} = \psi_{j,\bar{k},t+i} \Delta_{j,\bar{k},t+i} \quad (2.42)$$

Plugging equations (2.40), (2.41), and (2.42) into (2.39) gives the optimal reset wage as in Section 2.3.2

$$w_{j,t}^* = \mu \frac{\zeta E_t \sum_{i=0}^{\infty} (\alpha\beta)^i n_{j,t+i}^{1+\eta}}{E_t \sum_{i=0}^{\infty} (\alpha\beta)^i \frac{n_{j,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{\infty} (\alpha\beta)^i \psi_{j,\bar{k},t+i} \Delta_{j,\bar{k},t+i} \frac{n_{j,t+i}}{(1+\pi)^i}}. \quad (2.43)$$

where  $\mu = \frac{\theta}{\theta-1}$  denotes the markup. Rearranging equation (2.43) yields an equivalent expression to the labor supply equation (2.9). Applying the downward sloping labor demand equation (2.2) to equation (2.43), we can write equation (2.43) in terms of aggregate labor

$$w_{j,t}^{*(1+\theta\eta)} = \mu \frac{\zeta E_t \sum_{i=0}^{\infty} (\alpha\beta(1+\pi)^{\theta(1+\eta)})^i y_{t+i}^{1+\eta}}{E_t \sum_{i=0}^{\infty} (\alpha\beta(1+\pi)^{\theta-1})^i (1 - \psi_{j,\bar{k},t+i} \Delta_{j,\bar{k},t+i}) y_{t+i}}. \quad (2.44)$$

Substituting (2.4) for  $\Delta_{j,\bar{k},t+i}$  and dropping time indices yields the steady state expression of (2.44) given by

$$w_j^{*(1+\theta\eta)} = \mu \frac{\phi}{\chi}, \quad (2.45)$$

with

$$\phi = y^\eta \zeta E \sum_{i=0}^{\infty} (\alpha\beta(1+\pi)^{\theta(1+\eta)})^i, \quad (2.46)$$

$$\chi = E \sum_{i=0}^{\infty} (\alpha\beta(1+\pi)^{\theta-1})^i \left( 1 - \psi_j y \left[ \left( \frac{w_{j,\bar{k}}^*}{(1+\pi)^i} \right)^{1-\theta} - 1 \right] \right). \quad (2.47)$$

Next, to solve the model numerically, we need to let the infinite sums in equations (2.46) and (2.47) converge. The sum formulation in (2.46) can be written in terms of the infinite geometric sum according to the rule  $\sum_{k=0}^{\infty} x^k = \frac{1}{1-x}$ , which results in

$$\phi = y^\eta \zeta \frac{1}{1 - \alpha\beta(1+\pi)^{\theta(1+\eta)}}. \quad (2.48)$$

For equation (2.47), this is different. Note that the summation in (2.47) includes periods of envy as well as periods of guilt. While the worker feels envy in periods

$t = 0, \dots, \tau - 1$ , she feels guilt in periods  $t = \tau, \dots, \infty$ . The threshold  $\tau$  denotes the switching point of the sign on the left hand side of equation (2.4). Applying the indicator function (2.5), equation (2.47) reads

$$\begin{aligned} \chi &= E \sum_{i=0}^{\tau-1} \left( \alpha\beta (1+\pi)^{(\theta-1)} \right)^i \left( 1 - \varepsilon y \left[ \left( \frac{w_j^*}{(1+\pi)^i} \right)^{1-\theta} - 1 \right] \right) \\ &+ E \sum_{i=\tau}^{\infty} \left( \alpha\beta (1+\pi)^{(\theta-1)} \right)^i \left( 1 - \gamma y \left[ \left( \frac{w_j^*}{(1+\pi)^i} \right)^{1-\theta} - 1 \right] \right). \end{aligned} \quad (2.49)$$

The sum formulation in (2.49) can be written in terms of (in-)finite geometric sums. We apply the rules  $\sum_{k=0}^{\tau-1} x^k = \frac{1-x^{(\tau-1)+1}}{1-x}$  and  $\sum_{k=\tau}^{\infty} x^k = \frac{x^\tau}{1-x}$ . After some manipulations equation (2.49) becomes

$$\chi = \frac{y^{-1} + (\varepsilon + (\gamma - \varepsilon) (\alpha\beta(1+\pi)^{\theta-1})^\tau)}{1 - \alpha\beta(1+\pi)^{\theta-1}} - \frac{(\varepsilon + (\gamma - \varepsilon) (\alpha\beta(1+\pi)^{2(\theta-1)})^\tau)}{w_j^{*(\theta-1)} (1 - \alpha\beta(1+\pi)^{2(\theta-1)})}. \quad (2.50)$$

Plugging (2.48) and (2.50) back into (2.45) yields

$$w_j^{*(1+\theta\eta)} = \mu \frac{y^{\eta-1} \zeta (1 - \alpha\beta(1+\pi)^{\theta(1+\eta)})^{-1}}{\frac{y^{-1} + (\varepsilon + (\gamma - \varepsilon) (\alpha\beta(1+\pi)^{\theta-1})^\tau)}{1 - \alpha\beta(1+\pi)^{\theta-1}} - \frac{(\varepsilon + (\gamma - \varepsilon) (\alpha\beta(1+\pi)^{2(\theta-1)})^\tau)}{w_j^{*(\theta-1)} (1 - \alpha\beta(1+\pi)^{2(\theta-1)})}}. \quad (2.51)$$

Exploiting the steady state reset wage (2.14), equation (2.51) fully describes the relationship between output and steady state inflation, which can be solved for numerically. Therefore, equations (2.14) and (2.51) describe our long-run Phillips curve tradeoff. Note that for zero steady state inflation, i.e.  $\pi = 0$ , it holds that  $w_j^* = 1$  and the envy and guilt parts cancel each other out and vanish. What remains is the standard formulation from a model without envy and guilt, i.e.  $1 = \mu\zeta y^\eta$ .



2.11.2 A2. *The Long-Run Tradeoff Between Inflation and Aggregate  
Employment under the Calvo Nominal Contracts Scheme with Group  
Comparison*

To derive the relationship between inflation and aggregate labor, we first combine the equations for aggregate labor (2.12) and individual labor demand (2.2). This yields

$$n_t = y_t \underbrace{\int_0^1 w_{j,t}^{-\theta} dj}_{s_t}, \quad (2.52)$$

where  $s_t$  denotes the wage dispersion term, which can be written as

$$s_t = (1 - \alpha)w_{j,t}^{-\theta} + \alpha(1 - \alpha) \left( \frac{w_{j,t-1}}{(1 + \pi)^{-1}} \right)^{-\theta} + \alpha^2(1 - \alpha) \left( \frac{w_{j,t-2}}{(1 + \pi)^{-2}} \right)^{-\theta} + \dots \quad (2.53)$$

Equation (2.53) can be recursively written as

$$s_t = (1 - \alpha)w_{j,t}^{-\theta} + \alpha(1 + \pi)^\theta s_{t-1}. \quad (2.54)$$

In the steady state this yields

$$s = \frac{(1 - \alpha)w_j^{-\theta}}{1 - \alpha(1 + \pi)^\theta}. \quad (2.55)$$

Therefore, the steady state version of (2.52) - including the definition for  $s$  given by (2.55) - and long-run Phillips curve (2.51) yields the long-run tradeoff between inflation and aggregate labor.

2.11.3 A3. *Linear Inequality Aversion*

In this section we give proof of the inviability of the original version of Fehr and Schmidt's (1999) utility function in our model setup. We show that for zero inflation, the model does not break down to the standard NKM with trend

inflation.

Assume a utility function analogous to equation (2.3), only with inequality aversion entering linearly as suggested by Fehr and Schmidt (1999).

$$u_t(c_{j,t}, n_{j,t}, \Delta_{j,\bar{k},t}) = c_{j,t} - \zeta \frac{n_{j,t}^{1+\eta}}{1+\eta} - \psi_{j,\bar{k},t} \Delta_{j,\bar{k},t} \quad (2.56)$$

Income inequality  $\Delta_{j,\bar{k},t}$  is again defined by equation (2.4). Under linear inequality aversion  $\Delta_{j,\bar{k},t}$  changes signs, depending on the position in the income distribution, i.e.  $\Delta_{j,\bar{k},t} < 0$  for having a lower than average real income and  $\Delta_{j,\bar{k},t} > 0$  for having a higher than average real income. To make sure that inequality aversion always enters utility negatively, we calibrate the envy and guilt parameters according to the following scheme:

$$\psi_{j,\bar{k},t} = \begin{cases} -\varepsilon & \text{for } \Delta_{j,\bar{k},t} < 0 \\ \gamma & \text{for } \Delta_{j,\bar{k},t} > 0 \end{cases}. \quad (2.57)$$

Everything else equal, a resetting worker again maximizes utility (2.33) subject to her budget constraint (2.6), her labor demand function (2.2) and the definition of inequality aversion (2.4). Therefore, the general optimal reset wage is still given by equation (2.39). Only the partial derivative with respect to income inequality  $Z_\Delta$  is different in this case. In this case it is simply  $Z_\Delta = \psi_{j,\bar{k},t+i}$ . Therefore, the reset wage becomes

$$w_{j,t}^* = \mu \frac{\zeta E_t \sum_{i=0}^{\infty} (\alpha\beta)^i n_{j,t+i}^{1+\eta}}{E_t \sum_{i=0}^{\infty} (\alpha\beta)^i \frac{n_{j,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{\infty} (\alpha\beta)^i \psi_{j,\bar{k},t+i} \frac{n_{j,t+i}}{(1+\pi)^i}}. \quad (2.58)$$

In terms of aggregate labor, in the steady state, this yields

$$w_j^{*(1+\theta\eta)} = \mu \frac{y^\eta \zeta E \sum_{i=0}^{\infty} (\alpha\beta (1+\pi)^{\theta(1+\eta)})^i}{E \sum_{i=0}^{\infty} (\alpha\beta (1+\pi)^{\theta-1})^i (1 - \psi_{j,\bar{k}})}, \quad (2.59)$$

Applying the geometric sum rules, equation (2.59) becomes

$$w_j^{*(1+\theta\eta)} = \mu \frac{y^\eta \zeta \left(1 - \alpha\beta (1 + \pi)^{\theta(1+\eta)}\right)^{-1}}{\left(1 - \varepsilon - (\varepsilon - \gamma) \left(\alpha\beta (1 + \pi)^{(\theta-1)}\right)^\tau\right) \left(1 - \alpha\beta (1 + \pi)^{(\theta-1)}\right)^{-1}}. \quad (2.60)$$

Unlike equation (2.51), for zero steady state inflation ( $\pi = 0$ ), the envy-guilt parts do not cancel each other out. Consequently, envy and guilt would have effects, even in the absence of income inequality.

#### 2.11.4 A4. Steady State Relative Wage for the Calvo Nominal Contracts

##### Scheme

To calculate the steady state wage index we drop the time indices. The de-trended wage index in a Calvo world is given by

$$w_t = \left[ (1 - \alpha) w_{j,t}^{*1-\theta} + \alpha \left( \frac{w_{t-1}}{1 + \pi} \right)^{1-\theta} \right]^{\frac{1}{1-\theta}}. \quad (2.61)$$

In the steady state we drop time indices

$$w^{1-\theta} = (1 - \alpha) w_j^{*1-\theta} + \alpha \left( \frac{w}{1 + \pi} \right)^{1-\theta}, \quad (2.62)$$

and group terms.

$$\left(1 - \alpha (1 + \pi)^{\theta-1}\right) w^{1-\theta} = (1 - \alpha) w_j^{*1-\theta}. \quad (2.63)$$

Given  $w = 1$ , (2.63) breaks down to the optimal relative steady state wage given by

$$w_j^* = \left( \frac{1 - \alpha}{1 - \alpha (1 + \pi)^{\theta-1}} \right)^{\frac{1}{\theta-1}}. \quad (2.64)$$

## 2.11.5 A5. The Welfare Function

We find the optimal inflation rate by putting the steady state Phillips curve into the converging utility function of the worker. Discounted expected lifetime utility of a worker is given by

$$U = \sum_{i=0}^{\infty} (\alpha\beta)^i \left[ c_{j,t+i} - \zeta \frac{n_{j,t+i}^{1+\eta}}{1+\eta} - \psi_{j,\bar{k},t} \frac{\Delta_{j,\bar{k},t+i}^2}{2} \right], \quad (2.65)$$

which can be separated into three different motives: consumption, labor, and income inequality.

$$U = \sum_{i=0}^{\infty} (\alpha\beta)^i c_{j,t+i} - \sum_{i=0}^{\infty} \zeta (\alpha\beta)^i \frac{n_{j,t+i}^{1+\eta}}{1+\eta} - \varepsilon \sum_{i=0}^{\tau-1} (\alpha\beta)^i \frac{\Delta_{j,\bar{k},t+i}^2}{2} - \gamma \sum_{i=\tau}^{\infty} (\alpha\beta)^i \frac{\Delta_{j,\bar{k},t+i}^2}{2} \quad (2.66)$$

Plugging in the labor demand function to substitute for labor yields

$$U = \sum_{i=0}^{\infty} (\alpha\beta)^i c_{j,t+i} - \sum_{i=0}^{\infty} \zeta (\alpha\beta)^i \frac{\left( \left( \frac{w_{j,t}}{(1+\pi)^i} \right)^{-\theta} y_{t+i} \right)^{1+\eta}}{1+\eta} - \varepsilon \sum_{i=0}^{\tau-1} (\alpha\beta)^i \frac{\Delta_{j,\bar{k},t+i}^2}{2} - \gamma \sum_{i=\tau}^{\infty} (\alpha\beta)^i \frac{\Delta_{j,\bar{k},t+i}^2}{2}. \quad (2.67)$$

Applying the definition of inequality  $\Delta_{j,\bar{k},t+i}$ , dropping time indices, and re-writing the finite and infinite sums in terms of finite and infinite geometric sums, we find

$$U = \frac{y(\pi)}{1-\alpha\beta} - \frac{\zeta w_j^{-\theta(1+\eta)} \frac{y(\pi)^{1+\eta}}{1+\eta}}{1-\alpha\beta\pi^{\theta(1+\eta)}} - \frac{y(\pi)^2}{2} [\varepsilon a(\pi) + \gamma b(\pi)], \quad (2.68)$$

with

$$a(\pi) = \left[ w_j^{2(1-\theta)} \frac{1 - (\alpha\beta(1+\pi)^{2(\theta-1)})^\tau}{1 - \alpha\beta(1+\pi)^{2(\theta-1)}} - 2w_j^{1-\theta} \frac{1 - (\alpha\beta(1+\pi)^{\theta-1})^\tau}{1 - \alpha\beta(1+\pi)^{\theta-1}} + \frac{1 - (\alpha\beta)^\tau}{1 - \alpha\beta} \right] \quad (2.69)$$

and

$$b(\pi) = \left[ w_j^{2(1-\theta)} \frac{(\alpha\beta(1+\pi)^{2(\theta-1)})^\tau}{1-\alpha\beta(1+\pi)^{2(\theta-1)}} - 2w_j^{1-\theta} \frac{(\alpha\beta(1+\pi)^{\theta-1})^\tau}{1-\alpha\beta(1+\pi)^{\theta-1}} + \frac{(\alpha\beta)^\tau}{1-\alpha\beta} \right]. \quad (2.70)$$

Now we can again plug in  $y(\pi)$  and find the maximizing inflation rate.

### 2.11.6 A6. Derivation of Labor Supply Curve under the Taylor Nominal Contracts Scheme with Group Comparison

The worker maximizes discounted life-time utility

$$\max_{w_{h,t}} E_t \sum_{i=0}^{N-1} \beta^i [U(c_{h,t+i}) - V(n_{h,t+i}) - Z(\Delta_{h,\bar{k},t+i})] \quad (2.71)$$

subject to her budget constraint (2.21), her downward-sloping labor demand (2.2), and income inequality (2.20), where the latter is measured in deviations from the average income in the economy. The first order condition of this maximization problem yields

$$E_t \sum_{i=0}^{N-1} \beta^i \left[ (1-\theta)U_c \frac{n_{h,t+i}}{(1+\pi)^i} + \theta V_n \frac{n_{h,t+i}}{w_{h,t}} - (1-\theta)Z_\Delta \frac{n_{h,t+i}}{(1+\pi)^i} \right] = 0. \quad (2.72)$$

Rearranging equation (2.72) with respect to  $w_{j,t}$  yields

$$w_{h,t} = \frac{\theta}{\theta-1} \frac{E_t \sum_{i=0}^{N-1} \beta^i V_n n_{h,t+i}}{E_t \sum_{i=0}^{N-1} \beta^i U_c \frac{n_{h,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{N-1} \beta^i Z_\Delta \frac{n_{h,t+i}}{(1+\pi)^i}}. \quad (2.73)$$

From the utility function (2.19) we obtain the first order conditions  $V_n$ ,  $U_c$ , and  $Z_\Delta$ :

$$V_n = \zeta n_{h,t+i}^\eta, \quad (2.74)$$

$$U_c = 1, \quad (2.75)$$

$$Z_\Delta = \psi_{h,\bar{k},t+i} \Delta_{h,\bar{k},t+i} \quad (2.76)$$

Plugging equations (2.74), (2.75), and (2.76) into (2.73) gives the optimal reset wage for the Taylor model.

$$w_{h,t}^* = \mu \frac{\zeta E_t \sum_{i=0}^{N-1} \beta^i n_{h,t+i}^{1+\eta}}{E_t \sum_{i=0}^{N-1} \beta^i \frac{n_{h,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{N-1} \beta^i \psi_{h,\bar{k},t+i} \Delta_{h,\bar{k},t+i} \frac{n_{h,t+i}}{(1+\pi)^i}}. \quad (2.77)$$

Rearranging equation (2.77) yields the labor supply equation (2.25)

$$\mu \zeta E_t \sum_{i=0}^{N-1} \beta^i n_{h,t+i}^{1+\eta} = E_t \sum_{i=0}^{N-1} \beta^i (1 - \psi_{h,\bar{k},t+i} \Delta_{h,\bar{k},t+i}) \frac{w_{h,t}^* n_{h,t+i}}{(1+\pi)^i}. \quad (2.78)$$

### 2.11.7 A7. Steady State Relative Wage for the Taylor Nominal Contracts Scheme

The steady state wage index is a weighted average of the single cohorts wages, i.e.

$$w_t = \left[ \frac{1}{N} \sum_{h=0}^{N-1} (w_{h,t}^*)^{1-\theta} \right]^{\frac{1}{1-\theta}} \quad (2.79)$$

Given the evolution of the real wage over the contract period, this can be written as

$$w_t = \left[ \frac{1}{N} \sum_{h=0}^{N-1} \left( \frac{w_{h,t-i}^*}{(1+\pi)^i} \right)^{1-\theta} \right]^{\frac{1}{1-\theta}}. \quad (2.80)$$

which is equivalent to

$$w_t = \left[ \frac{1}{N} \left( (w_{h,t}^*)^{1-\theta} + \left( \frac{w_{h,t-1}^*}{(1+\pi)} \right)^{1-\theta} + \dots + \left( \frac{w_{h,t-N+1}^*}{(1+\pi)^{N-1}} \right)^{1-\theta} \right) \right]^{\frac{1}{1-\theta}}. \quad (2.81)$$

In the steady state  $w_{h,t}^* = w_{h,t-1}^* = \dots = w_{h,t-N+1}^* = w_h^*$ , which yields

$$\frac{w_h^*}{w} = \left[ \frac{1}{N} \left( 1 + (1+\pi)^{\theta-1} + \dots + (1+\pi)^{(N-1)(\theta-1)} \right) \right]^{\frac{1}{\theta-1}}. \quad (2.82)$$

The part in parentheses can be expressed as the finite geometric sum of the form  $\sum_{i=0}^{n-1} x^i = \frac{1-x^n}{1-x}$ . Furthermore, it holds that  $w = 1$ . Therefore, the real

reset wage under the Taylor nominal contracts scheme is given by

$$w_h^* = \left[ \frac{1}{N} \frac{1 - (1 + \pi)^{N(\theta-1)}}{1 - (1 + \pi)^{\theta-1}} \right]^{\frac{1}{\theta-1}}. \quad (2.83)$$

### 2.11.8 A8. Derivation of Labor Supply Curve under the Taylor Nominal Contracts Scheme with Bilateral Comparison

The worker maximizes her utility function

$$\max_{w_{h,t}} E_t \sum_{i=0}^{N-1} \beta^i [U(c_{h,t+i}) - V(n_{h,t+i}) - Z(\Delta_{h,k,t+i})] \quad (2.84)$$

subject to her budget constraint (2.21), her downward-sloping labor demand curve (2.2), and income inequality (2.28), where the latter is measured in bilateral deviations from each other worker  $k$  in the economy. In generalized form, the first order condition and the optimal reset wage are equal to equations (2.72) and (2.73), respectively. The difference comes from the partial derivative with respect to income inequality, given by

$$Z_\Delta = \frac{1}{N-1} \sum_{k \neq h} \psi_{h,k,t+i} \Delta_{h,k,t+i}. \quad (2.85)$$

Plugging (2.74), (2.75), and (2.85) into the optimal reset wage (2.73) yields

$$w_{h,t}^* = \mu \frac{\zeta E_t \sum_{i=0}^{N-1} \beta^i n_{h,t+i}^{1+\eta}}{E_t \sum_{i=0}^{N-1} \beta^i \frac{n_{h,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{N-1} \beta^i \frac{n_{h,t+i}}{(1+\pi)^i} \frac{1}{N-1} \sum_{k \neq h} \psi_{h,k,t+i} \Delta_{h,k,t+i}}. \quad (2.86)$$

Rearranging equation (2.86) yields the labor supply equation under bilateral comparison and Taylor staggering.

$$\begin{aligned}
& \mu\zeta E_t \sum_{i=0}^{N-1} \beta^i n_{h,t+i}^{1+\eta} \tag{2.87} \\
& = E_t \sum_{i=0}^{N-1} \beta^i \frac{w_{h,t}^* n_{h,t+i}}{(1+\pi)^i} - E_t \sum_{i=0}^{N-1} \beta^i \frac{w_{h,t}^* n_{h,t+i}}{(1+\pi)^i} \frac{1}{N-1} \sum_{k \neq h} \psi_{h,k,t+i} \Delta_{h,k,t+i}
\end{aligned}$$



### 3. LOSS AVERSE CONSUMERS: AN ALTERNATIVE THEORY OF PRICE ADJUSTMENT

#### *3.1 Outline*

Ample empirical evidence indicates that prices and output respond imperfectly and asymmetrically to positive and negative demand shocks. While firms accommodate positive temporary demand shocks by increasing quantity rather than price, negative temporary demand shocks are more likely to be accommodated by temporary price cuts (Hall et al., 2000). In the event of a permanent demand shock, surprisingly, the asymmetry works the other way around. In this case, prices are generally more responsive to positive shocks than to negative ones, implying that output is more responsive to negative shocks than to positive ones (DeLong and Summers, 1988; Cover, 1992; Weise, 1999; among others). Current theories of price adjustment (e.g. Taylor, 1979; Rotemberg, 1982; Calvo, 1983; among many others) fail to account for these asymmetric price and output responses to positive and negative demand shocks. This chapter, by contrast, offers a theoretical rationale for the observed empirical asymmetries described above.

In particular, we present a new theory of firms' price adjustment in response to consumer loss aversion, as specified in prospect theory (Kahnemann and Tversky, 1979). The resulting theory of price adjustment is starkly at variance with past theories. We find that prices are more upward sluggish than downward in response to temporary demand shocks (implying that output is more responsive to negative temporary shocks than positive ones), while they are more downward sluggish than upward in response to permanent demand

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shocks (implying that output is less responsive to negative permanent shocks than positive ones).

The basic idea underlying our theory is simple. Price increases are associated with utility losses for consumers, whereas price decreases are associated with utility gains. In the spirit of prospect theory, losses are weighted more heavily than gains of equal magnitude. Consequently, demand responses are more elastic to price increases than to price decreases. The result is a kinked demand curve<sup>1</sup>, for which the kink depends on the consumers' reference price. In the spirit of Kőszegi and Rabin (2006), we assume that the reference price is the consumers' rational price expectations.

We assume that consumers know whether any given product demand shock is temporary or permanent. Permanent shocks induce changes in consumers' rational price expectations and thereby on their reference price, while temporary shocks do not. Given the shock is temporary, since the demand curve is kinked, small demand shocks do not affect the firm's price. This is the case of price rigidity. For larger shifts, the firm's price will respond temporarily, but the size of the response will be asymmetric for positive and negative shifts of equal magnitude. Since negative shocks move the firm along the relatively steep portion of the demand curve, prices decline stronger to negative shocks than they increase to positive ones. In turn, this implies that quantities are less responsive to negative shocks than to positive ones. Given the demand shock is permanent, the firm can foresee not only the change in demand following the immediate pricing decision, but also the resulting change in the consumers' reference price. A rise in the reference price raises the firms' long-run profits (since the reference price is located at the kink in the demand curve), whereas a fall in the reference price lowers long-run profits. On this account, firms are averse to initiating permanent price reductions. By implication, prices are more down-

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<sup>1</sup>Modeling price sluggishness by means of a kinked demand curve is of course a well-trodden path. Sweezy (1939) and Hall and Hitch (1939) modeled price rigidity in an oligopolistic framework along these lines. In these models, oligopolistic firms do not change their prices flexibly because of their expected asymmetric competitor's reactions to their pricing decisions. A game theoretic foundation of such model is presented by Maskin and Tirole (1988).

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ward sluggish than upward. This in turn implies that output is more responsive to negative permanent shocks than positive ones.

The chapter is structured as follows. Section 3.2 reviews the relevant literature. Section 3.3 presents our general model setup and in Section 3.4 we analytically and numerically analyze the effects of various demand shocks on prices and quantities. Section 3.5 concludes.

### 3.2 *Relation to the Literature*

As noted, ample empirical evidence suggests that prices and output respond imperfectly and asymmetrically to exogenous shocks of different sign but equal magnitude. Furthermore, the implied asymmetry depends on the nature of the shock, i.e. whether it is permanent or temporary.

Given the nature of a demand shock is permanent, for instance, DeLong and Summers (1988), Cover (1992), Morgan (1993), Weise (1999), Kandil (2002), and Ravn and Sola (2004) show for the United States that in the context of monetary policy shocks prices are generally more responsive to positive shocks than to negative ones, implying that output is more responsive to negative shocks than to positive ones. Similar empirical evidence is provided by Karras (1996) for a variety of European economies, Karras and Stokes (1999) for 12 different OECD countries, and Tan et al. (2010) and Mehrara and Karsalari (2011) for a variety of non-OECD countries. Moreover, Kandil (1998, 1999) documents this asymmetry for a wide range of developing and developed countries in response to aggregate demand shocks and Kandil (2001, 2002) provides empirical evidence for the asymmetric output reaction to government spending shocks in the United States.

Looking particularly at temporary demand shocks, Hall et al. (2000) find that firms respond to temporary increases in demand adjusting quantity rather than price. Furthermore, firms state that a fall in demand is more likely to lead to a price cut than a rise in demand is to lead to a price increase. Additional evidence is provided by Kehoe and Midrigan (2008), who analyze temporary

price movements. They find that - on average - temporary price cuts are larger (by a factor of almost two) than temporary price increases. Final support for our result can be found in the literature on “sales,” which shows that there are few and only minor temporary price increases, while there are many and significant price decreases (Eichenbaum et al., 2011). Stronger downward price reactions, on the other hand, imply weaker quantity reactions.

Despite this evidence, asymmetric reactions to demand shocks have remained mainly unexplored by current theories of price adjustment. Neither the current time-dependent pricing models (Taylor, 1979; Calvo, 1983), nor the current state-dependent adjustment cost models of  $(S, s)$  type (e.g., Sheshinski and Weiss, 1977; Rotemberg, 1982; Caplin and Spulber, 1987; Caballero and Engel, 1993, 2007; Golosov and Lucas, 2007; Gertler and Leahy, 2008; Dotsey et al., 2009; Midrigan, 2011) are able to account for these asymmetry properties in price dynamics in response to positive and negative exogenous shifts in demand.

In this chapter we offer a new theory of firm price setting resting on consumer loss aversion in an otherwise standard model of monopolistic competition. The resulting theory provides a novel rationale for the above described asymmetric price sluggishness. Even though (to our knowledge) there is no hard evidence for a direct link from consumer loss aversion to price sluggishness, yet, there is ample evidence that firms do not adjust their prices flexibly in order to avoid harming their customer relationships (see, in particular, Fabiani et al. (2006) for a survey of euro area countries, Hall et al. (2000) for the United Kingdom, and Blinder et al. (1998) for the United States).<sup>2</sup>

Furthermore, there is extensive empirical evidence that customers are indeed loss averse in prices. Kalwani et al. (1990), Mayhew and Winer (1992), Krishnamurthi et al. (1992), Putler (1992), Hardie et al. (1993), Kalyanaram and

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<sup>2</sup>Further evidence for OECD countries is provided by, for example, Fabiani et al. (2004) for Italy, Loupias and Ricart (2004) for France, Zbaracki et al. (2004) for the United States, Álvarez and Hernando (2005) for Spain, Amirault et al. (2005) for Canada, Aucremanne and Druant (2005) for Belgium, Stahl (2005) for Germany, Lünemann and Mathä (2006) for Luxembourg, Langbraaten et al. (2008) for Norway, Hoerberichts and Stokman (2010) for the Netherlands, Kwapil et al. (2010) for Austria, Martins (2010) for Portugal, Ólafsson et al. (2011) for Iceland, and Greenslade and Parker (2012) for the United Kingdom.

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Little (1994), Raman and Bass (2002), Dossche et al. (2010), and many others find evidence for consumer loss aversion with respect to many different product categories available in supermarkets. Furthermore, loss aversion in prices is also well documented in diverse activities such as restaurant visits (Morgan, 2008), vacation trips (Nicolau, 2008), real estate trade (Genesove and Mayer, 2001), phone calls (Bidwell et al., 1995), and energy use (Griffin and Schulman, 2005; Adeyemi and Hunt, 2007; Ryan and Plourde, 2007).

In our model, loss-averse consumers evaluate prices relative to a certain reference price. Kőszegi and Rabin (2006, 2007, 2009) and Heidhues and Kőszegi (2005, 2008, forthcoming) argue that reference points are determined by agents' rational expectations about outcomes from the recent past. There is much empirical evidence suggesting that reference points are determined by expectations, in concrete situations such as in police performance after final offer arbitration (Mas, 2006), in the United States TV show "Deal or no Deal" (Post et al., 2008), with respect to domestic violence (Card and Dahl, 2011), in cab drivers' labor supply decisions (Crawford and Meng, 2011), or in the effort choices of professional golf players (Pope and Schweitzer, 2011). In the context of laboratory experiments, Knetsch and Wong (2009) and Marzilli Ericson and Fuster (2011) find supporting evidence from exchange experiments and Abeler et al. (2011) do so through an effort provision experiment. Endogenizing consumers' reference prices in this way allows our model to capture that current price changes influence the consumers' future reference price and thereby affect the demand functions via what we call the "reference-price updating effect." This effect rests on the observation that firms tend to increase the demand for their product by raising their consumers' reference price through, for example, setting a "suggested retail price" that is higher than the price actually charged (Thaler, 1985; Putler, 1992). These pieces of evidence are consonant with the assumptions underlying our analysis. Our analysis works out the implications of these assumptions for state-dependent price sluggishness in the form of asymmetric price adjustment.

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There are only a few other theoretical studies that study the implications of consumer loss aversion on firms' pricing decisions. Sibly (2002, 2007) analyzes how the pricing decision of a monopolist is affected by loss averse consumers, but in his model the consumers' reference price is exogenously given and he neither distinguishes between the different kinds of shocks nor formally derives his results. Heidhues and Kőszegi (2008) analyze monopolistic pricing decisions to cost shocks under the assumption that the reference price is determined as a consumer's recent rational expectations personal equilibrium in the spirit of Kőszegi and Rabin (2006). Spiegel (2012) repeats the Heidhues and Kőszegi (2008) exercise and shows that incentives for price rigidity are even stronger for demand shocks compared to cost shocks. Common to all of the above mentioned studies is a static framework. By contrast, we consider a dynamic approach to the pricing decision of a monopolistic competitive firm facing loss averse consumers with endogenous reference price formation. Our dynamic approach not only confirms earlier findings that consumer loss aversion engenders price rigidity, but also allows us to study the asymmetry characteristics of prices reactions to temporary and permanent demand shocks of different sign. The study closest to ours is probably Popescu and Wu (2007); although they analyze optimal pricing strategies in repeated market interactions with loss averse consumers and endogenous reference prices, they do not analyze the model's reaction to demand shocks, as in this chapter.

Finally, this chapter offers a new rationale for state-dependent pricing, derived completely from microfoundations. The importance of state-dependence for firms' pricing decisions is well documented. For instance, in the countries of the euro area (Fabiani et al., 2006; Nicolitsas, 2013), Scandianvia (Apel et al., 2005; Langbraaten et al., 2008; Ólafsson et al., 2011), the United States (Blinder et al., 1998), and Turkey (Şahinöz and Saraçoğlu, 2008), approximately two third of the firms' pricing decisions are indeed driven by the current state of the environment. Only in the United Kingdom (Hall et al., 2000) and Canada (Amirault et al., 2004) state-dependence seems to be somewhat less important

for firms' pricing decision. Adjustment or menu costs, giving rise to most of the current state-dependent pricing models, are clearly rejected as a significant driver for deferred price adjustments in each of the empirical studies above.

### 3.3 Model

We incorporate reference-dependent preferences and loss aversion into an otherwise standard model of monopolistic competition. Consumers are price takers and loss averse with respect to prices. Prices are evaluated relative to the consumers' reference prices, which depend on their rational price expectations. Prices higher than the reference price are associated with utility losses, while prices lower than the reference price are associated with utility gains. Losses are weighted more heavily than gains of equal magnitude. Firms are monopolistic competitors, supplying non-durable differentiated goods. Firms can change their prices freely in each period to maximize their profits.

#### 3.3.1 Consumers

The representative consumer's period-utility  $U_t$  depends positively on the consumption of  $n$  imperfectly substitutable nondurable goods  $q_{i,t}$  with  $i \in (1, \dots, n)$  and negatively on the ratio of the price  $p_{i,t}$  of good  $i$  to the consumer's respective reference price  $r_{i,t}$  of the good. The consumer's preferences in period  $t$  are represented by the following utility function:

$$U_t(q_{1,t}, \dots, q_{n,t}) = \left[ \sum_{i=1}^n \left( \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} q_{i,t} \right)^\rho \right]^{\frac{1}{\rho}}, \quad (3.1)$$

where  $0 < \rho < 1$  denotes the degree of substitutability between the different goods. The parameter  $\mu$  is an indicator function of the form

$$\mu = \begin{cases} \Gamma & \text{for } p_{i,t} < r_{i,t}, \text{ i.e. gain domain} \\ \Delta & \text{for } p_{i,t} > r_{i,t}, \text{ i.e. loss domain} \end{cases}, \quad (3.2)$$

which describes the degree of the consumer's loss aversion. For loss averse consumers,  $\Delta > \Gamma$ , i.e. the utility losses from price increases are larger than the utility gains from price decreases of equal magnitude. The consumer's reference price  $r_{i,t}$  is formed at the beginning of each period. In the spirit of Kőszegi and Rabin (2006), we assume that the consumer's reference price depends on her rational price expectation. Shocks materialize unexpectedly in the course of the period and therefore do not enter the information set available to the consumer at the beginning of the period. We assume that consumers know, with a one-period lag, whether a shock is temporary or permanent. While temporary shocks do not provoke a change in the consumer's reference price, the reference price changes in the period after the occurrence of a permanent shock. Thus the consumer's reference price is given by  $r_{i,t} = E_{t-1}[p_{i,t}]$ . The consumer's budget constraint is given by

$$\sum_{i=1}^n p_{i,t} q_{i,t} = I_t, \quad (3.3)$$

where  $I_t$  denotes the consumer's income in period  $t$  which is assumed to be constant. For simplicity, we abstract from saving. This implies that consumers are completely myopic.<sup>3</sup> In each period the consumer maximizes her period-utility function (3.1) with respect to her budget constraint (3.3). The result is the consumer's period  $t$  demand for the differentiated good  $i$  which is given by

$$q_{i,t}(p_{i,t}, r_{i,t}, \mu) = \tilde{p}_t^{\eta-1} \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu(\eta-1)} \frac{I_t}{p_{i,t}^\eta}, \quad (3.4)$$

where  $\eta = \frac{1}{1-\rho}$  denotes the elasticity of substitution between the different product varieties. The aggregate price index  $\tilde{p}_t$  is given by

$$\tilde{p}_t = \left[ \sum_{i=1}^n \left( p_{i,t} / \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} \right)^{1-\eta} \right]^{\frac{1}{1-\eta}}. \quad (3.5)$$

<sup>3</sup>Evidence to support this assumption is provided by Elmaghraby and Keskinocak (2003) who show that many purchase decisions take place in economic environments which are characterized by myopic consumers.



A large number of firms  $n$  is assumed, so that the pricing decision of a single firm does not affect the aggregate price index  $\tilde{p}_t$ . Defining  $\lambda = \eta(1 + \mu) - \mu$ , we can simplify equation (3.4) to

$$q_{i,t}(p_{i,t}, r_{i,t}, \lambda) = r_{i,t}^{(\lambda-\eta)} p_{i,t}^{-\lambda} \tilde{p}_t^{\eta-1} I_t, \quad (3.6)$$

where the parameter  $\lambda$  denotes the price elasticity of demand, which depends on  $\mu$  and therefore takes different values for losses and gains. To simplify notation, we define

$$\lambda = \begin{cases} \gamma & \text{for } p_{i,t} < r_{i,t} \\ \delta & \text{for } p_{i,t} > r_{i,t} \end{cases}, \quad (3.7)$$

with  $\delta = \eta(1 + \Delta) - \Delta > \gamma = \eta(1 + \Gamma) - \Gamma$ . Equation (3.6) indicates that the consumer's demand function for good  $i$  is kinked at the reference price  $r_{i,t}$ . The kink, lying at the intersection of the two demand curves  $q_{i,t}(p_{i,t}, r_{i,t}, \gamma)$  and  $q_{i,t}(p_{i,t}, r_{i,t}, \delta)$ , is given by the price-quantity combination

$$(\widehat{p}_{i,t}, \widehat{q}_{i,t}) = \left( r_{i,t}, r_{i,t}^{-\eta} \tilde{p}_t^{\eta-1} I_t \right), \quad (3.8)$$

where “ $\widehat{\phantom{x}}$ ” denotes the value of a variable at the kink. Changes in the reference price  $r_{i,t}$  give rise to a change of the position of the kink and also shift the demand curve as a whole. The direction of this shift depends on the sign of the difference  $\lambda - \eta$ . We restrict our analysis to  $\lambda \geq \eta$ , i.e. we assume that an increase in the reference price shifts the demand curve outwards and vice versa.<sup>4</sup>

Needless to say, abstracting from reference-dependence and loss aversion in the consumer's preferences represented by utility function (3.1), restores the standard textbook consumer's demand function for a differentiated good  $i$ , given

<sup>4</sup>The positive relationship between reference price and demand has become a common feature in the marketing sciences (e.g., Thaler, 1985; Putler, 1992; Greenleaf, 1995). It manifests itself, e.g., through the “suggested retail price,” by which raising the consumers' reference price causes increases in demand (Thaler, 1985). Furthermore, Putler (1992) provides evidence that an extensive use of promotional pricing in the late 80's had led to an erosion in demand by lowering consumers' reference prices.

by

$$q_{i,t}(p_{i,t}) = p_{i,t}^{-\eta} \tilde{p}_t^{\eta-1} I_t. \quad (3.9)$$

We use the standard model as benchmark case, against which we compare the pricing decisions of a monopolistic competitive firm facing loss averse consumers.

### 3.3.2 Monopolistic Firms

All firms are identical, enabling us to drop the subscript  $i$ . In what follows we assume that the firm's total costs are given by  $C_t(q_t) = \frac{c}{2} q_t^2$  with  $c$  being a constant, implying that marginal costs are linear in output:  $MC_t(q_t) = cq_t$ . In the presence of loss aversion ( $\delta > \gamma$ ), the downward-sloping demand curve has a concave kink at the current reference price:  $\hat{p}_t = r_t$ . Thus the firm's marginal revenue curve is discontinuous at the kink:

$$MR_t(q_t, r_t, \lambda) = \left(1 - \frac{1}{\lambda}\right) \left(\frac{q_t}{r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t}\right)^{-\frac{1}{\lambda}}, \quad (3.10)$$

with  $\lambda = \gamma$  for gain domain and  $\lambda = \delta$  for the loss domain, respectively. The interval  $[MR_t(\hat{q}_t, r_t, \gamma), MR_t(\hat{q}_t, r_t, \delta)]$ , where  $MR_t(\hat{q}_t, r_t, \gamma) < MR_t(\hat{q}_t, r_t, \delta)$ , we call "marginal revenue gap"  $MRG_t(\hat{q}_t, r_t, \gamma, \delta)$ . We assume that in the initial steady state, the exogenously given reference price is  $r_{ss}$ . Furthermore, in the steady state the firm's marginal cost curve intersects the marginal revenue gap, as depicted in Figure 3.1.

This implies that the firm's optimal price in the initial steady state  $p_{ss}^*$  is equal to  $r_{ss}$ . The proof is straightforward: Let  $\nu$  be an arbitrarily small number. Then for prices equal to  $r_{ss} + \nu$  the firm faces a situation in which marginal revenue is higher than marginal costs and decreasing the price would raise the firm's profit, while for prices equal to  $r_{ss} - \nu$  the firm faces a situation in which marginal revenue is lower than marginal costs and increasing the price would raise the firm's profit. Thus  $p_{ss}^* = r_{ss}$  has to be the profit maximizing price in the initial steady state.

In the following analysis we distinguish between two types of firms facing

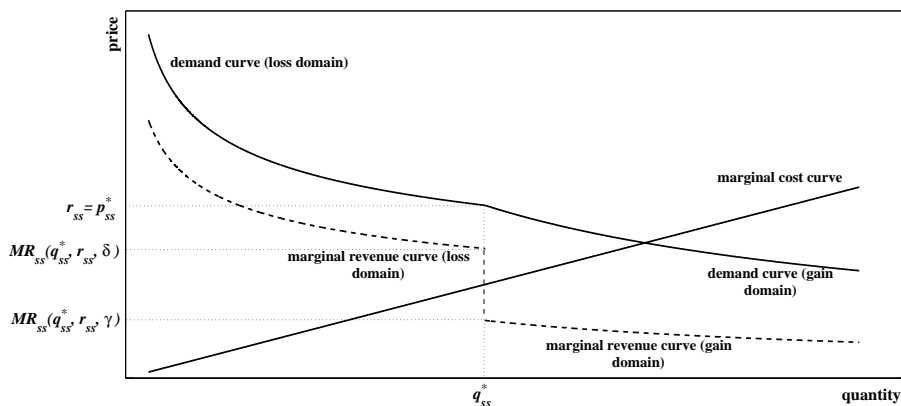


Fig. 3.1: Initial steady state

loss averse consumers: the myopic firm and the forward-looking firm. While the former simply seeks to maximize its current period profit, the latter optimizes intertemporally. We compare the pricing behavior of these two firms to our benchmark case which we refer to as the standard firm.

### 3.4 Demand Shocks

We assume that the government can affect the demand for each product  $i$ , either temporarily or permanently. These demand shocks, represented by  $\varepsilon_t$ , are unexpected and enter the demand function multiplicatively:

$$q_t(p_t, r_t, \lambda, \varepsilon_t) = r_t^{(\lambda-\eta)} \tilde{p}_t^{-\lambda} \tilde{p}_t^{\eta-1} I_t \varepsilon_t. \quad (3.11)$$

The corresponding marginal revenue functions of the firm are

$$MR_t(q_t, r_t, \lambda, \varepsilon_t) = \left(1 - \frac{1}{\lambda}\right) \left(\frac{q_t}{r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t \varepsilon_t}\right)^{-\frac{1}{\lambda}}. \quad (3.12)$$

We consider the effects of a demand shock that hits the economy in period  $t = 0$ . To fix ideas, we assume that initially the marginal cost curve crosses the

midpoint of the discontinuity in the marginal revenue curve.<sup>5</sup> This assumption permits us to derive the symmetry characteristics of responses to positive and negative demand shocks. The demand shock shifts the marginal revenue curve, along with the marginal revenue gap  $MRG_t(\hat{q}_t, r_t, \gamma, \delta, \varepsilon_t)$ . Naturally, for a sufficiently small shock, the marginal cost curve still intersects the marginal revenue curve at the discontinuity in the latter, but for a sufficiently large shock, this is not the case. The maximum size of a small shock for the demand function (3.11) is

$$\bar{\varepsilon}_t(\lambda) = \left(1 - \frac{1}{\lambda}\right) \frac{r_t^{1+\eta}}{c\tilde{p}_t^{\eta-1}I_t}, \quad (3.13)$$

i.e.  $\bar{\varepsilon}_t(\lambda)$  is the shock size for which the marginal cost curve lies exactly on the boundaries of the shifted marginal revenue gap  $MRG_t(\hat{q}_t, r_t, \gamma, \delta, \bar{\varepsilon}_t(\lambda))$ .<sup>6</sup> We consider small and large demand shocks separately and distinguish between temporary and permanent demand shocks.

### 3.4.1 Myopic Firm

We start our analysis with the simple case of the myopic firm. This approach proves useful, as the results are straightforward to interpret and relevant to our later examination of the more realistic case of a forward-looking firm. The myopic firm simply cares about maximizing its current period profit. The model therefore collapses to a one-period model and we do not need to distinguish between temporary and permanent shocks for the analysis of the myopic firm's behavior.<sup>7</sup>

**Proposition 1:** *For myopic firms, small demand shocks are translated one-to-one into changes in quantities transacted, while prices remain rigid.*

<sup>5</sup>To satisfy this condition, the slope parameter  $c$  of the marginal cost curve has to take the value  $c = \frac{1}{2q_{ss}} [MR_t(q_{ss}, r_{ss}, \gamma) + MR_t(q_{ss}, r_{ss}, \delta)]$

<sup>6</sup>For  $\bar{\varepsilon}(\delta)$ , the marginal cost curve intersects the marginal revenue gap on the upper bound, whereas for  $\bar{\varepsilon}(\gamma)$  it intersects it on the lower bound.

<sup>7</sup>Obviously, this distinction can be omitted for the standard firm in the one-period model as well.

As noted, for a small demand shock  $\varepsilon_0^s \leq \bar{\varepsilon}_0(\lambda)$  the marginal cost curve still intersects the marginal revenue gap, i.e.  $MC_0(\hat{q}_0) \in MRG_0(\hat{q}_0, r_{ss}, \gamma, \delta, \varepsilon_0^s)$ . Therefore, the prevailing steady state price remains the myopic firm's profit-maximizing price,<sup>8</sup> i.e.  $p_0^* = p_{ss}^*$ , and we have complete price rigidity. Consequently, the shock elasticity of price for small demand shocks  $\eta_{p,\varepsilon^s}$  is zero. By contrast, the profit-maximizing quantity changes in response to a small demand shock. The new profit-maximizing quantity is  $q_0^* = r_{ss}^{-\eta} \tilde{p}_0^{\eta-1} I_0 \varepsilon_0^s$  while the change of quantity is given by

$$\Delta q_0^* = \frac{q_0^*}{q_{ss}^*} = \frac{\varepsilon_0^s}{\varepsilon_{ss}} = \varepsilon_0^s \neq 1. \quad (3.14)$$

The shock elasticity of demand for small shocks  $\eta_{q,\varepsilon^s}$  is unity. Both holds true irrespective of the sign of the small demand shock.

The result of full price rigidity for small demand shocks is in clear contrast to the behavior of the standard firm since demand shocks always induce quantity and price adjustments in that case.<sup>9</sup>

**Proposition 2:** *For myopic firms, large demand shocks are translated less than one-to-one into quantities transacted, while prices are sluggish (i.e. they respond, but not fully, to the demand shocks).*

For a large shock, i.e.  $\varepsilon_0^l > \bar{\varepsilon}_0(\lambda)$ , the marginal cost curve intersects the marginal revenue curve outside the discontinuity of the latter. Consequently both, a price and a quantity reaction are induced. The new profit-maximizing quantity of the myopic firm is

$$q_0^* = \left( \frac{1}{c} \left( 1 - \frac{1}{\lambda} \right) \right)^{\frac{\lambda}{\lambda+1}} \left( r_{ss}^{(\lambda-\eta)} \tilde{p}_0^{\eta-1} I_0 \varepsilon_0^l \right)^{\frac{1}{\lambda+1}}, \quad (3.15)$$

<sup>8</sup>Compare the proof from Section 3.3.2.

<sup>9</sup>It can be easily shown that the shock elasticities of price and demand for the standard firm are  $\tilde{\eta}_{\varepsilon,p}, \tilde{\eta}_{\varepsilon,q} \in (0, 1)$ .

and its corresponding profit-maximizing price is

$$p_0^* = \left( \frac{r_{ss}^{(\lambda-\eta)} \tilde{p}_0^{\eta-1} I_0 \varepsilon_0^l}{q_0^*} \right)^{\frac{1}{\lambda}}. \quad (3.16)$$

In comparison to the standard firm the price reaction of the myopic firm to a large demand shock is smaller, whereas the quantity reaction is larger. For large demand shocks we therefore find that loss aversion induces price sluggishness for the myopic firm. The intuition is obvious once we decompose the demand shock into the maximum small shock and the remainder:

$$\varepsilon_0^{large} = \bar{\varepsilon}_0(\lambda) + \varepsilon_0^{rem}. \quad (3.17)$$

From our theoretical analysis above we know that the maximum small shock  $\bar{\varepsilon}_0(\lambda)$  has no price effects, but feeds one-to-one into demand for the myopic firm but not for the standard firm. By contrast, the remaining shock  $\varepsilon_0^{rem}$  induces a price and quantity reaction for both. Yet, the price reaction of the myopic firm induced by  $\varepsilon_0^{rem}$  is smaller. The reason is that the degree, to which the adjustment takes place, depends negatively on the price elasticity of demand in the respective firm's demand function. According to demand functions (3.6) and (3.9), the price elasticities of demand are  $\lambda$  for the myopic firm and  $\eta$  for the standard firm. Since by definition  $\lambda > \eta$ , the price reaction of the myopic firm must be smaller than that of the standard firm. Hence, for the myopic firm the overall effect is clearly less pronounced for prices, which implies a larger output reaction.

**Proposition 3:** *For myopic firms facing small shocks, quantities respond symmetrically to negative and positive demand shocks. For those facing large shocks, prices are more responsive to negative demand shocks than to positive ones (implying that quantities are less responsive to negative shocks than to positive ones).*

To see this, the decomposition (3.17) again proves useful. As we have seen, the maximum small shock  $\bar{\varepsilon}_0(\lambda)$  has symmetric effects for the myopic firm: no price effect and symmetric quantity effects. This holds true irrespective of the sign of the shock. However, the remainder  $\varepsilon_0^{rem}$  has asymmetric effects, for the simple reason that large positive demand shocks move the myopic firm along the relatively flat portion of the demand curve, whereas large negative demand shocks move it along the relatively steep portion of the demand curve. The reaction of the optimal price and quantity of the myopic firm in response to a large positive shock is therefore smaller than the reaction to a large negative shock. This asymmetry in the reaction to positive and negative large demand shocks is a distinct feature of consumer loss aversion and stands clearly in contrast to the case of the standard monopolist where no such asymmetry is found.

#### 3.4.2 Forward-Looking Firm

The forward-looking firm seeks to maximize the discounted stream of current and future profits. The one-period-lagged updating of the consumers' reference price induced by permanent demand shocks therefore influences the forward-looking firm's immediate pricing decision in the shock period. In order to capture this we extend the model of the previous section to two periods.<sup>10</sup>

**Proposition 4:** *For the temporary shock, forward-looking firms exhibit the same price-quantity reactions as myopic firms.*

Since there is no updating of the consumers' reference price in the case of temporary demand shocks, the behavior of the forward-looking firm in the shock period is identical to that of the myopic firm and needs not to be repeated.

Instead we focus on permanent demand shocks. If the forward-looking firm changes its price in the shock period  $t = 0$  in response to a permanent demand

<sup>10</sup>The two-period problem approximates the case in which the firm is non-myopic, but a hyperbolic discounter.

shock to  $p_0^*$ , consumers update their reference price in the following period  $t = 1$ , i.e.  $r_1 = E_0[p_1] = p_0^*$ . Therefore, price increases in response to permanent positive demand shocks lead to increases in the consumers' reference price. Consequently, the demand curve shifts and the kink rises to

$$(\hat{p}_1, \hat{q}_1) = \left( r_1, r_1^{-\eta} \tilde{p}_1^{\eta-1} I_1 \varepsilon_1 \right). \quad (3.18)$$

Analogously, for price decreases in response to permanent negative demand shocks the reference price falls and the kink drops. The forward-looking firm can anticipate this. Thus, it may have an incentive to set its price above the optimal myopic price ( $p'_0 > p_0^*$ ) to prevent the reference price from adjusting downwards and thereby avoid the further reduction in demand for its product in the following period (at least to some extent). We term this phenomenon the “reference-price updating effect.”<sup>11</sup>

Whether or not the forward-looking firm exploits the reference-price updating effect depends on the outcome of the following tradeoff: On the one hand, increasing the price above the current period profit-maximizing price<sup>12</sup> lowers the firm's current period profit suboptimally. On the other hand, the rightward shift of the kinked demand curve resulting from updating the consumers' reference price in the next period increases demand in that period and hence profits. To analyze which effect dominates, we calibrate the model and solve it numerically.

### 3.4.3 Calibration

We calibrate the model for a quarterly frequency in accordance with standard values in the literature. We assume an annual interest rate of 4 percent, which yields a discount factor  $\beta = 0.99$ . We follow Schmitt-Grohé and Uribe (2007b) and set the monopolistic markup to 25 percent, i.e.  $\eta = 5$ , which is also close

<sup>11</sup>Needless to say, lowering the price with the aim to decrease the reference price permanently is not a preferable option for the forward-looking firm. The resulting drop of the reference price crowds out future demand and therewith profits.

<sup>12</sup>This is just the optimal price chosen by the myopic firm.



Parameter	Symbol	Value
Discount rate	$\beta$	0.99
Elasticity of substitution	$\eta$	5
implying substitutability	$\rho$	0.8
Price elasticity (gain domain)	$\gamma$	6
Price elasticity (loss domain)	$\delta$	12
Loss aversion	$\kappa$	2
Exogenous income	$I$	1
Exogenous price index	$\tilde{p}_t$	1

Tab. 3.1: Base calibration

to the value supported by Erceg et al. (2000) and which implies that goods are only little substitutable, i.e.  $\rho = 0.8$ . Since we impose  $\lambda \geq \eta$ , we set  $\gamma = 6$  in our base calibration. Loss aversion is measured by the relative slopes of the demand curves in the gain and loss domain, i.e.  $\kappa = \frac{\delta}{\gamma}$ . The empirical literature on loss aversion in prices finds that losses induce demand reactions approximately twice as large as gains (Tversky and Kahnemann, 1991; Putler, 1992; Hardie et al., 1993; Griffin and Schulman, 2005; Adeyemi and Hunt, 2007). Therefore, we set  $\kappa = 2$ . The exogenous variables income  $I$  and price index  $\tilde{p}_t$  are normalized to unity.<sup>13</sup> The base calibration is summarized in Table 3.1.

#### 3.4.4 Numerical Simulation

Tables 3.2 and 3.3 present the numerical results of our base calibration for positive and negative demand shocks in the two-period model. In the tables we report the shock-arc-elasticities of price ( $\tilde{\eta}_{\varepsilon,p} = \frac{\% \Delta p}{\% \Delta \varepsilon}$ ) and output ( $\tilde{\eta}_{\varepsilon,q} = \frac{\% \Delta q}{\% \Delta \varepsilon}$ ) in the period of the shock  $t = 0$  for the myopic firm, the forward-looking firm, and the standard firm. We focus on permanent demand shocks since we are interested in the influence of the reference-price updating effect on the immediate price and output reaction of the forward-looking firm.<sup>14</sup>

The results in Tables 3.2 and 3.3 confirm the theoretical analysis above for

<sup>13</sup>All results are completely robust to variations of these numerical values.

<sup>14</sup>Note that in the two-period model there is no difference in the immediate price and output reaction of the myopic firm with respect to temporary and permanent demand shocks. The reason is that the myopic firm simply ignores future periods for its current period decision. The same holds true for the standard firm, since the problem of the intertemporally optimizing standard firm is completely time-separable.

	myopic firm		forward-looking firm		standard firm	
	$\eta_{\varepsilon,p}$	$\eta_{\varepsilon,q}$	$\eta_{\varepsilon,p}$	$\eta_{\varepsilon,q}$	$\tilde{\eta}_{\varepsilon,p}$	$\tilde{\eta}_{\varepsilon,q}$
$\varepsilon_0^s = 1.01$	0	1	0.0100	0.8789	0.1660	0.1660
$\varepsilon_0^s = 1.03$	0	1	0.0667	0.1866	0.1646	0.1646
$\varepsilon_0^l = 1.05$	0.0035	0.9560	0.0755	0.0717	0.1633	0.1633
$\varepsilon_0^l = 1.07$	0.0232	0.7046	0.0790	0.0216	0.1620	0.1620

Tab. 3.2: Shock elasticities of price and output in  $t = 0$  to positive permanent demand shocks,  $\bar{\varepsilon}_0(\gamma) = 1.0476$

the myopic firm, summarized in Propositions 1-4. However, not all of these results carry over to the forward-looking firm in the case of permanent demand shocks as the following propositions show.

**Proposition 5:** *For forward-looking firms, small and large positive permanent demand shocks are associated with price sluggishness, but not full price rigidity. This implies that outputs respond to the shocks, but not one-to-one.*

Due to the reference-price updating effect the price adjustment of the forward-looking firm is generally more pronounced than that of the myopic firm for positive demand shocks. We find that in response to positive demand shocks the forward-looking firm increases its price irrespective of the size of the shock (see Table 3.2). The reference-price updating effect therefore invalidates the result of full price rigidity for small positive demand shocks found for the myopic firm.

**Proposition 6:** *For forward-looking firms, small negative permanent demand shocks are associated with price rigidity and large negative permanent demand shocks are associated with price sluggishness. This implies that outputs respond more sensitively to negative shocks than to positive ones of equal magnitude.*

In contrast to the positive shock, the price response is muted for negative demand shocks in case of the forward-looking firm. Table 3.3 shows that prices of the forward-looking firm are fully rigid in response to small negative demand

	myopic firm		forward-looking firm		standard firm	
	$\eta_{\varepsilon,p}$	$\eta_{\varepsilon,q}$	$\eta_{\varepsilon,p}$	$\eta_{\varepsilon,q}$	$\tilde{\eta}_{\varepsilon,p}$	$\tilde{\eta}_{\varepsilon,q}$
$\varepsilon_0^s = 0.99$	0	1	0	1	0.1674	0.1674
$\varepsilon_0^s = 0.97$	0	1	0	1	0.1688	0.1688
$\varepsilon_0^l = 0.95$	0.0072	0.9592	0.0012	0.9934	0.1702	0.1702
$\varepsilon_0^l = 0.93$	0.0484	0.7264	0.0013	0.9927	0.1717	0.1717

Tab. 3.3: Shock elasticities of price and output in  $t = 0$  to negative permanent demand shocks;  $\bar{\varepsilon}_0(\delta) = 0.9524$

shocks. For large negative demand shocks the forward-looking firm adjusts its price but to a considerably lower extent than for large positive shocks of equal size. Intuitively, by keeping the price (almost) unaltered in response to negative demand shocks, the forward-looking firm seeks to stabilize the consumers' reference price. This in turn avoids the negative reference-price updating effect (i.e. a further permanent reduction in demand), which otherwise would follow from the price decrease. Therefore, loss aversion offers a rationale for downward nominal price rigidity. Furthermore, Proposition 6 together with Propositions 2 and 4 have striking implications for the analysis of price setting strategies. Since the forward-looking firm avoids price reductions, which lead to downward-adjustments in the reference price, but conducts price reductions, which do not influence the reference price, loss aversion offers a simple rationale for the firm's practice of "sales."

**Proposition 7:** *The price reaction of the forward-looking firm is smaller for negative compared to positive permanent demand shocks, due to the reference-price updating effect.*

Proposition 7 follows directly from our results summarized in Propositions 5 and 6. Due to the reference-price updating effect, the forward-looking firm always sets its price above the optimal price of the myopic firm, meaning that the forward-looking firm lowers the price by less in response to a negative shock and increases the price more in response to a positive shock. Consequently price

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rigidity is considerably more pronounced for negative than for positive demand shocks. Therefore, the asymmetry of positive and negative shocks reverses, when moving from temporary to permanent shocks. Intuitively this result is straightforward: In the face of a large negative shock, a strong price reduction is favorable only, as long as it does not involve a permanent downward adjustment of the reference price.

**Proposition 8:** *Loss aversion induces price sluggishness irrespective of the sign and the size of the demand shock and irrespective of whether the model is static or dynamic.*

The results from Tables 3.2 and 3.3 clearly indicate that prices are generally more sluggish for the forward-looking firm compared to the standard firm for each case considered. This result, thus, carries over from the myopic firm. Irrespective of the sign and the size of the demand shock and irrespective of whether the model is static or dynamic, facing loss averse consumers leads firms to mute their price responses to demand shocks, relative to firms, which face standard consumers.

To summarize, propositions 1-8 imply that consumer loss aversion with respect to prices generates price sluggishness in the form of price adjustments that are asymmetric for positive and negative demand shocks of equal size. The central prediction of our theory – for permanent shocks, output is more responsive to negative shocks than positive ones, but for temporary shocks, output is more responsive to positive shocks – may seem surprising at first glance. However, the underlying intuition is straightforward. As noted, for temporary shocks, consumers abstract from updating their reference price. Therefore, the firm does not risk to suffer from a permanent reduction in demand due to a negative reference-price updating effect, when encountering a drop in demand with a temporary price reduction. On the other hand, for positive temporary shocks, the firm cannot generate permanent increases in demand due to upward-

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adjustments of the reference price. Since consumers react more sensitive to price increases relative to price decreases, the price and quantity reactions are larger for negative temporary shocks compared to positive ones (Proposition 3). Due to the presence of the reference-price updating effect, this changes for permanent shocks. A permanent price reduction (as reaction to a negative shock) initiates a drop in the consumers' reference price, decreasing demand even further and thereby reducing profits. By keeping the price (almost) fixed, the firm avoids this permanent negative effect. Therefore, the price reaction is almost entirely muted, giving rise to a large reduction in quantity. The opposite holds true for a positive permanent shock. The firm can exploit future higher demand by exploiting the reference-price updating effect. Therefore, the firm raises its price more than proportionate to the temporary shock price level, reducing quantity but increasing future expected profits. Both of these asymmetries find much empirical support in the literature, as indicated in Section 3.2.

### 3.5 *Summary and Concluding Remarks*

In contrast to the standard time-dependent and state-dependent models of price sluggishness, our theory of price adjustment is able to account for different price and quantity adjustments to large and small shocks and asymmetric price and quantity responses to positive and negative shocks of equal magnitude. Again, in contrast to the standard time-dependent and state-dependent models, our explanation of price adjustments is derived entirely from microfoundations, without any recourse to ad hoc assumptions concerning the frequency of price changes or physical costs of price adjustments.

Future research needs to extend our theory in various ways. Consideration of heterogeneous firms and multi-product firms will enable this model to generate asynchronous price changes, as well as the simultaneous occurrence of large and small price changes, and heterogeneous frequency of price changes across product. Extending the model to a stochastic environment will generate testable implications concerning the variability of individual prices.

### 3.6 Appendix B

#### 3.6.1 B1. Demand Curve of Loss Averse Consumers

The loss averse consumer maximizes her utility function (3.1) subject to her budget constraint (3.3). The corresponding Lagrangian problem reads:

$$\max_{q_{i,t}} L = \left[ \sum_{i=1}^n \left( \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} q_{i,t} \right)^\rho \right]^{\frac{1}{\rho}} - \varphi \left[ \sum_{i=1}^n p_{i,t} q_{i,t} - I_t \right], \quad (3.19)$$

where  $\varphi$  is the Lagrangian multiplier. The first-order condition of the Lagrangian function (3.19) is

$$\frac{\partial L_t}{\partial q_{i,t}} = \frac{1}{\rho} \left[ \sum_{i=1}^n \left( \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} q_{i,t} \right)^\rho \right]^{\frac{1}{\rho}-1} \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu\rho} q_{i,t}^{\rho-1} \rho - \varphi p_{i,t} = 0. \quad (3.20)$$

We collect all terms including demand components on the left hand side

$$q_{i,t}^{\rho-1} \left[ \sum_{i=1}^n \left( \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} q_{i,t} \right)^\rho \right]^{\frac{1-\rho}{\rho}} = \varphi p_{i,t} \left( \frac{p_{i,t}}{r_{i,t}} \right)^{\mu\rho}, \quad (3.21)$$

and simplify the exponentials

$$q_{i,t} \left[ \sum_{i=1}^n \left( \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} q_{i,t} \right)^\rho \right]^{-\frac{1}{\rho}} = \left( \varphi p_{i,t} \left( \frac{p_{i,t}}{r_{i,t}} \right)^{\mu\rho} \right)^{\frac{1}{\rho-1}}. \quad (3.22)$$

We define overall demand according to a Dixit and Stiglitz (1977) aggregate, which reads

$$q_t = \left[ \sum_{i=1}^n \left( \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} q_{i,t} \right)^\rho \right]^{\frac{1}{\rho}}. \quad (3.23)$$

Applying (3.23) as well as the definition of the elasticity of substitution (i.e.  $\eta = \frac{1}{1-\rho}$ ), we can simplify (3.22) to

$$q_{i,t} = (\varphi p_{i,t})^{-\eta} \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu(\eta-1)} q_t. \quad (3.24)$$

To determine the Lagrangian multiplier  $\varphi$ , we plug (3.24) into (3.23)

$$q_t = \left[ \sum_{i=1}^n \left( \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} (\varphi p_{i,t})^{-\eta} \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu(\eta-1)} q_t \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (3.25)$$

which after some simple manipulations yields

$$\varphi = \left[ \sum_{i=1}^n \left( p_{i,t} / \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu} \right)^{1-\eta} \right]^{\frac{1}{\eta-1}} \equiv \tilde{p}_t^{-1}. \quad (3.26)$$

We define the inverse of the Lagrangian multiplier  $\varphi$  as the overall price index  $\tilde{p}_t$ . Plugging (3.26) back into (3.24) yields

$$q_{i,t} = \tilde{p}_t^\eta \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu(\eta-1)} p_{i,t}^{-\eta} q_t. \quad (3.27)$$

Applying the budget constraint (3.3) yields

$$q_{i,t} = \tilde{p}_t^{\eta-1} \left( \frac{p_{i,t}}{r_{i,t}} \right)^{-\mu(\eta-1)} p_{i,t}^{-\eta} I_t. \quad (3.28)$$

Finally, we simplify (3.28) using the definition  $\lambda = \eta(1 + \mu) - \mu$ , which yields the demand curve for the differentiated good  $i$

$$q_{i,t} = r_{i,t}^{\lambda-\eta} p_{i,t}^{-\lambda} \tilde{p}_t^{\eta-1} I_t. \quad (3.29)$$

Including the shock term, equation (3.29) reads

$$q_{i,t} = r_{i,t}^{\lambda-\eta} p_{i,t}^{-\lambda} \tilde{p}_t^{\eta-1} I_t \varepsilon_t. \quad (3.30)$$

### 3.6.2 B2. Price and Quantity at the Kink

The kink is given by the particular price at which the two demand curves intersect, i.e.  $q_{i,t}(p_{i,t}, r_{i,t}, \gamma) = q_{i,t}(p_{i,t}, r_{i,t}, \delta)$ . Given (3.30) and  $\lambda \in (\gamma, \delta)$ , it must hold that

$$r_{i,t}^{\gamma-\eta} p_{i,t}^{-\gamma} \tilde{p}_t^{\eta-1} I_t \varepsilon_t = r_{i,t}^{\delta-\eta} p_{i,t}^{-\delta} \tilde{p}_t^{\eta-1} I_t \varepsilon_t, \quad (3.31)$$

which simplifies to

$$r_{i,t}^{\gamma-\eta} p_{i,t}^{-\gamma} = r_{i,t}^{\delta-\eta} p_{i,t}^{-\delta}. \quad (3.32)$$

Sorting terms yields

$$p_{i,t}^{\delta-\gamma} = r_{i,t}^{\delta-\eta-\gamma+\eta}. \quad (3.33)$$

From (3.33) it is obvious that  $p_{i,t} = r_{i,t}$  at the kink. Plugging (3.33) back into (3.30) gives the quantity at the kink

$$q_{i,t} = r_{i,t}^{-\eta} \tilde{p}_t^{\eta-1} I_t \varepsilon_t. \quad (3.34)$$

### 3.6.3 B3. Demand Curve of Standard Consumers

The standard consumer (i.e. the non-loss averse consumer) maximizes her utility function

$$U_t(q_{1,t}, \dots, q_{n,t}) = \left[ \sum_{i=1}^n q_{i,t}^\rho \right]^{\frac{1}{\rho}}, \quad (3.35)$$

subject to her budget constraint (3.3). The corresponding Lagrangian problem reads:

$$\max_{q_{i,t}} L = \left[ \sum_{i=1}^n q_{i,t}^\rho \right]^{\frac{1}{\rho}} - \phi \left[ \sum_{i=1}^n p_{i,t} q_{i,t} - I_t \right], \quad (3.36)$$



where  $\phi$  is the Lagrangian multiplier for the standard textbook problem. The first-order condition of the Lagrangian problem (3.36) is

$$\frac{\partial L_t}{\partial q_{i,t}} = \frac{1}{\rho} \left[ \sum_{i=1}^n q_{i,t}^\rho \right]^{\frac{1}{\rho}-1} q_{i,t}^{\rho-1} \rho - \phi p_{i,t} = 0. \quad (3.37)$$

We collect all terms including demand components on the left hand side and simplify the exponentials

$$q_{i,t} \left[ \sum_{i=1}^n q_{i,t}^\rho \right]^{-\frac{1}{\rho}} = (\phi p_{i,t})^{\frac{1}{\rho-1}}. \quad (3.38)$$

We define overall demand for the standard consumer by a Dixit and Stiglitz (1977) aggregate of the form

$$q_t = \left[ \sum_{i=1}^n q_{i,t}^\rho \right]^{\frac{1}{\rho}}. \quad (3.39)$$

Applying (3.39) as well as the definition of the elasticity of substitution, we can simplify (3.38) to

$$q_{i,t} = (\phi p_{i,t})^{-\eta} q_t. \quad (3.40)$$

To determine the Lagrangian multiplier  $\phi$ , we plug (3.40) into (3.39)

$$q_t = \left[ \sum_{i=1}^n \left( (\phi p_{i,t})^{-\eta} q_t \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (3.41)$$

which after some simple manipulations yields

$$\phi = \left[ \sum_{i=1}^n p_{i,t}^{1-\eta} \right]^{\frac{1}{\eta-1}} \equiv \bar{p}_t^{-1}. \quad (3.42)$$

We define the inverse of the Lagrangian multiplier  $\phi$  as the overall price index  $\bar{p}_t$  for the standard textbook problem. Plugging (3.42) back into (3.40) yields

$$q_{i,t} = \tilde{p}_t^\eta p_{i,t}^{-\eta} q_t. \quad (3.43)$$

Applying the budget constraint (3.3) yields the demand curve for the differentiated good  $i$  for the standard consumer

$$q_{i,t} = p_{i,t}^{-\eta} \tilde{p}_t^{\eta-1} I_t. \quad (3.44)$$

Including the shock term, equation (3.44) reads

$$q_{i,t} = p_{i,t}^{-\eta} \tilde{p}_t^{\eta-1} I_t \varepsilon_t. \quad (3.45)$$

#### 3.6.4 B4. Marginal Revenue Curve

Since all firms are assumed to be identical, we drop the subscript  $i$  for the firm derivations. Revenue is given by

$$R_t = p_t(q_t)q_t = \left( \frac{q_t}{r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t \varepsilon_t} \right)^{-\frac{1}{\lambda}} q_t, \quad (3.46)$$

or in short

$$R_t = \left( r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t \varepsilon_t \right)^{\frac{1}{\lambda}} q_t^{1-\frac{1}{\lambda}}. \quad (3.47)$$

The first-order condition with respect to  $q$  yields the marginal revenue curve

$$MR_t = \frac{\partial R_t}{\partial q_t} = \left( 1 - \frac{1}{\lambda} \right) \left( \frac{q_t}{r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t \varepsilon_t} \right)^{-\frac{1}{\lambda}}. \quad (3.48)$$

#### 3.6.5 B5. Critical Shock Size

The critical value for the small shock is given by the particular shock  $\bar{\varepsilon}(\lambda)$ , for which the marginal cost curve exactly intersects the critical bounds of the

shifted marginal revenue gap, i.e.

$$MC(q_t^*) \stackrel{!}{=} MR(\lambda, r_t, q_t^*, \bar{\varepsilon}_t(\lambda)), \quad (3.49)$$

where  $MC(q_t) = \frac{\partial C(q_t)}{\partial q_t} = cq_t$ , with  $C(q_t) = \frac{c}{2}q_t^2$ . Evaluating the marginal revenue curve (3.48) and the marginal cost curve at the post-shock optimum yields

$$cq_t^* = \left(1 - \frac{1}{\lambda}\right) \left(\frac{q_t^*}{\bar{\varepsilon}_t(\lambda) r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t}\right)^{-\frac{1}{\lambda}}. \quad (3.50)$$

From the analysis of small shocks we know that the new quantity of the maximum small shock is  $q_t^* = \bar{\varepsilon}_t(\lambda) r_t^{-\eta} \tilde{p}_t^{\eta-1} I_t$ . Applying this, we obtain

$$c\bar{\varepsilon}_t(\lambda) r_t^{-\eta} \tilde{p}_t^{\eta-1} I_t = \left(1 - \frac{1}{\lambda}\right) \left(\frac{\bar{\varepsilon}_t(\lambda) r_t^{-\eta} \tilde{p}_t^{\eta-1} I_t}{\bar{\varepsilon}_t(\lambda) r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t}\right)^{-\frac{1}{\lambda}}. \quad (3.51)$$

Solving for  $\bar{\varepsilon}_t(\lambda)$  yields the critical shock size

$$\bar{\varepsilon}_t(\lambda) = \left(1 - \frac{1}{\lambda}\right) \frac{r_t^{1+\eta}}{c\tilde{p}_t^{\eta-1} I_t}. \quad (3.52)$$

### 3.6.6 B6. Optimal Price and Quantity in Reaction to a Large Shock for the Myopic Firm

The new optimal price lies at the intersection of the marginal cost curve with the shifted marginal revenue curve, which by definition is outside the marginal revenue gap

$$MC(q_t^*, \varepsilon_t) = MR(\lambda, r_t, q_t^*, \varepsilon_t). \quad (3.53)$$

Applying the respective functions yields

$$cq_t^* = \left(1 - \frac{1}{\lambda}\right) \left(\frac{q_t^*}{r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t \varepsilon_t}\right)^{-\frac{1}{\lambda}}. \quad (3.54)$$

Solving this equation for  $q$ , we obtain

$$q_t^* = \left( \frac{1}{c} \left( 1 - \frac{1}{\lambda} \right) \right)^{\frac{\lambda}{\lambda+1}} \left( r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t \varepsilon_t \right)^{\frac{1}{\lambda+1}}. \quad (3.55)$$

The optimal price can be calculated by plugging  $q_t^*$  into the inverse demand curve, given by

$$p_t^* = \left( \frac{q_t^*}{r_t^{(\lambda-\eta)} \tilde{p}_t^{\eta-1} I_t \varepsilon_t} \right)^{-\frac{1}{\lambda}}. \quad (3.56)$$

#### 4. ESTIMATING A HIGH-FREQUENCY NEW-KEYNESIAN PHILLIPS CURVE

The paper “Estimating a high-frequency New-Keynesian Phillips curve,” is joint work with Dr. Stephen Sacht. This paper has been published in *Empirical Economics*, volume 46, issue 2, March 2014, pages 607-628. The journal article is available at:

<http://link.springer.com/article/10.1007/s00181-013-0684-7>.

## 5. STATE-DEPENDENCE VS. TIME-DEPENDENCE: AN EMPIRICAL MULTI-COUNTRY INVESTIGATION OF PRICE SLUGGISHNESS

### 5.1 *Outline*

The effectiveness of monetary policy to impact real variables such as employment and output crucially depends on the extent to which prices react sluggishly to central banks' policy innovations. Therefore, mechanisms of price sluggishness have become a central aspect of modern DSGE models. In terms of the standard NKM, price sluggishness strongly influences aggregate inflation dynamics yielding a non-vertical NKPC in the short run.

The most widely used price-updating mechanism is the Calvo (1983) staggered contracts model, where a constant, randomly selected fraction of firms adjust their prices at each time instance in a monopolistically competitive market. Despite its popularity, this time-dependent specification has been frequently criticized as being a rather restrictive description of the price setting process (Caplin and Leahy, 1991; Wolman, 1999). In particular, indicative evidence by Fernández-Villaverde and Rubio-Ramírez (2010) suggests that the Calvo parameter should not be regarded as a structural parameter in the sense of a “deep” and state-invariant coefficient.

The contribution of this chapter is an empirical investigation of the behavior of aggregate price setting. We implement a testing procedure by means of a nonparametric representation of the structural form NKPC. Such a functional-coefficient regression model allows to express the Calvo parameter as a functional coefficient which may be systematically affected by observable factor variables

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such as inflation, inflation uncertainty ( $IU$ , henceforth), or both factors simultaneously (Danziger, 1983). This specification nests both the typically employed time- and state-dependent pricing rules. This corresponds to testing for the null hypothesis of parameter constancy (time-dependent pricing) against the alternative hypothesis of inflation- or  $IU$ -induced price revisions.

For this purpose, we obtain a so-called functional coefficient representation of the NKPC. This semiparametric model class allows to express functional dependence of parameters on observable factor variables (Cai et al., 2000). An important advantage of our approach is that it allows to draw inference on the state-dependence of the pricing scheme by taking potential heteroscedasticity of the disturbances into account, which is particularly critical in models which relate price adjustment to inflation or  $IU$  (Sims, 2001). To address residual heteroscedasticity in the inference process regarding functional dependence, we make use of the so-called factor-based bootstrap (Herwartz and Xu, 2009).

The distinction between time- and state-dependent pricing schemes is of crucial importance from the policy maker's point of view. The welfare implications, measured by minimizing an objective function which is quadratic in inflation and the output gap (Woodford, 2003), under both schemes generally do not coincide (Lombardo and Vestin, 2008). Applying the Calvo model to a state-dependent world, monetary policy runs the risk of putting too little weight on inflation stabilization.

To summarize the most important findings, we first confirm assertions frequently made in theoretical discussions that the Calvo scheme is a rather restrictive model of aggregate price setting. Moreover, it is documented that a number of shortcomings of empirical NKPC model representations in explaining inflation data may be addressed by means of a state-dependent pricing rule. In particular, problems of insignificant or even implausibly negative estimates of the relation between inflation and marginal costs are considerably reduced in the framework of our more general NKPC specification. The remainder of this paper is organized as follows. Section 5.2 reviews the relevant literature. Section

5.3 describes the data set and introduces the model framework. Subsequently, our approach to estimation and inference is introduced. Section 5.4 summarizes and discusses the empirical results. Section 5.5 concludes.

## 5.2 Relation to the Literature

Mechanisms of price sluggishness can be assigned to either time-dependent models of price setting or state-dependent models of price setting. In time-dependent price setting models, firms change prices in discrete (Taylor, 1979) or random (Calvo, 1983) time intervals, independent of the underlying economic environment. In contrast, state-dependent price setting models assume price adjustments to be somewhat costly<sup>1</sup> and therefore price changes depend on observable fundamental economic factors such as inflation or  $IU$  (Fabiani et al., 2006). Although, especially the newer state-dependent models (e.g. Golosov and Lucas, 2007; Gertler and Leahy, 2008; Costain and Narkov, 2011a,b; Dotsey et al., 2009; Midrigan, 2011) reasonably well resemble a fair amount of the stylized facts of price setting behavior, time-dependent models - especially the Calvo (1983) model - are still the most widely adopted price updating schemes in the literature on monetary policy. The straightforward reason is their analytical elegance and tractability.

For time-dependent price setting models firms' price changing decisions are independent of economic fundamentals - including inflation and  $IU$  -, but depends exclusively on time. This is in stark contrast with theoretical and empirical evidence. The theoretical literature suggests inflation to have a positive influence on the frequency of price adjustment (Sheshinski and Weiss, 1977<sup>2</sup>; Naish, 1986; Ball et al., 1988; Romer, 1990; Golosov and Lucas, 2007). In the

<sup>1</sup>These costs can take a variety of different forms, e.g. physical adjustment or "menu" costs (Sheshinski and Weiss, 1977; Rotemberg, 1982; Mankiw, 1985; Golosov and Lucas, 2007; Gertler and Leahy, 2008; among many others), information costs (Reis, 2006; Woodford, 2009; Maćkowiak and Wiederholt, 2009), or consumer costs such as customer disenchantment (Sibly, 2002, 2007), customer anger (Rotemberg, 2005), and customer regret (Rotemberg, 2010).

<sup>2</sup>Sheshinski and Weiss (1977) show that in general inflation has an ambiguous effect on the frequency of price changes. The negative effect of inflation on price changes occurs, however, only under unreasonably high inflation rates.



context of DSGE models, Fernández-Villaverde and Rubio-Ramírez (2010) find that movements in the Calvo pricing parameter are negatively correlated with inflation. Canova (2006) estimates a small-scale NKM for a variety of data samples for the United States and reports that the Calvo parameter seems to be relatively stable over most subsamples, with some variation for a few subsamples. Also Cogley and Sbordone (2005) find some weak evidence for variation of the Calvo parameter over different time periods for a non-zero steady state NKPC with indexation and strategic complementarities. These theoretical predictions are strongly supported by empirical evidence of, e.g. Klenow and Kryvtsov (2008), Nakamura and Steinsson (2008), and Klenow and Malin (2010) for the United States and Álvarez et al. (2006), Dyhne et al. (2006), and Vermeulen (2012) for the euro area. For  $IU$  the picture is less clear cut. While  $IU$  might be used to cover increases in firms' markup (Van Hoomissen, 1988; Bénabou, 1992; Tomassi, 1994) and thereby increases the frequency of price adjustments, it might also induce stronger search effort by customers, which leads to a closer monitoring of prices and consequently reduces price changes (Bénabou, 1992; Bénabou and Konieczny, 1994). Furthermore, a negative impact of  $IU$  on the frequency of price adjustment is also apparent in the presence of price adjustments costs (Sheshinski and Weiss, 1983; Danziger, 1999).

The distinction between time- and state-dependent pricing schemes is of crucial importance from the policy maker's point of view. First, the output effects of monetary shocks are typically stronger and longer lasting for time-dependent models relative to state-dependent models (Dotsey et al., 1999; Golosov and Lucas, 2007; Gertler and Leahy, 2008; Midrigan, 2011). Second, the welfare implications, measured by minimizing an objective function which is quadratic in inflation and the output gap (Woodford, 2003), under both schemes generally do not coincide (Lombardo and Vestin, 2008).<sup>3</sup>

Our empirical approach is based on the semiparametric estimation of a so-

<sup>3</sup>This holds even true for the comparison of Calvo (1983) and Rotemberg (1982) pricing, which up to a first-order approximation around the zero inflation steady state, result in observationally equivalent reduced-form macroeconomic dynamics (Roberts, 1995).

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called functional coefficient model. This allows to express functional dependence of parameters on observable factor variables (Cai et al., 2000). This method enables us to test for state-dependence of the Calvo parameter. An important advantage of this approach is that we can draw inference on the state-dependence of the pricing scheme by taking potential heteroscedasticity of the disturbances into account. This is required in models which relate price adjustment to inflation or  $IU$ , since such processes are characterized by conditional heteroscedasticity (Sims, 2001). If prices are more flexible at higher inflation rates or  $IU$ , this is likely reflected in the conditional volatility of inflation (Cogley and Sargent, 2005; Fernández-Villaverde and Rubio-Ramírez, 2007). To address residual heteroscedasticity in the inference process regarding functional dependence, we make use of the recently proposed factor-based bootstrap (Herwartz and Xu, 2009). This scheme resamples factor observations in contrast to drawing from the residuals as it is common, e.g. in the typically employed residual bootstrap. We describe the bootstrap scheme in detail after the introduction of the estimation method.

### 5.3 *Empirical Approach*

#### 5.3.1 *Data*

The data set comprises quarterly observations of real output, the implicit output deflator, and unit labor costs for  $N = 14$  advanced economies, namely Australia, Belgium, Canada, Finland, France, Italy, Japan, Netherlands, New Zealand, Portugal, Spain, Sweden, the United Kingdom, and the United States, from 1961Q3 to 2011Q4 taken from the OECD Economic Outlook No. 90. All series are seasonally adjusted. Inflation is defined as quarterly percentage change, i.e.  $\pi_t = 400 \times (p_t - p_{t-1})$  with  $p_t$  denoting the natural logarithm of the implicit output deflator and  $t = 1, \dots, T$  representing the time instances between 1961Q3 and 2011Q4, i.e.  $T = 201$ . Since real marginal costs  $mc_t$  are unobservable, we follow the suggestion of Galí and Gertler (1999) and use the

labor's share of income  $s_t$  as proxy instead, i.e.  $mc_t = s_t$ . The labor's share of income is equivalent to real unit labor costs and in log-linearized terms given by  $s_t = ulc_t - p_t$ , with  $ulc_t$  being nominal unit labor cost. Finally, we follow the mainstream procedure in the macroeconomic literature on estimating NKPC and generate the output gap  $\tilde{y}_t = y_t - \bar{y}_t$  by applying the Hodrick-Prescott filter with smoothing parameter  $\lambda = 1600$  to the series of real output  $y_t$ , which obtains the long-run trend estimate  $\bar{y}_t$  (Galí and Gertler, 1999; Galí et al., 2001).

### 5.3.2 Model Framework

Recent microeconomic studies on pricing behavior show that neither time-dependent nor state-dependent models alone are capable of fully replicating the various patterns of price movements in the data (Klenow and Kryvtsov, 2008; Nakamura and Steinsson, 2008; Klenow and Malin, 2010). Nevertheless, the majority of monetary policy analysis is conducted in NKMs resting on purely time-dependent pricing mechanisms such as the prominent Calvo (1983) staggered pricing scheme (e.g. Clarida et al., 1999; Eggertsson and Woodford, 2003; Smets and Wouters, 2003; Schmitt-Grohe and Uribe, 2007a; among others). According to the Calvo scheme, each period individual firms have a certain probability  $(1 - \theta)$  to be allowed to reset their price, while with probability  $\theta$  they have to remain their previous price. In the aggregate, such pricing behavior leads to the New Keynesian recitation of the Phillips curve, which relates inflation to expected future inflation and a measure of real marginal costs

$$\tilde{\pi}_t = \beta E_t \tilde{\pi}_{t+1} + \frac{(1 - \theta)(1 - \theta\beta)}{\theta} \tilde{m}c_t, \quad (5.1)$$

where  $\tilde{\pi}_t$  denotes inflation,  $\tilde{m}c_t$  represents real marginal costs and  $\beta < 1$  is a discount factor. Moreover, the Calvo probability  $\theta \in [0, 1]$  determines the degree of price inertia, where  $\theta = 0, 1$  refers to cases of fully flexible and fully rigid prices, respectively. In the model of Calvo (1983), the average duration of non-adjustment amounts to a fixed spell of  $1/(1 - \theta)$  quarters for the aggregate

price level. Substitution of the expectation error  $\varepsilon_t = \beta[E_t[\tilde{\pi}_{t+1}] - \tilde{\pi}_{t+1}]$  under rational expectation yields

$$\tilde{\pi}_t = \beta\tilde{\pi}_{t+1} + \frac{(1-\theta)(1-\theta\beta)}{\theta}\check{s}_t + \varepsilon_t, \quad (5.2)$$

In the framework of the NKPC, both, the specification in equation (5.2) and the shorthand representation, which is obtained by letting  $\kappa \equiv ((1-\theta)(1-\theta\beta))/\theta$ , have an economic interpretation. Galí and Gertler (1999) refer to  $\kappa$  as a “reduced form” parameter and distinguish this quantity from the “structural” coefficients of the NKPC from equation (5.2). As the term “structural” indicates, the price adjustment speed parameter  $\theta$  is treated as a constant, i.e.  $\theta$  is assumed to be independent of any economic fundamentals. However, allowing the frequency of price adjustment to co-vary with economic fundamentals influences the reduced form parameter  $\kappa$  and thus leads to a change in the sensitivity of inflation to innovations in real marginal cost (Gertler and Leahy, 2008) and hence to changes in the central banks ability to stabilize inflation via the nominal interest rate.

To allow for such non-constant behavior of the Calvo parameter, we employ a state-dependent NKPC, where the frequency of price adjustment depends on economic fundamentals rather than solely on time. The result is that the Calvo parameter  $\theta(\omega)$  is a function of  $\omega$ , where  $\omega$  represents potential factors variables. The simplest way to introduce such state-dependence into the Calvo (1983) mechanism is to allow firms to choose their optimal stochastic arrival rate  $\theta$ , given a cost of changing price. Such an approach has been introduced, among others, by Romer (1990), Kiley (2000), Devereux and Yetman (2002), and Levin and Yun (2007). In this context the authors derive a state-dependent Calvo parameter  $\theta(\pi)$ , with  $\frac{\partial\theta(\pi)}{\partial(\pi)} < 0$  (Bakhshi et al., 2007b).<sup>4</sup> Bakhshi et al. (2007a) show that the Calvo purely time-dependent NKPC, equation (5.1), is a special case of a more general Calvo state-dependent NKPC with  $\theta(\omega)$ . Therefore, we apply the generalization  $\theta(\omega)$  to equation (5.1) and refer to equation (5.3) as

<sup>4</sup>A related widespread approach to derive a state-dependent NKPC based on the Calvo mechanism is presented by Dotsey et al. (1999).

our state-dependent NKPC. Thus, equation (5.3) reads

$$\tilde{\pi}_t = \beta \tilde{\pi}_{t+1} + \frac{(1 - \theta(\omega))(1 - \theta(\omega)\beta)}{\theta(\omega)} \check{s}_t + \varepsilon_t, \quad (5.3)$$

where  $\omega = (w^{(1)}, w^{(2)})$ , i.e. we allow for bivariate state-dependence of the Calvo parameter. This formulation may be employed to detect changes in firms' price setting behavior which are driven by potential factor variables  $w_t^{(\bullet)}$ , where ' $\bullet = 1, 2$ ' indicates (1) lagged inflation  $\pi_{t-1}$  and (2) lagged inflation uncertainty  $IU_{t-1}$ . Inflation uncertainty is defined as  $IU_{t-1} = |\Delta\pi_{t-1}| = |\pi_{t-1} - \pi_{t-2}|$ , i.e. the absolute error of the inflation forecast from a random walk model. Such predictions are frequently found to obtain superior predictive performance as compared to other inflation forecasting schemes (Canova, 2007; Stock and Watson, 2007, 2008). To account for different scales of the inflation and  $IU$  processes,  $w_t^{(\bullet)}$  is considered in standardized form, i.e.  $w_t^{(\bullet)} = \tilde{w}_t^{(\bullet)} / \sigma(\tilde{w})$  with  $\sigma(\tilde{w})$  denoting the standard error of  $\tilde{w}_t^{(\bullet)}$ .

To examine the potential factor dependence of the Calvo parameter  $\theta$ , the influence of  $\tilde{\pi}_{t+1}$  on  $\tilde{\pi}_t$  and  $\check{m}c_t$  is accounted for by means of a partial regression step prior to the introduction of the state-dependent NKPC. To isolate the effect of  $\tilde{\pi}_{t+1}$  on  $\check{m}c_t$ , we let  $\check{m}c = (\check{m}c_1, \dots, \check{m}c_T)'$ ,  $\check{\pi} = (\check{\pi}_1, \dots, \check{\pi}_T)'$ , and  $\check{\pi}_+ = (\check{\pi}_2, \dots, \check{\pi}_{T+1})'$ , assuming that one additional observation is available. Then,  $\check{m}c = (I_T - \check{\pi}_+(\check{\pi}'_+\check{\pi}_+)^{-1}\check{\pi}'_+)\check{m}c$  where  $I_T$  denotes the identity matrix of dimension  $T$ , whereas  $\pi = \check{\pi} - \beta\check{\pi}_+$  may be obtained by presetting  $\beta = 0.99$ . Such magnitudes of the discount parameter  $\beta$  are commonly calibrated for quarterly data (Smets and Wouters, 2003; Altig et al., 2005; Sbordone, 2005; Dufour et al., 2006). Estimation of  $\beta$  also yields values close to 0.99 (Galí and Gertler, 1999; Dufour et al., 2006). Accounting for the effect of  $\pi_{t+1}$  in this way results in an equivalent representation of equation (5.3). The condensed representation is advantageous since we focus on the state-dependence of  $\theta$ . The

state-dependent NKPC is given by

$$\pi_t = \frac{(1 - \theta(\omega))(1 - \beta\theta(\omega))}{\theta(\omega)} mc_t + e_t, \quad (5.4)$$

where  $e_t$  denotes the error term in the regression after controlling for the effect of  $\tilde{\pi}_{t+1}$  on  $\tilde{p}_t$  and  $\tilde{m}c_t$ .

### 5.3.3 Estimation

Estimation of the factor dependent price adjustment frequency proceeds in analogy to the semiparametric Nadaraya Watson estimation method (Nadaraya, 1964; Watson, 1964). Thereby, we express functional dependence of the price adjustment parameter on  $\pi_{t-1}$  and  $IU_{t-1}$ . Apart from potential state-dependence, the employed estimation procedure has to take account of the potential endogeneity of  $mc_t$ , which is standard practice in the related literature, where estimation of the NKPC is discussed (see Galí and Gertler, 1999; Sbordone, 2005; and the references therein). The estimation of the NKPC commonly proceeds by means of the generalized method of moments (GMM). In the framework of the functional coefficient model (5.4), we account for regressor endogeneity by estimating  $\theta(\omega)$  according to

$$\hat{\theta}(\omega) = \arg \min_{\theta} q(\theta, K_h(\omega)), \quad (5.5)$$

with  $q(\cdot)$  denoting the GMM objective function

$$q(\theta, K_h, \omega) = \bar{m}(\cdot)' \Phi \bar{m}(\cdot), \quad (5.6)$$

where  $K_h(u) = K(u/h)/h$ , with  $K(\cdot)$  being a kernel function depending on the so-called bandwidth parameter  $h > 0$ . Moreover,  $\Phi$  represents a positive definite weighting matrix and  $\bar{m}(\cdot)$  is shorthand for the (empirical) moment condition

$$\bar{m}(\theta, K_h, \omega) = (1/T) \sum_{t=1}^T z_t e_t K_h(w_t^{(1)} - w^{(1)}) K_h(w_t^{(2)} - w^{(2)}). \quad (5.7)$$

In equation (5.7),  $z_t$  represents a vector of instrument variables.

#### 5.3.4 Implementation

Theoretical descriptions of how price adjustment responds to  $\pi$  or  $IU$  suggest that nominal rigidity is decreasing for higher inflation rates and in cases of rising  $IU$  (Ball et al., 1988). If the response of  $\theta$  to  $\pi$  or  $IU$  is not excessively volatile, observations  $w_t^{(\bullet)}$  near point  $w^{(\bullet)}$  should be informative for the value of the functional  $\theta(w^{(1)}, w^{(2)})$  near  $w^{(\bullet)}$  (Eubank, 1988; Härdle, 1990). The closer observations  $w_t^{(\bullet)}$  are to a point  $w^{(\bullet)}$ , the more informative they will typically be regarding the behavior of the functional  $\theta(\omega)$  near  $w^{(\bullet)}$ . These differences in the predictive content are incorporated in the estimation by means of the kernel function, which puts higher relative weight on those observations in proximity to  $w^{(\bullet)}$ . In equation (5.4), the relation between  $\pi_t$  and  $mc_t$  is evaluated in a neighborhood of  $\omega$  by means of the kernel weighting function  $K_h(\cdot)$ . Estimation of  $\hat{\theta}(\omega)$  yields local averages of the hypothesized state-dependent relation. An important part of semiparametric regression is the choice of  $h$ . This parameter determines how the tradeoff between unbiasedness and efficiency of estimation is addressed. While smaller bandwidths tend to increase the variability of estimates, larger values may hide local characteristics of the relation between  $\theta$  and  $\omega$ . For increasing  $h$ ,  $\hat{\theta}(\omega)$  approaches the limit of the usual time-invariant GMM estimate. This highlights that the functional coefficient method is suitable to contrast systematic variation in  $\theta$  from time invariance, since the NKPC under the latter assumption is nested in the state-dependent regression model (5.4). We choose the bandwidth according to Scott's rule of thumb (Scott, 1992), which obtains as  $h = 1.06T^{-1/5}$ , since the factor variables are considered in standardized form. We employ the logistic Kernel, i.e.  $K(u) = \Lambda(u)/(1 - \Lambda(u))$ , where  $\Lambda(u) = 1/(1 + \exp(-u))$ . For the graphical display of the functional dependence,  $\theta(w^{(1)} = v^{(1)}, w^{(2)} = v^{(2)})$  is evaluated at particular states  $(v^{(1)}, v^{(2)})$  from the

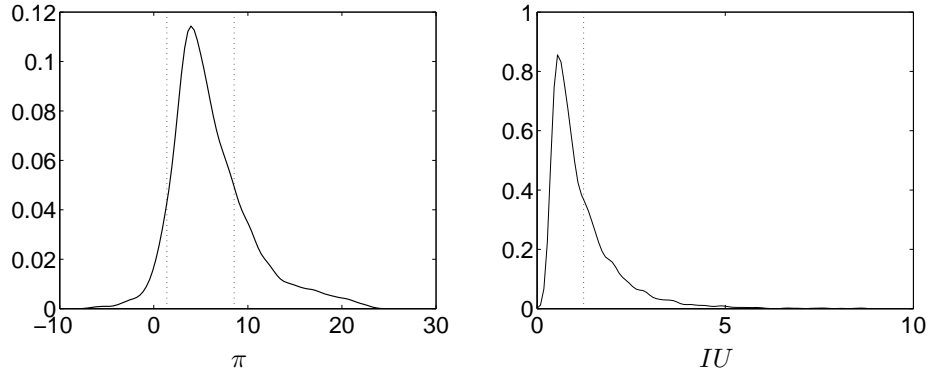


Fig. 5.1: Inflation rates and  $IU$ : Smoothed empirical densities of factor observations

equidistant grid

$$v^{(\bullet)} = c_{\text{lo}}^{(\bullet)}, c_{\text{lo}}^{(\bullet)} + k\mathcal{L}^{(\bullet)}, \dots, c_{\text{up}}^{(\bullet)}, \quad k = 1, 2, \dots, \quad (5.8)$$

where  $c_{\text{lo}}^{(\bullet)}, c_{\text{up}}^{(\bullet)}$  denote lower and the upper quantiles of the factor observations  $w_t^{(\bullet)}$ ,  $t = 1, \dots, T$  and  $\mathcal{L}^{(\bullet)}$  determines the step length. Particular choices of quantiles from  $w_t^{(\bullet)}$ ,  $t = 1, \dots, T$ , are determined to facilitate the graphical exposition and numerical accuracy of results. Functional coefficient estimates feature highest local efficiency at the center of a (unimodal) empirical factor distribution. In our case, the sample period covers observations from higher inflation regimes from the more distant past. Corresponding levels of  $\pi$  have only in few instances been observed during recent times. A choice of  $\{c_{\text{lo}}, c_{\text{up}}\} = \{0.2, 0.8\}$  determines a range of inflation and  $IU$  which is currently observed in most advanced economies. This can be seen from Figure 5.1, where estimates of the empirical density function of inflation are depicted. In the left plot, density estimates for  $\pi_{it}$ ,  $i = 1, \dots, 14$ ,  $t = 1, \dots, T$  are shown. The plot on the right shows respective kernel estimates for the  $IU$  series. Dashed lines indicate the cutoff points, which are determined as  $\{c_{\text{lo}}, c_{\text{up}}\} = \{0.01, 0.8\}$  as a suitable range of  $IU$  for which local dependence of  $\theta$  is examined.



### 5.3.5 Inference

In the framework of the functional coefficient NKPC, we intend to test if the adjustment parameter is constant or state-dependent. In the literature on functional coefficient estimation, such tests are routinely implemented by means of bootstrap approaches, i.e. by resampling from the disturbance term (Cai et al., 2000). The conclusions drawn from this resampling scheme, however, might be affected by heteroscedasticity in the disturbances (Herwartz and Xu, 2009). This is particularly relevant, since changes in the variance of inflation series over time are empirically well documented for a wide range of economies (Engle, 1982; Hartmann and Herwartz, 2012). For this reason, we employ the so-called factor-based bootstrap as suggested by Herwartz and Xu (2009), which is designed to circumvent the problems encountered by residual-based resampling procedures in case of heteroscedastic disturbances.

1. Functional coefficients evaluated at particular realizations of the data and for a given choice of  $h$  may be described as

$$\hat{\theta}(\omega) = \theta \left( \pi_t, mc_t, \omega_t = (w_t^{(1)}, w_t^{(2)}), h, t = 1, \dots, T \right). \quad (5.9)$$

2. To distinguish state-dependence from structural constancy in the pricing scheme, local estimates  $\hat{\theta}(\omega)$  are compared to their bootstrap counterparts

$$\hat{\theta}^*(\omega) = \theta \left( \pi_t, mc_t, \omega_t^* = (w_t^{(1*)}, w_t^{(2*)}), h, t = 1, \dots, T \right), \quad (5.10)$$

with binary tuples  $(w_t^{(1*)}, w_t^{(2*)})$  being drawn with replacement from the factor observations  $(w_t^{(1)}, w_t^{(2)})$ .

3. A large number as, e.g.  $\mathfrak{R} = 1000$  resampling estimates  $\hat{\theta}^*(\omega)$  obtains the bootstrap distribution of  $\hat{\theta}^*(\omega)$ . The corresponding confidence interval is employed to assess the local state-dependence of  $\theta(\omega)$ . In this study, we reject state-invariance at the 10 percent level, if  $\hat{\theta}(\omega)$  is either below the 5

percent or above the 95 percent-quantile of the bootstrap distribution at any level of the factor variables.

As it can be seen from step number 2 as described above, in this approach, the bootstrap confidence intervals are obtained by imposing  $H_0$  “directly” during the bootstrap, i.e. we distort the relation between  $\theta$  and the factor observations in  $\omega$  and thereby guarantee that  $H_0 : \theta(\omega) = \theta \forall \omega$  holds irrespectively of potential heterogeneity in the errors (or the factor observations).

#### 5.4 Results

In the following, we report estimates and test outcomes for the state-dependence of  $\theta$  and we comment on the magnitudes and economic plausibility of implied estimates of the NKPC relation. Results obtained by means of pooled panel estimation, where observations for all economies are jointly considered are also reported. In the literature it is well documented that the considered economies feature distinctive characteristics, particularly with respect to different levels of inflation or  $IU$  (Judson and Orphanides, 1999; Caporale and Kontonikas, 2009). Therefore, the conventional pooled estimation framework might be regarded as rather restrictive. However, the functional coefficient representation captures individual economies’ idiosyncratic characteristics through the influence of factor variables. This introduces considerable flexibility also in the pooled estimation setting.

Figure 5.2 and Figure 5.3 show estimates obtained according to equation (5.5) for the United States and the pooled sample. Solid lines represent the estimates  $\hat{\theta}$ , dashed lines stand for 90 percent bootstrap confidence intervals. The latter are obtained according to the factor-based bootstrap as described in Section 5.3.5. Local state-dependence at particular factor levels is indicated if estimates are outside the interval. For clarity, we present only a subset of estimates from the entire range of the factor space. Dependence of  $\theta$  on one of the factors is plotted conditional on a certain level of the respective other

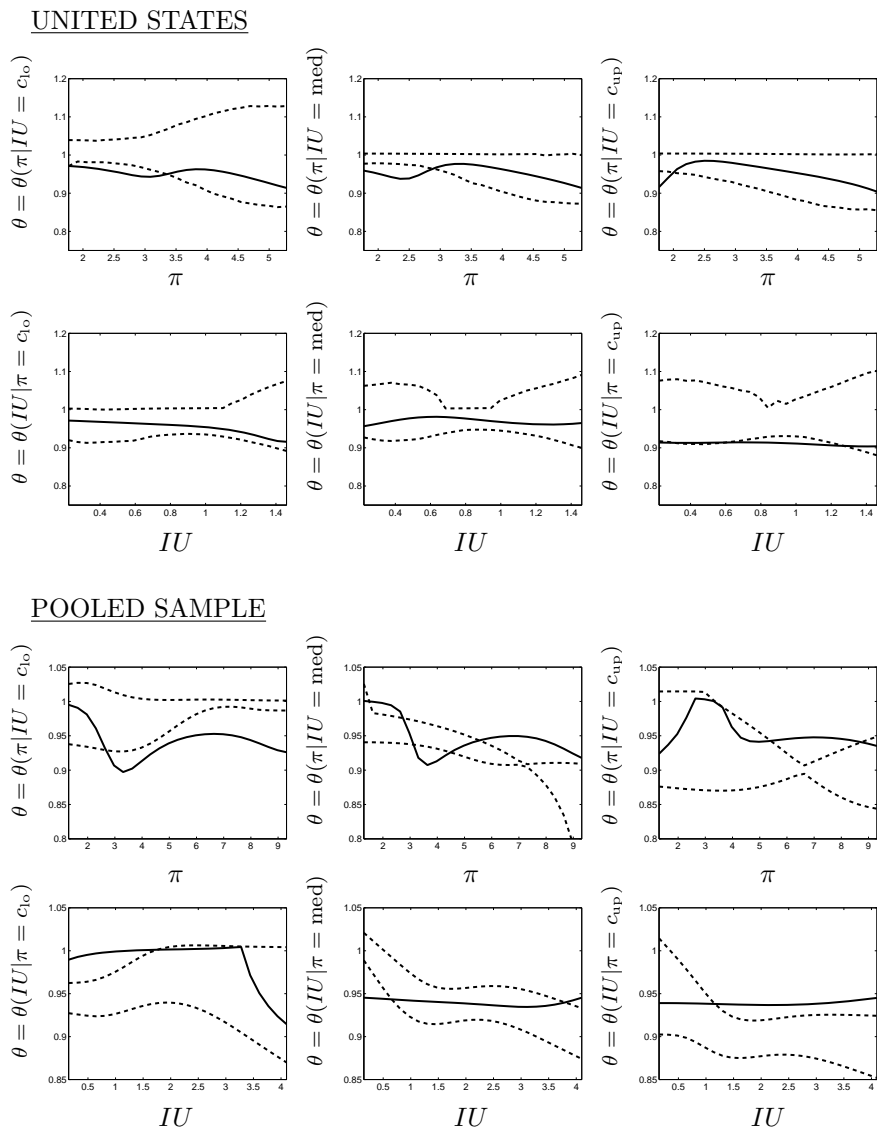


Fig. 5.2: Functional coefficient estimates for the United States and the pooled sample

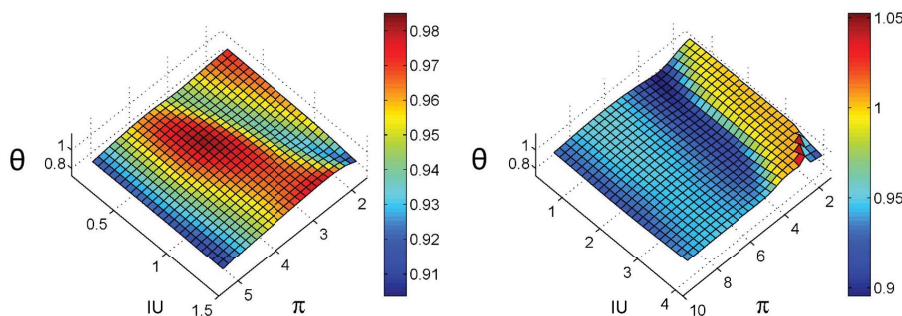


Fig. 5.3: Surface plots for the United States (left) and the pooled sample (right)

factor. For example,  $\theta = \theta(\pi|IU = c_{up})$  means that potentially inflation-induced variation in  $\theta$  is depicted for an  $IU$  level equal to the upper quantile of the  $IU$  series.

The estimates  $\hat{\theta}$  in Figure 5.2 reinstate the theoretical prediction that  $\frac{\partial \theta(\omega)}{\partial \pi} < 0$ , i.e. the frequency of price adjustment increases for higher inflation rates. This finding is also in line with recent evidence from Nakamura and Steinsson (2008) and Klenow and Kryvtsov (2008). In contrast, we do not find evidence for a uniform sign of the  $IU$  impact. This is in line with the discussion in Bénabou (1992), where both signs are described as plausible. As a robustness check, we also obtain estimates of Calvo parameters based on data for the remaining 13 single economies. For 10 out of 13 economies, an impact of either  $\pi$  or  $IU$  on  $\theta$  is detected. Only for Canada, Italy and Finland, the  $H_0$  of a constant Calvo pricing scheme cannot be rejected.

In Figure 5.3, surface plots for the United States and the pooled estimate are depicted to provide an impression on the joint impact of  $\pi$  and  $IU$  on  $\theta$ . Surfaces for the remaining individual economies are qualitatively similar and not reported to economize on space. Both plots of Figure 5.3 show that while  $\theta$  takes an initially high level for low inflation rates, the estimates drop at intermediate levels of  $\pi$  around 3 percent. In case of the pooled estimate, the updating frequency is less responsive for much higher  $\pi$ . At first, the price inertia for values of  $\pi$  which are currently observed in most advanced economies might appear

	ARCH(1)	ARCH(4)	$J \times 10^3$		ARCH(1)	ARCH(4)	$J \times 10^3$
AT	41.70	52.07	0.09	JP	18.89	26.01	0.01
BE	9.24	24.41	0.01	NL	32.37	111.74	0.32
CA	28.61	33.40	0.03	NZ	41.31	53.47	7.21
ES	34.94	42.81	0.01	PT	38.44	52.26	0.04
FN	74.89	102.17	0.97	SW	76.26	81.09	0.01
FR	42.67	51.31	0.51	UK	77.99	79.46	0.00
IT	26.25	42.10	0.12	US	43.99	51.42	0.01

Tab. 5.1: Regression diagnostics

relatively high. This is in contrast to micro-price studies which find averagely fixed prices between one and two quarters (Bils and Klenow, 2004; Klenow and Kryvtsov, 2008; Nakamura and Steinsson, 2008; Klenow and Malin, 2010). One reason for this divergence is the use of different observational frequencies. While the above mentioned studies use monthly consumer price index time series in their estimations, this paper applies quarterly aggregates of the GDP deflator. Ellis (2009) and Abe and Tonogi (2010) show that lower frequency data leads to larger estimates of price stickiness by construction. Micro-price studies at very high frequencies, such as weekly or even daily, report price spells of less than a quarter (Kehoe and Midrigan, 2007; Ellis, 2009; Abe and Tonogi, 2010; Cavallo, 2012). Moreover, estimating a high-frequency NKPC, Chapter 4 of this thesis shows that also on the macro level higher-frequency data leads to lower average price spells.

The magnitude of  $\theta$ , however, is close to estimates reported in other studies which investigate aggregate pricing (Smets and Wouters, 2003; Levin et al., 2006; Eichenbaum and Fisher, 2007; Nason and Smith, 2008; Fernández-Villaverde and Rubio-Ramírez, 2010). The influence of  $IU$  on  $\theta$  is in both cases confined to moderate inflation rates. However, this range of inflation is also currently most frequently observed. Whereas higher  $IU$  leads to decreasing  $\theta$  in the United States for low  $\pi$ , the effect is ambiguous in case of the pooled estimate. This suggests that  $IU$  influences  $\theta$  in a rather idiosyncratic way.

In Table 5.1, diagnostic test statistics are summarized. These statistics are obtained for estimates of equation (5.2) assuming no state-dependence of  $\theta$ .

Columns 1-2 and 4-5 report ARCH-LM test statistics (Engle, 1982) for the residuals from estimation of equation (5.2) with  $q = 1, 4$  denoting the lag order of squared disturbances. These ARCH-LM tests confirm the presence of conditional heteroscedasticity in the residuals for each considered economy. Our findings are in line with the findings of Fernández-Villaverde and Rubio-Ramírez (2010), who point out that ARCH-effects might lead to spurious conclusions regarding state-dependence or dynamics in  $\theta$ . Similarly, residual-based bootstrap methods as considered by, e.g., Cai et al. (2000) are unreliable in cases when disturbances feature ARCH dynamics (Herwartz and Xu, 2009). In such a situation, the factor-based bootstrap approach might be a more suitable means to draw inference on functional dependence of coefficients. Furthermore, Columns 3 and 6 report  $J$ -t est statistics for overidentifying restrictions in the GMM estimation procedure. The  $J$ -statistics in Table 5.1 indicate no evidence against the null hypothesis of joint exogeneity of the instrument variable (IV) set. We choose  $z_t = (\tilde{y}_{t-1}, \tilde{y}_{t-2})'$  as instrument variables, a subset of the instrument variables considered by, e.g. Galí and Gertler (1999), where  $\tilde{y}_t = y_t - \bar{y}_t$  denotes the output gap, i.e. the deviation of gross domestic product  $y_t$  from its long term trend  $\bar{y}_t$ .

With 2 instrument variables, the  $J$ -test for overidentification adheres to a  $\chi^2(1)$  distribution under  $H_0$  of at least one of the instrument variables being exogenous. Depending on initial examination of the  $J$ -statistic, we determine the IV set alternatively as  $z_t = \tilde{y}_{t-1}$  in cases where exogeneity is rejected.

A further way to assess the plausibility of the obtained estimates is to examine the magnitude and significance of the reduced-form parameter  $\kappa \equiv ((1 - \theta)(1 - \theta\beta))/\theta$ . A puzzling finding of many studies, where similar to Galí and Gertler (1999) the labor's share of income is employed as an explanatory variable in the structural NKPC is that estimates of  $\kappa$  are insignificant or even have a theoretically implausible negative sign (Jondeau and Bihan, 2005; Rudd and Whelan, 2005; Abbas and Sgro, 2011; Kuttner and Robinson, 2012).

Table 5.2 shows reduced form Phillips curve estimates  $\kappa$  and corresponding

	$\kappa$	$t$ -stat.		$\kappa$	$t$ -stat.
AT	0.01	0.01	JP	0.01	0.01
BE	0.02	0.02	NL	0.01	0.01
CA	0.01	0.01	NZ	0.02	0.11
ES	0.02	0.03	PT	0.02	0.25
FN	0.01	0.02	SW	0.03	0.02
FR	0.02	0.03	UK	0.05	0.06
IT	0.01	0.11	US	0.01	0.01

Tab. 5.2: Estimates for equation (5.2) (constant  $\theta$  case)

$t$ -statistics based on Newey and West (1987) standard errors, as they are typically reported in related studies. For the economies we consider, the sign of the Phillips curve relation is positive, as predicted by economic theory. The magnitudes of estimates are for all economies similar to the findings reported by Galí and Gertler (1999), Galí et al. (2001), or Sbordone (2005), among many others. Moreover, in line with existing empirical evidence, none of the coefficients is statistically significant. Since disturbances are found to be heteroscedastic,  $t$ -statistics are based on a robust covariance estimator (Newey and West, 1987).

The recurring finding of implausible NKPC parameter estimates has led to doubts about the suitability of the labor's share of income as a measure of marginal costs (Wolman, 1999; Neiss and Nelson, 2002; Kiley, 2007). The criticism put forth in these studies is also based on theoretical arguments. However, Wolman (1999) and Galí et al. (2005) point out that it might be the overly restrictive assumption of a constant price updating frequency, as implied by the Calvo (1983) scheme, that gives rise to estimation problems. This hypothesis can be addressed by means of the functional coefficient framework. In analogy to the investigation described above, we estimate the reduced-form NKPC, allowing for state-dependence such that  $\kappa = \kappa(\omega)$ . Since functional dependence of  $\theta$  is detected in the majority of economies, the same might also hold for  $\kappa$ .<sup>5</sup> Local estimates of  $\kappa$  and corresponding  $t$ -statistics for distinct levels of  $\pi$  and  $IU$  indicate if the generalization reinstates the theory with empirical NKPC

<sup>5</sup>Functional coefficient estimates which allow for state-dependence of both  $\theta$  and the discount parameter  $\beta$  suggest that  $\beta$  is not affected by either  $\pi$  or  $IU$ . These results are not reported in detail and might be obtained from the authors upon request.

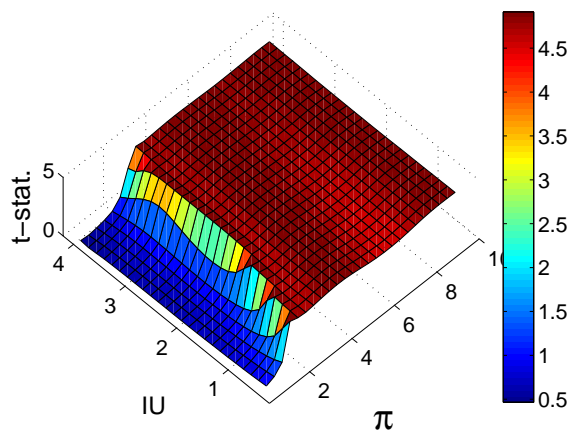


Fig. 5.4: State-dependent  $t$ -statistics for the reduced-form Phillips curve parameter  $\kappa$

estimates. We find that allowing for state-dependence of  $\kappa$  obtains estimates at similar magnitudes as reported in Table 5.2. The  $t$ -statistics are mostly higher than their counterparts in Table 5.2 but are, however, throughout insignificant also in this case. However, insufficient degrees of freedom might deteriorate the power of  $t$ -tests regarding local semiparametric estimates to a larger extent than in the parametric case. We, therefore, compare pooled estimates under the assumption of a constant and state-dependent  $\kappa$ . As depicted in Figure 5.4, the  $t$ -statistics for functional coefficient estimates of  $\kappa$  are highly significant over almost the entire range of the factor space. The respective state-invariant pooled  $t$ -statistic, in contrast, is equal to  $t_{\text{pooled}} = 1.04$ . Though significance tests for individual economies are not rejected, these findings are at least an indication that state-dependence is a meaningful generalization of the Calvo scheme.

For macroeconomic theory the results obtained above are particularly noteworthy, since most studies on monetary policy are conducted in a time-dependent, rather than a state-dependent, framework. The reason is straightforward: there seems to be a widespread agreement in the literature that both approaches are almost equivalent (Ascari and Rossi, 2012) and time-dependent models are analytically simpler and much more tractable. The equivalency result is true,



however, only under very restrictive assumptions. For instance, Roberts (1995) shows that the standard approaches to time- and state-dependent pricing (which are the time-dependent approaches by Taylor (1979) and Calvo (1983) and the state-dependent approach by Rotemberg (1982)) yield observationally equivalent reduced-form dynamics up to a first-order Taylor approximation around the zero-inflation steady state. Ascari and Rossi (2012), however, show that this does not hold true anymore in the presence of trend inflation. Also, the welfare implications under these approaches, measured by minimizing an objective function which is quadratic in inflation and the output gap (Woodford, 2003), coincide up to a second-order Taylor approximation only as long as the steady state is efficient<sup>6</sup> (Nisticò, 2007; Lombardo and Vestin, 2008; Damjanovic and Nolan, 2011).

Finally, the output effects of monetary shocks are typically stronger and longer lasting for time-dependent models relative to state-dependent models (Dotsey et al., 1999; Golosov and Lucas, 2007; Gertler and Leahy, 2008; Midrigan, 2011). Intuitively, the reason is straightforward. While a positive monetary policy shock increases inflation, this in turn increases the price updating frequency. With more prices being updated, the Phillips curve flattens and the output reaction ceases. In time-dependent models, as noted, the average frequency of nominal adjustment is independent of inflation. Additionally, state-dependent models feature a selection effect, which is not met by time-dependent models. In state-dependent models those firms change prices, whose prices are most out of line. Therefore, nominal adjustments are quite large compared to the adjustment under time-dependent models. Consequently, state-dependent models feature a much stronger nominal flexibility (Caplin and Spulber, 1987; Golosov and Lucas, 2007).

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<sup>6</sup>In the sense that distortions from monopolistic competition are met by a subsidy to the firm, which elevates the quantity supplied to the level under perfect competition.

### 5.5 *Summary and Concluding Remarks*

In this chapter, the method of functional coefficient regression is applied to investigate on the state-dependence of the frequency of price updating. We find that both the inflation rate and  $IU$  significantly affect aggregate price adjustment. Inference is based on a bootstrap methodology which is unaffected by heteroscedasticity in the regression disturbances. Nonspherical disturbances are described as a principal impediment to valid inference in previous empirical examinations of state-dependent pricing rules. We find that the updating frequency increases at higher inflation rates. Moreover, functional coefficient estimates of the Phillips curve relation are found to be more in line with theory than estimates obtained under the assumption of constant coefficients. These findings imply that the “deep parameter” interpretation of the standard Calvo (1983) price setting scheme is a too restrictive assumption for actual price setting behavior.

Our results are of particular importance for the conduct of monetary policy analysis. First, the welfare implications under time- and state-dependent approaches coincide only under the very restrictive assumption of an efficient steady state, which is unlikely to be met. Second, output effects of monetary shocks are typically stronger and longer lasting for time-dependent models relative to state-dependent models. Therefore, the correct application of time- or state-dependent pricing schemes to the particular economy of interest is of crucial importance from the policy maker’s point of view.

## 6. SUMMARY AND OUTLOOK

This thesis has taken alternative views on preferences and nominal rigidities and their interaction with monetary policy.

In the theoretical part of this thesis (Chapters 2 and 3) we show that an alternative view on preferences allows us to provide rationales for long-run effects of monetary policy and endogenous price stickiness.

In particular, Chapter 2 has incorporated inequality aversion into an otherwise standard DSGE model with staggered, monopolistically competitive nominal wage contracts. In this context, we have derived a backward-bending long-run Phillips curve, so that increases in money growth lead to higher employment and output at low inflation, but to lower employment and output at high inflation. We show that the welfare maximizing inflation rate is just under 2 percent. This result is striking since the mainstream literature on optimal monetary policy places the optimal inflation rate in the range between zero and a negative number (minus the real interest rate, as implied by the Friedman rule). Endogenizing the probability of wage adjustment does not restore monetary long-run neutrality, as long as wage changes are costly. Furthermore, the tradeoff remains robust to variations in the price adjustment scheme and the specification of inequality aversion. Clearly, envy and guilt are not the only behavioral motives entering the utility function of homo-sociologicus. Further research will include analyzing other important motives such as status preferences or pride with regard to their explanatory power of the long-run neutrality puzzle.

Chapter 3 has incorporated consumer loss aversion in the price dimension into an otherwise standard neoclassical model of monopolistic competition. The resulting theory of price adjustment is starkly at variance with past neoclassical

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and Keynesian theories. We have shown that loss averse consumers generate state-dependent price sluggishness in the form of asymmetric price adjustments. In line with ample empirical evidence, we show that for permanent demand shocks, output is more responsive to negative shocks than positive ones, but for temporary shocks, output is more responsive to positive shocks. Standard time-dependent and state-dependent models fail to account for these asymmetries. Furthermore, in contrast to the standard time-dependent and state-dependent models, our explanation of price adjustments is derived entirely from microfoundations, without any recourse to ad hoc assumptions concerning the frequency of price changes or physical costs of price adjustments. Clearly, loss aversion in prices is only one aspect. It is easy to think of other aspects, households are loss averse towards to. For instance, assuming that households or workers are loss averse with respect to their nominal wages rather than prices, gives rise to a rationale for downward nominal wage rigidity in response to permanent labor demand shocks. We will analyze this phenomenon in a subsequent paper.

In the empirical part of this thesis, we have focused completely on the firm side of the economy, represented by the NKPC. In Chapters 4 and 5, we propose two alternative methods to estimate the structural short-run NKPC, to improve the estimation procedure with the goal to realign the macroeconomic estimates with microeconomic evidence.

In particular, Chapter 4 has estimated a higher-frequency NKPC. The estimation on a higher observation frequency mitigates the small-sample bias and avoids the overstatement of the true price stickiness, which arises from lower frequency price aggregates. Our results are, again, in stark contrast to the standard literature. While price stickiness estimated from quarterly macro data often highly overstates price stickiness estimated from micro price data, our high-frequency estimates from macro price data are consistent with estimates from micro price data. With Argentine data from late 2007 to early 2011 we have found that Argentine prices remain fixed - on average - for much less than a quarter. This finding has immediate implications for monetary policy analy-

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sis in Argentina. For the case of Argentina, a quarterly model would need to be calibrated as flexible price model, instead of a sticky price model. Alternatively, to apply a sticky price model, it must be calibrated at most on a monthly frequency. Whether this holds true for other economies (especially the United States or the countries of the euro area) will be the focus of future research in this area.

Finally, in Chapter 5 has empirically investigated the time-dependent and state-dependent behavior of aggregate price setting, by implementing a testing procedure by means of a nonparametric representation of the structural form NKPC. By means of the so-called functional coefficient regression we have tested for potential dependence of the Calvo parameter on inflation and inflation uncertainty. We have confirmed that the Calvo scheme is a too restrictive model of aggregate price setting. Furthermore, we have documented that a number of shortcomings of empirical NKPC representations in explaining inflation data may be addressed by means of a state-dependent pricing rule.

To summarize, taking an alternative view on preferences and nominal rigidities highly influences the way we think about monetary policy analysis. As this thesis has shown, diverging from the standard assumption of the homo-economicus, can have substantial effects on the incentive systems of economic agents. Therefore, the results from this thesis issue a word of caution with regard to the careless application of homo-economicus in economic analysis. As indicated in the paragraphs above, much is left to be analyzed with respect to the motivational underpinnings of economic agents' preferences for macroeconomic phenomena. This will be subject of future research along the lines presented in thesis.

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## CURRICULUM VITAE



## Steffen Ahrens

### **Personal Information**

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Date of Birth: October 18, 1979  
Citizenship: German  
E-Mail: steffen.ahrens@tu-berlin.de

### **Affiliations**

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Technische Universität Berlin - Department of Economics and Law  
Collaborative Research Center 649 "Economic Risk"  
Kiel Institute for the World Economy

### **Research Interests**

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Monetary Macroeconomics, Labor Economics, Behavioral Economics, Experimental Economics

### **Education**

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05/2008 - present    Doctoral program "Quantitative Economics" at Kiel University, Germany  
08/2006 - 05/2007    Academic year at the University of Illinois at Urbana-Champaign, USA  
10/2002 - 02/2008    Diplom in economics from Kiel University, Germany

### **Work Experience**

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05/2013 - present    Research affiliate at the Technische Universität Berlin, Berlin, Germany,  
Faculty of Economics and Economic Law, Chair of Macroeconomics  
05/2008 - present    Research economist at the Presidential Department of the Kiel Institute  
for the World Economy, Kiel, Germany  
05/2008 - 04/2013    Coordinator of the *Kiel-Illinois Student Exchange Program* between Kiel  
University and the University of Illinois at Urbana-Champaign, USA  
05/2008 - 04/2013    Teaching assistant to Professor Dennis J. Snower, Ph.D. at Kiel University,  
Department of Economics, Chair of Economic Theory, Kiel, Germany  
2011                    Session Organizer at the Global Economic Symposium, Kiel, Germany  
Session: The Economics and Psychology of Building Sustainable Finance  
2010                    Session Organizer at the Global Economic Symposium, Istanbul, Turkey  
Session: Fighting Sovereign Debt Crises Worldwide  
2009                    Session Organizer at the Global Economic Symposium, Plön, Germany  
Session: The Future of Global Financial Governance  
2008                    Session Organizer at the Global Economic Symposium, Plön, Germany  
Session: How Globalization Transforms the Welfare State

## Teaching Experience

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### TU Berlin:

#### Lectures:

Winter Term 2013/14 Monetary Theory and Policy

#### Tutorials:

Winter Term 2013/14 Monetary Theory and Policy

### Kiel University:

#### Tutorials:

Winter Term 2012/13 Introduction to Macroeconomic Theory

Summer Term 2012 Behavioral- and Neuroeconomics

Winter Term 2011/12 Introduction to Macroeconomic Theory

Summer Term 2011 Behavioral- and Neuroeconomics

Winter Term 2010/11 Advanced Macroeconomics II

Winter Term 2010/11 Introduction to Macroeconomic Theory

Summer Term 2010 Labor Economics II

Summer Term 2010 Dynamic Monetary and Labor Theory

Winter Term 2009/10 Introduction to Macroeconomic Theory

Summer Term 2009 Dynamic Monetary and Labor Theory

Summer Term 2009 Labor Economics II

Winter Term 2008/09 Introduction to Macroeconomic Theory

Summer Term 2008 Dynamic Monetary and Labor Theory

#### Seminars:

Winter Term 2011/12 Shocks, Crises and Spurts in Regional and Global Governance,  
joint with Professor Dr. Rolf Langhammer

Winter Term 2011/12 Behavioral- and Neuroeconomics: Emotions in Economics,  
joint with Professor Dennis J. Snower, Ph.D.

Winter Term 2010/11 Global, Regional and National Crisis Management in an Integrated  
World Economy, joint with Professor Dr. Rolf Langhammer

Winter Term 2009/10 Labor Economics,  
joint with Professor Dennis J. Snower, Ph.D.

Winter Term 2009/10 Scrutinizing the Biggest Post-War Economic Crisis from a Global  
Perspective, joint with Professor Dr. Rolf Langhammer

## Conferences, Seminars and Workshops

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- 2014 Annual Meeting of the American Economic Association, Philadelphia, USA
- 2013 6th Global Economic Symposium, Kiel, Germany
- 2013 Annual Meeting of the CRC 649 “Economic Risk”, Motzen, Germany
- 2013 18th Spring Meeting of Young Economists, Aarhus, Denmark
- 2013 Research Seminar at the Technische Universität Berlin, Berlin, Germany
- 2013 Research Seminar at the Federal Reserve Bank of Boston, Boston, USA
- 2013 Annual Meeting of the American Economic Association, San Diego, USA
- 2012 66th Congress of the Econometric Society, Málaga, Spain
- 2012 27th Congress of the European Economic Association, Málaga, Spain
- 2012 Dynare Summer School at the Banque de France, Paris, France
- 2012 Interdisciplinary Congress “Junge Wissenschaft und Praxis,” Leipzig, Germany
- 2012 17th Spring Meeting of Young Economists, Mannheim, Germany
- 2011 4th Global Economic Symposium, Kiel, Germany
- 2011 Annual Meeting of the German Economic Association, Frankfurt, Germany
- 2011 17th International Conference on Computing in Economics and Finance, San Francisco, USA
- 2011 Annual Meeting of the Swiss Society of Economics and Statistics, Lucerne, Switzerland
- 2011 Eurasia Business and Economics Society Conference, Istanbul, Turkey
- 2011 16th Spring Meeting of Young Economists, Groningen, Netherlands
- 2010 DIW Macroeconometric Workshop, Berlin, Germany
- 2010 3rd Global Economic Symposium, Istanbul, Turkey
- 2010 Annual Meeting of the German Economic Association, Kiel, Germany
- 2010 NBER Summer Institute 2010, Boston, USA
- 2010 Zeuthen Workshop on Macroeconomics with Jordi Galí, Copenhagen, Denmark
- 2009 Seminar on Macroeconomics at the University of Illinois at Urbana-Champaign, USA
- 2009 2nd Global Economic Symposium, Plön, Germany
- 2008 1st Global Economic Symposium, Plön, Germany

## Merits

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- 2011 Partial Scholarship for the Chinese Language and Culture Program at Zhejiang University, Hangzhou, China
- 2008 Erich-Schneider-Award for 6-month diploma thesis “Marginal Costs and Inflation Dynamics: An Econometric Study”
- 2006/2007 Tuition-waiver at the University of Illinois at Urbana-Champaign, USA

## Languages

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- German Native language
- English Fluent in spoken and written

## Software

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Microsoft Office, Scientific Workplace, LaTeX, EViews, Matlab, Mathematica

## Referee

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Economic Modelling, Oxford Bulletin of Economics and Statistics

## Publications

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Ahrens, S. and Snower, D.J. (2014), *Envy, Guilt, and the Phillips Curve*. Journal of Economic Behavior & Organization, volume 99, pages 69–84, Elsevier, Amsterdam.

Ahrens, S. and Sacht, S. (2014), *Estimating a High-Frequency New-Keynesian Phillips Curve*. Empirical Economics, volume 46, pages 607–628, Springer, Berlin/Heidelberg.

Ahrens, S. and Snower, D. J. (2012), *Auch aus der Sicht von Zentralbanken: Der Mensch als soziales Wesen*, IfW-Highlights 2011, Kiel Institute for the World Economy.

Ahrens, S. (2009), *Fiscal Responses to the Financial Crisis*, Kiel Policy Brief 11, Kiel Institute for the World Economy. In: *The Crisis and Beyond*, 2009, edited by H. Klodt and H. Lehment.

## Working Papers

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Ahrens, S. and Hartmann, M. (2013), *State- vs. Time-Dependence? A Multi-Economy Investigation of Price Sluggishness*, Kiel Working Papers No. 1907, Kiel Institute for the World

Ahrens, S., Pirschel, I. and Snower, D.J. (2013), *Loss Averse Consumers: An Alternative Theory of Price Adjustment*. German Economic Association Annual Conference 2013 (Duesseldorf): Competition Policy and Regulation in a Global Economic Order No. 79793.

Ahrens, S. (2012), *Inequality Aversion and the Phillips Curve: Bilateral versus Group Comparison*, Kiel Working Papers No. 1802, Kiel Institute for the World Economy.

Ahrens, S. and Wesselbaum, D. (2009), *On the Introduction of Firing Costs*. Kiel Working Papers No. 1559, The Kiel Institute for the World Economy.

## Work in Progress

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Ahrens, S., Braun, S., Friedl, A., Schmidt, U. and Snower, D.J. (2013), *Explaining International Differences in Payment Schemes*.

Ahrens, S., Graham, L. and Snower, D.J. (2013), *A Theory of Nominal Inertia*.

## EIDESSTATTLICHE ERKLÄRUNG

Ich erkläre hiermit an Eides Statt, dass ich meine Doktorarbeit *Preferences, Nominal Rigidities, and Monetary Policy* selbständig und ohne fremde Hilfe angefertigt habe und dass ich alle von anderen Autoren wörtlich übernommenen Stellen wie auch die sich an die Gedanken anderer Autoren eng anlehnenden Ausführungen meiner Arbeit besonders gekennzeichnet und die Quellen nach den mir angegebenen Richtlinien zitiert habe.

Kiel, 03. Dezember 2013

(Steffen Ahrens)