Pricing When Customers Care about Fairness but Misinfer Markups

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PRELIMINARY AND INCOMPLETE

Abstract

In various contexts, prices seem somewhat rigid: they are not fixed, but they do not respond fully to marginal-cost shocks either. Price rigidity has many implications in public economics, international economics, industrial organization, and macroeconomics. However, the theories developed to explain it find little support in surveys of price-setters, which indicate that firms stabilize prices out of fairness for their customers. This paper proposes a theory of price rigidity consistent with the survey evidence. The theory relies on two psychological assumptions. First, customers care about the fairness of prices: they enjoy more a good priced at a low markup than at a high markup over marginal costs. Second, customers misinfer marginal costs from prices: when prices rise after an increase in marginal costs, customers underappreciate the increase in marginal costs and partially misattribute higher prices to higher markups. As they perceive transactions as less fair, the price elasticity of their demand for goods rises, and firms respond by reducing markups. Hence, the passthrough of marginal costs into prices is less than one—prices are somewhat rigid. In general equilibrium, our theory explains why money is nonneutral and why the Phillips curve has a backward-looking component.

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1. Introduction

Empirical evidence suggests that prices are somewhat rigid: they are not exactly fixed, but they do not respond fully to marginal-cost shocks, at least in the short run. Four recent studies document this property in various contexts: they show that in response an exogenous change in marginal costs, prices quickly adjust but the passthrough of marginal costs into prices is much less than one; furthermore, the passthrough often remains below one at longer time horizon. The first study, by Benzarti and Carloni (2016), analyzes a 14-percentage-point cut of the value-added tax applied to sit-down restaurants in France in 2009. It finds that restaurants prices decreased only by a small amount, with a low passthrough of about 15%. The second study, by Carlsson and Skans (2012), uses Swedish matched data on product-level prices and firms' unit labor cost. It finds a moderate passthrough of marginal-cost changes into prices: about 35%. The third study, by De Loecker et al. (2016), finds that after trade liberalization in India in the 1990s, marginal costs fell significantly because input tariffs were reduced, and prices fell as well, but much less than marginal costs. Indeed, firms offset the reductions in marginal costs by raising markups, leading to a passthrough of about 30%. The fourth study, by Gopinath and Rigobon (2008), uses microdata on US import prices at the dock and finds that even conditioning on a price change, the exchange-rate passthrough into import prices is low, about 20%. Many more studies find similar results: we discuss them below.

Price rigidity has many implications. For instance, in macroeconomics, it explains why monetary policy is nonneutral—it affects employment and output. In international economics, it explains deviations from the law of one price, and the behavior of real exchange rates. In public economics, it affects the incidence of taxes. In industrial organization, it determines the responses of firm-level markups and production to shocks.

Many theories have been developed to explain this price rigidity. For instance, in macroeconomics, a common theory is that firms face constraints when changing their prices. Many such constraints have been explored in depth: long-term nominal contracts, price-adjustment costs, or information-collection costs. One avenue that has received limited attention is the role of fairness in explaining price rigidity. This avenue seems promising because a growing body of evidence suggests that firms are not constrained in setting prices so much as reluctant to raise prices for fear of alienating customers, who are averse to paying prices that they regard as unfair (for example, Blinder et al. 1998; Fabiani et al. 2006). Given that the microfoundations of price rigidity determine the welfare properties of the model, and that price-rigidity models are used for policy analysis across fields, it seems useful to offer a model that not only matches facts but also conforms to the motivations of price setters.

In this paper, we develop a model of pricing consistent with firms' view that addressing customers' concern for fairness is an important aspect of pricing. Our model rests upon two psychological assumptions. The first assumption is that customers dislike paying prices that exceed a fair markup on what they perceive as marginal costs. The assumption is motivated by the seminal work of Kahneman, Knetsch, and Thaler (1986), who find that despite regarding it as acceptable for firms to raise prices in response to higher marginal costs, most people find it unfair for firms to raise prices in response to elevated demand. Several firm and consumer surveys, our own survey of French bakers, as well as historical pricing norms appearing in religious and legal texts also suggest that customers dislike paying prices exceeding some fair markup on marginal costs, and that firms understand this. Because customers typically do not observe firms' costs, their perceptions of the fairness of firms' prices depend crucially upon their estimates of firms' marginal costs. The second assumption is that customers update their beliefs about firms' marginal costs less than rationally from available information. Customers who underinfer about firms' marginal costs partially misattribute higher prices to higher markups rather than to higher marginal costs; these customers therefore conclude that the higher prices are less fair. This assumption is motivated by evidence suggesting that in general people are less than rational when inferring others' private information from their actions (for example, Samuelson and Bazerman 1985; Weizsäcker 2010).

We embed these two psychological assumptions into a simple model of monopolistic pricing. In modeling customers' concern for fair prices, we assume that the utility derived from consuming a good depends on the perceived fairness of the transaction—a perception that depends on the purchase price and the consumer's estimate of the good's marginal cost. Formally, when a good is sold at price P and has a perceived marginal cost of MC^p, customers perceive its markup to be $K^p = P/MC^p$. When customers judge the fair markup to be some K^f, they weight each unit of consumption by a factor of $F = 2/\left[1+(K^p/K^f)^\theta\right]$. Here θ parametrizes fairness concerns. When $\theta = 0$, customers do not care about fairness, and the model reduces to a typical monopoly model. When $\theta > 0$, customers care about the fairness of prices.

In our formulation, the demand faced by the monopoly is decreasing in the price P in two ways. First, a high P reduces demand through the standard channel: because paying a high price affects customers' budget constraint. Second, a high P reduces demand through the fairness channel: because paying a price that is perceived to be unfairly high lowers the marginal utility of consumption. Fairness concerns, operating through the fairness measure F, lead the demand to have a higher price elasticity than it would in a standard model without fairness.

Because customers do not directly observe firms' marginal costs, their perceptions of how fairly firms price their goods depend upon their estimates of these costs. Thus, the inferences that they draw about marginal costs play a pivotal role. We make the assumption that customers misperceive the monopoly's marginal cost to be $MC^p = \left(MC^b\right)^{\chi} \times MC^{1-\chi}$, where MC^b represents customers' prior belief about the marginal cost and MC the firm's true marginal cost. The parameter $\chi \in [0,1]$ measures customers' naivety when inferring marginal costs. When $\chi = 0$, customers rationally infer marginal costs and hence markups. In that case, fairness plays absolutely not role. When $\chi > 0$, customers underappreciate the extent to which changes in prices reveal changes in marginal costs. In that case, fairness will matter. Such customers do update their beliefs in the right direction from available information, but stop short of rational inference because their beliefs move too little relative to their priors. Since customers who incompletely infer underappreciate the change in marginal cost when they observe a price change, they misattribute part of the price change to a change in the underlying markup.

When customers care about fairness but incompletely infer marginal costs, prices are somewhat rigid in that the passthrough of marginal cost into prices is less than one. After an increase in price caused by higher marginal cost, customers underappreciate the increase in marginal cost, so they partially misattribute the higher price to a higher markup, which they find unfair. Since the perceived fairness of the transactions decreases, the elasticity of the demand for goods increases. In response, the monopoly reduces its markups. Therefore, the price increases, albeit less than proportionally with the marginal cost. Hence, the passthrough is below one. In this sense, prices exhibit a mild form of rigidity, exactly as observed in international economics, industrial organization, and public economics.

Last, we embed our pricing model into a simple New Keynesian model to illustrate how our two psychological assumptions generate money nonneutrality. We find that in steady state, higher inflation leads to higher employment, so the long-run Phillips curve is not vertical. We also find that in the short run, monetary policy affects employment. Unlike in the standard New Keynesian model, however, the short-run Phillips curve is not purely forward looking: it is both foward and backward looking. Hence, the short-run Phillips curve links current inflation and employment to expected inflation and past inflations.

2. Related Literature

Rotemberg (2005) pioneered the study of the implications of fairness for price rigidity.[1] He assumes that customers care about firms' altruism—their taste for increasing customers welfare—which they re-evaluate after every price change. Customers buy a normal amount from the firm unless they can reject the hypothesis that the firm is altruistic toward them, in which case they withhold all demand in order to lower the firm's profits. Given such discontinuity in demand, firms react by refraining from passing on small cost increases, which leads to price rigidity.

In this paper, we retool the psychological assumption of Rotemberg (2005) that customers refuse to purchase from unfair firms by assuming that customers experience less enjoyment from a good when they regard its price as less fair. Despite broad similarities, the two assumptions differ conceptually: unlike Rotemberg's, our assumption implies that customers would withhold demand from unfair firms even if doing so did not hurt the firms. Importantly, the two assumptions yield different models. In our model, customers do not withhold demand from unfair firms to punish them but do so because they enjoy consuming unfairly priced goods less. This allows us to move away from Rotemberg's discontinuous, buy-normally-or-buy-nothing formulation to one in which customers continuously reduce demand as the unfairness of the transaction increases. The greater tractability of our continuous formulation allows us to do comparative statics and to embed the pricing model into a general-equilibrium, macroeconomic framework. It also allows us to clarify the role of inference about marginal costs in explaining price rigidity. We find that fairness is necessary but not sufficient to obtain price rigidity; prices are rigid only when fairness is combined with underinference about marginal costs.

Our work is also related to other papers that introduce fairness considerations into otherwise standard models to explain various phenomena. For example, Akerlof (1982) and Akerlof and Yellen (1990) introduce fairness into labor-market models to explain the prevalence of unem-

[1] Rotemberg (2011) further explores the implications of fairness for pricing, focusing on other phenomena such as price discrimination.

ployment and wage rigidity. Rabin (1993) and Fehr and Schmidt (1999) introduce fairness in game-theoretic models to explain departures from pure self-interest observed in laboratory experiments, notably public-good and ultimatum games. Fehr, Klein, and Schmidt (2007) explore the implications of fairness for contract theory. Last, Zajac (1985) describes how principles of fairness can be incorporated in the regulation of public utilities.[2]

A lot of the work on fairness, like the work of Rotemberg (2005), uses social preferences, such as the those of Rabin (1993), Fehr and Schmidt (1999), and Charness and Rabin (2002). These preferences have the property that fairness considerations do not affect people's marginal rates of substitution amongst different goods or between labor and leisure. Consequently, people behave in general equilibrium as if they did not care about fairness (Dufwenberg et al. 2011). Our formulation of fairness has the advantage that it has effects even in general equilibrium. Customers who feel mistreated by firms withhold demand not to punish firms, as in models of social preferences, but instead because they derive less joy from consuming unfairly priced goods. Fairness perceptions affect marginal rates of substitution between goods, influencing even the general equilibrium. We view our approach and the social-preference approach as complementary: while we fully agree with Schmidt (2011) that models of social preferences offer important insights on agency problems in organizational settings, we also believe that our preferences could help develop the role of fairness in macroeconomics.

Finally, our pricing model is related to other models that rely on a nonconstant price elasticity of demand to create variations in markups after shocks. In international economics, these models have been used for a long time to explain the behavior of exchange rates and prices (for example, Dornbusch 1985). More recent models include those by Bergin and Feenstra (2001), Atkeson and Burstein (2008), Melitz and Ottaviano (2008), and Gopinath and Itskhoki (2010). In macroeconomics, such models have been used to create real rigidities—in the sense of Ball and Romer (1990)—that amplify nominal rigidities. The presursor in this literature was Kimball (1995), with several studies building up on his model (for example, Eichenbaum and Fisher 2007; Klenow and Willis 2016). Several of these models make reduced-form assumptions (either in the utility function or directly in the demand curve) to obtain a nonconstant price elasticity of demand: our model provides a microfoundation for this property, explaining why the price elasticity of demand may be increasing in the price.

[2] These papers have generated rich literatures. For surveys, see Fehr and Gachter (2000), Jones and Mann (2001), and Fehr, Goette, and Zehnder (2009).

3. Fairness and Misinference: Empirical Evidence

We present evidence that people care about the fairness of prices, and we describe what a fair price is. We also document that people fail to attend fully to the information revealed by observable actions about hidden facts. The assumptions of our pricing model are designed to capture parsimoniously—although perhaps a bit coarsely—this empirical evidence.

3.1. Fairness

The principal motivation for including fairness considerations into a pricing model is that when managers are asked to evaluate the relevance of different pricing theories to explain price rigidity in their firm, they always rank into the most relevant theories a fairness theory called "implicit contracts" and described as follows: "firms tacitly agree to stabilize prices, perhaps out of fairness to customers." The firm surveys used to elicit firms' view on pricing are described in Table 1. The first survey of the sort was conducted by Blinder et al. (1998) in the United States; other surveys followed in Canada and Europe, interviewing more than 11,000 firms in total.

The ranking of this fairness theory is displayed in Table 2, together with the ranking of the other theories of price rigidity mentioned in the surveys. The fairness theory is the most appealing to price setters: it has a median rank of 1 and a mean rank of 2.1, out of more than 10 other theories proposed to respondents. The other theories of price rigidity garner less support. The second most popular theory is the theory of nominal contracts: prices do not change because they are fixed by contracts. This theory has a median rank of 3 and a mean rank of 2.8. Two common macroeconomic theories of price rigidity—menu cost and information delays—do not resonate at all with price setters. They are consistently among the least popular theories, gathering mean and median ranks around 10.

In light of customers' response to price increases, it is not surprising that firms take fairness into account when they set prices. In a survey conducted by Shiller (1997), 85% of respondents report that they dislike inflation because when they "go to the store and see that prices are higher", they "feel a little angry at someone" (p. 21). The most common culprits include "manufacturers", "store owners", and "businesses" , and the most common causes include "greed" and "corporate profits" (p. 25). If firms aim to nurture customers' goodwill, they will certainly account for customers' aversion to price increases when setting prices.

Table 1. Description of Firm Surveys About Pricing

Study	Country	Period	Sample size	Sales to customers
Blinder et al. (1998)	United States	1990–1992	200	85%
Hall, Walsh, and Yates (2000)	United Kingdom	1995	654	59%
Apel, Friberg, and Hallsten (2005)	Sweden	2000	626	86%
Amirault, Kwan, and Wilkinson (2006)	Canada	2002–2003	170	–
Kwapil, Baumgartner, and Scharler (2005)	Austria	2004	873	81%
Aucremanne and Druant (2005)	Belgium	2004	1,979	78%
Loupias and Ricart (2004)	France	2004	1,662	54%
Lunnemann and Matha (2006)	Luxembourg	2004	367	85%
Hoeberichts and Stokman (2006)	Netherlands	2004	1,246	–
Martins (2005)	Portugal	2004	1,370	83%
Alvarez and Hernando (2005)	Spain	2004	2,008	86%

Table 2. Ranking of Theories Explaining Price Rigidity Across Surveys

	Country												
Theory	US	GB	SE	CA	AT	BE	FR	LU	NL	PT	ES	Mean	Median
Implicit contracts	4	5	1	2	1	1	4	1	2	1	1	2.1	1
Nominal contracts	5	1	3	3	2	2	3	3	1	5	3	2.8	3
Coordination failure	1	3	4	5	5	5	2	9	4	2	2	3.8	4
Pricing points	8	4	7	–	10	13	8	10	7	11	6	8.4	8
Menu costs	6	11	11	10	7	15	10	13	8	10	7	9.8	10
Information delays	11	–	13	11	6	14	–	15	–	8	9	10.9	11

Notes: Respondents to the surveys rated the relevance of several pricing theories in explaining price rigidity in their own firm. The table shows how common theories rank amongst the alternatives. Blinder et al. (1998, Table 5.1) describes the theories proposed to respondents as follows (the wording varies slightly across surveys): "implicit contracts" stands for "firms tacitly agree to stabilize prices, perhaps out of 'fairness' to customers"; "nominal contracts" stands for "prices are fixed by contracts"; "coordination failure" stands for two closely related theories, which are investigated in separate surveys: "firms hold back on price changes, waiting for other firms to go first" and "the price is sticky because the company loses many customers when it is raised, but gains only a few new ones when the price is reduced" (which is labeled "kinked demand curve"); "pricing points" stands for "certain prices (like $9.99) have special psychological significance"; "menu costs" stands for "firms incur costs of changing prices"; "information delays" stands for two closely related theories, which are investigated in separate surveys: "hierarchical delays slow down decisions" and "the information used to review prices is available infrequently." The rankings of the theories are reported in Table 5.2 in Blinder et al. (1998); Table 3 in Hall, Walsh, and Yates (2000); Table 4 in Apel, Friberg, and Hallsten (2005); Table 8 in Amirault, Kwan, and Wilkinson (2006); Table 5 in Kwapil, Baumgartner, and Scharler (2005); Table 18 in Aucremanne and Druant (2005); Table 6.1 in Loupias and Ricart (2004); Table 8 in Lunnemann and Matha (2006); Table 10 in Hoeberichts and Stokman (2006); Table 4 in Martins (2005); and Table 5 in Alvarez and Hernando (2005).

In modeling fairness, we assume that people care about the fairness of the markups charged by firms—they do not care about prices in and of themselves. Religious and legal texts written over the ages suggest that this norm has a long history. For example, Talmudic law specifies the highest markup that is fair and allowable in trade. The law posits that a good cannot be sold at a markup higher than 20% over the cost of producing the good—1/6 of the final price.[3] If the price deviates by more, the buyer is entitled to a refund. Another example comes from the 18th century in France. Bread prices were fixed by local authorities: the authorities determined bread prices that were "fair" for bakers and customers and announced the prices in official decrees. In the city of Rouen, for instance, the official bread prices accounted for the price of grain and the costs of rent, milling, wood, and labor, and they granted a "modest profit" to the baker (Miller 1999, p. 36). The official bread prices therefore fixed the markup that bakers could charge. Even today, French bakers attach such importance to convincing their customers of fair markups that their trade union decomposes into minute detail the cost of bread and the rationale for any price rise, calculating the markups for various breads and explaining their evolution over time.[4] A last example comes from the United States, where public-utility regulation set prices so as to deliver "fair returns" on costs (see Okun 1981, p. 153; Jones and Mann 2001, p. 153). In other words, public utilities must set prices at a "fair" markup over costs.

In fact, there is a trove of empirical evidence suggesting that people care about the fairness of the markups charged by firms.[5] An implication of our assumption that people care of the fairness of markups is that people dislike price increases unexplained by cost increases, because these increases involve a rise in markup. In a telephone survey of a hundred Canadian residents, Kahneman, Knetsch, and Thaler (1986) establish this pattern. They describe the following situation: "A hardware store has been selling snow shovels for $15. The morning after a large snowstorm, the store raises the price to $20." Only 18% of customers regard this pricing behavior as acceptable, whereas 82% regard this behavior as unfair (p. 729).

Another implication of our assumption that people care of the fairness of markups is that

[3]See the statement of Shmuel, p. 49b of *Bava Metzhia, Nezikin*, available at http://www.halakhah.com/pdf/nezikin/Baba_Metzia.pdf. Although the statement of Shmuel does not mention it, it seems that the maximum markup of 20% is limited to "essential items", while for some "nonessential items," the maximum markup is 100%, and for yet other items, there may not be any limitation on the markup. "Essential items" seems to be food items, but there is a debate about the exact boundaries of each category of goods (essential, nonessential, and other). Warhaftig (1987) discusses these rules.

[4]See http://www.boulangerie.net/forums/bnweb/prixbaguette.php.

[5]See Xia, Monroe, and Cox (2004) for a survey of the large literature studying the norms of price fairness.

customers do not mind a price increase following a cost increase as long as the markup remains constant. Kahneman, Knetsch, and Thaler also find this, for instance in response to the following situation: "Suppose that, due to a transportation mixup, there is a local shortage of lettuce and the wholesale price has increased. A local grocer has bought the usual quantity of lettuce at a price that is 30 cents per head higher than normal. The grocer raises the price of lettuce to customers by 30 cents per head." 79% of customers regard the grocer's behavior as acceptable, and only 21% find it unfair (pp. 732–733).

The results obtained by Kahneman, Knetsch, and Thaler have been confirmed in many studies conducted in very different contexts. For example, in a survey of 1,750 households in Switzerland and Germany, Frey and Pommerehne (1993, pp. 297–298) confirmed the finding that customers dislike a price increase that involves an increase in markup. This finding was also confirmed in a comparative survey of 391 respondents in Russia and 361 in the United States by Shiller, Boycko, and Korobov (1991, p. 389). And with an online survey of 307 Dutch individuals, Gielissen, Dutilh, and Graafland (2008, Table 2) confirm that the price increases after an increase in cost are fair, but those after an increase in demand are not. These three surveys use vignettes that are nearly identical to those in the original study.

The results have also been refined in various ways in subsequent studies. One question arising in the snow-shovel vignette is whether people find the price increase unfair because it occurs during period of hardship (a snowstorm), or because any price increase unexplained by a cost increase is unfair. To address this question, Maxwell (1995) replicates the survey question with 72 students at a university in Florida. While fewer respondents find the increase unfair when it is triggered by an increase in demand other than the snowstorm (69% versus 86%), it remains that more than two thirds of the respondent think that a higher price unjustified by a higher cost is unfair; in contrast about 90% of respondents found that it was fair to keep the price at $15 in the face of higher demand (Table 1).

For symmetry we assume in our model that customers regard it as unfair for firms not to pass along cost decreases. The evidence on this assumption is weaker in Kahneman, Knetsch, and Thaler (1986). They describe the following situation: "A small factory produces tables and sells all that it can make at $200 each. Because of changes in the price of materials, the cost of making each table has recently decreased by $20. The factory does not change its price of tables." Only 47% of respondents find this unfair, even though the markup has increased

(p. 734). However, subsequent studies seem to challenger this finding and suggest that people do expect the price to fall after the cost reduction. For instance, Kalapurakal, Dickson, and Urbany (1991) conducted a survey of 189 business students in the United States, and asked them to consider the following scenario: "A department store has been buying an oriental floor rug for \$100. The standard pricing practice used by department stores is to price floor rugs at double their cost so the selling price of the rug is \$200. This covers all the selling costs, overheads and includes profit. The department store can sell all of the rugs that it can buy. Suppose because of exchange rate changes the cost of the rug rises from \$100 to \$120 and the selling price is increased to \$220. As a result of another change in currency exchange rates, the cost of the rug falls by \$20 back to \$100." Then two alternative scenarios were evaluated: "The department store continues to sell the rug for \$220" compared to "The department store reduces the price of the rug to \$200." The scenario in which the department store reduces the price in response to the decrease in cost was considered significantly more fair: the fairness rating was $+2.3$ instead of -0.4 (where -3 is extremely unfair and $+3$ extremely fair). Similarly, using a survey with US respondents, Konow (2001, Table 6) finds that if a factory sells a table at \$150 and suddenly finds a supplier who charges \$20 less for the materials needed to make each table, on average the new fair price is \$138, well below \$150.

One issue with the theory is that firms could take advantage of it: by being inefficient or putting less effort, they would face higher costs, but they could pass them onto accepting customers. This is a question that has been explored in more recent studies. For example, in a survey of 1,530 cable-car customers in Switzerland, Bieger, Engeler, and Laesser (2010, Table 3) find that while an external, uncontrollable cost increase (for instance, from increased security requirements) is perceived as a fair reason to raise prices, an internal, controllable cost increase (for instance, from higher marketing expenditures) is perceived as a less fair reason for raising prices. Nevertheless, respondents find both types of price increase much fairer than a price increase not accompanied by an explanation.

Finally, in our model we assume that customers who find a transaction unfair derive lower utility from consuming the good, which reduces their propensity to purchase the good. In a telephone survey of 40 US consumers, Urbany, Madden, and Dickson (1989) explore whether a price increase justified by a cost increase is perceived as more fair than one unjustified, and importantly, how fairness perceptions affect customers' behavior. The scenario is a 25-cent fee added to use an ATM machine at a local bank. While 58% of respondents find that the introduction of the fee is fair if it is justified by a cost increase, only 29% find the introduction fair if it is not justified (Table 1, panel B). And people who find the behavior of the bank unfair have a different behavior than those who find it fair, as predicted by our model. Of course even people who find the fee fair are more likely to switch, just because the bank becomes more costly; but those who find it unfair are much more likely to switch banks (52% versus 35%), presumably compounding the budget effect and unfairness (Table 1, panel C). People who find it unfair are also more likely to complain to the bank about it.

We assume not only that customers bristle at unfair markups, but also that firms understand how customers feel. Blinder et al. (1998, p. 153, p. 157) find evidence that they do: 64% of firms say that customers do not tolerate price increases after increases in demand; 71% of firms say that customers do tolerate price increase after increase in cost. These responses suggest that the norm for fair pricing must take the form of a fair markup over marginal cost. Indeed, based on a survey of businessmen in the United Kingdom, Hall and Hitch (1939, p. 19) report that the "the 'right' price, the one which 'ought' to be charged" is widely perceived to be a markup (generally, 10%) over average cost. Okun (1975, p. 362) also observes through discussions with business people that "empirically, the typical standard of fairness involves cost-oriented pricing with a markup."

To better understand how firms incorporate fairness into their pricing decisions, we interviewed 31 bakers in France in 2007. The French bread market makes a good case study because the market is large, bakers set their prices freely, and French people care enormously about bread.[6] We sampled bakeries in cities and villages around Grenoble, Aix-en-Provence, Paimpol, and Paris. The interviews were only loosely directed. The number of interviews is small, yet the responses shed light on fairness constraints on pricing.

Overall, the interviews show that bakers' efforts to preserve customer loyalty constrain price variations. Price adjustments are guided by norms of fairness to avoid antagonizing customers;

[6]In 2005, bakeries employed 148,000 workers, for a yearly turnover of 3.2 billion euros (Fraichard 2006). Since 1978, French bakers have been free to set their own prices, except during the inflationary period 1979–1987 when price ceilings and growth caps were imposed. For centuries, bread prices caused major social upheaval in France. Miller (1999, p. 35) explains that before the French Revolution, "affordable bread prices underlay any hopes for urban tranquility." During the Flour War (1775), mobs chanted "if the price of bread does not go down, we will exterminate the king and the blood of the Bourbons"; following these riots, "under intense pressure from irate and nervous demonstrators, the young governor of Versailles had ceded and fixed the price 'in the King's name' at two sous per pound, the mythohistoric just price inscribed in the memory of the century" (Kaplan 1996, p. 12).

in particular, cost-based pricing is widely used. Bakers explained that they would raise the price of bread only in response to cost increases: when the price of flour goes up (generally once a year in September at the end of harvest), when utilities go up (especially gas, required to operate the oven), or when wages go up. Some bakers explained that their largest costs were the wages of their employees, which are linked to the minimum wage. Since the minimum wage is updated every July 1st and the bakers only change their price in response to a cost change, they only change their price once a year on July 1st. They emphasize that prices increase only in response to cost increases, with any increase announced long in advance and explained carefully.

Bakers seem to set their prices as a fixed markup over their costs, and they also deliberately refuse to increase prices in response to increased demand. Several bakers explained that they refuse to change prices during weekends (when more people shop at bakeries), during the holiday absences of local competitors (when their demand and market power rise), or during the summer tourist season (again, when demand rises). Bakers feel that a price rise would be unfair and would anger and drive away customers.

3.2. Misinference

Customers do not directly observe firms' marginal costs, so their perceptions of how fairly firms price their goods depend upon their estimates of these costs. In modeling the inferences that customers draw about marginal costs, we assume that customers underappreciate the extent to which changes in prices reveal changes in marginal costs. In our model, a rational customer would understand that marginal costs move in proportion to prices. Instead, we assume that customers draw subproportional inferences: upon observing a price change, they update their belief about the marginal cost in the right direction, but stop short of rational, proportional inference.

Our assumption of subproportional inference is motivated by numerous experimental studies which find in various contexts that people underinfer other people's information from their actions. Samuelson and Bazerman (1985), Holt and Sherman (1994), and Carillo and Palfrey (2011), among others, provide evidence in the context of bilateral bargaining with asymmetric information that bargainers underappreciate adverse selection in trade. The papers collected in Kagel and Levin (2002) present evidence that bidders underattend to the winner's curse in common-value auctions. In a metastudy of social-learning experiments, Weizsäcker (2010) finds evidence that subjects behave as if they underinfer their predecessors' private information from their actions. Last, in a voting experiment, Esponda and Vespa (2014) show that people underinfer others' private information from their votes.

Furthermore, subproportional inference naturally leads to money illusion, which is documented by Shafir, Diamond, and Tversky (1997). Households evaluate the markup charged by a firm to assess the fairness of a transaction. But with subproportional inference, the evaluation of the markup is contaminated by the price charged by the firm: when the price is higher, households believe that the firm captures a larger markup; when the price is lower, households believe that the firm captures a smaller markup. As households' evaluation of the transaction is contaminated by its price level, their behavior exhibits money illusion. Thus Shafir, Diamond, and Tversky report evidence that indirectly supports our assumption. They present the following situation: "Changes in the economy often have an effect on people's financial decisions. Imagine that the US experienced unusually high inflation which affected all sectors of the economy. Imagine that within a six-month period all benefits and salaries, as well as the prices of all goods and services, went up by approximately 25%. You now earn and spend 25% more than before. Six months ago, you were planning to buy a leather armchair whose price during the 6-month period went up from \$400 to \$500. Would you be more or less likely to buy the armchair now?" The higher prices were distinctly aversive to buying: while 55% of respondents were as likely to buy as before and 7% were more likely to buy as before, 38% of respondents were less likely to buy as before (p. 355). Our model of subproportional inference exactly makes this prediction because some households perceive markups to be higher when prices are higher, which reduces the fairness of the transaction and households' willingness to pay for it.

Finally, our assumption of subproportional inference resembles several recent models of limited attention. It could be a form of the "anchoring heuristic" documented by Tversky and Kahneman (1974): consumers understand that higher prices reflect higher marginal costs but they do not adjust sufficiently their estimate of the marginal cost. It could be a form of the "availability heuristic" documented by Tversky and Kahneman (1973) and formalized by Gennaioli and Shleifer (2010): people infer information content by drawing upon a limited set of scenarios that come to mind: higher prices suggest increased markups and greed, rather than higher marginal costs. Customers in our model are also "coarse thinkers" in the sense of Mullainathan, Schwartzstein, and Shleifer (2008) because they do not distinguish between scenarios where changes in price reflect changes in cost and those where they reflect changes in markup. Lastly, whereas we regard households' failure to infer marginal costs as a cognitive error, it might also result from economizing on attention costs along the lines proposed by Gabaix (2014, 2016).

4. Static Partial-Equilibrium Model

We extend a simple static model of monopoly pricing to include fairness considerations. The analysis is partial equilibrium: it takes the household's income and prices of all other goods as given. Customers do not observe the monopoly's marginal cost but attempt to infer it from the price. When inference is rational or proportional, fairness plays no role. But when inference is subproportional, fairness affects the profit-maximizing markup in two important ways. First, it increases the price elasticity of demand and thus reduces the markup. Second, it makes the price elasticity of demand increasing in the price; as a consequence, the markup falls after an increase in marginal cost, and the passthrough of marginal costs into prices is less than one.

4.1. Assumptions

We consider a monopoly firm that sells a good to a representative customer for whom fairness matters. We assume that the firm cannot price-discriminate, so that each unit of good produced by the firm is sold at the same price P.

The customer assesses the fairness of its transaction with the monopoly by comparing the purchase price to its perception of the firm's marginal cost of production. We assume that the firm's marginal cost MC is unobservable to buyers—it is the firm's private information. When a buyer purchases the firm's good at price P, it makes an inference about the firm's marginal cost of production, denoted by $MC^p(P)$; for simplicity, we restrict $MC^p(P)$ to be deterministic. We compare different inference processes below. Having inferred the marginal cost, the buyer deduces that the markup charged by the monopoly is

$$K^p(P) = \frac{P}{MC^p(P)}. \tag{1}$$

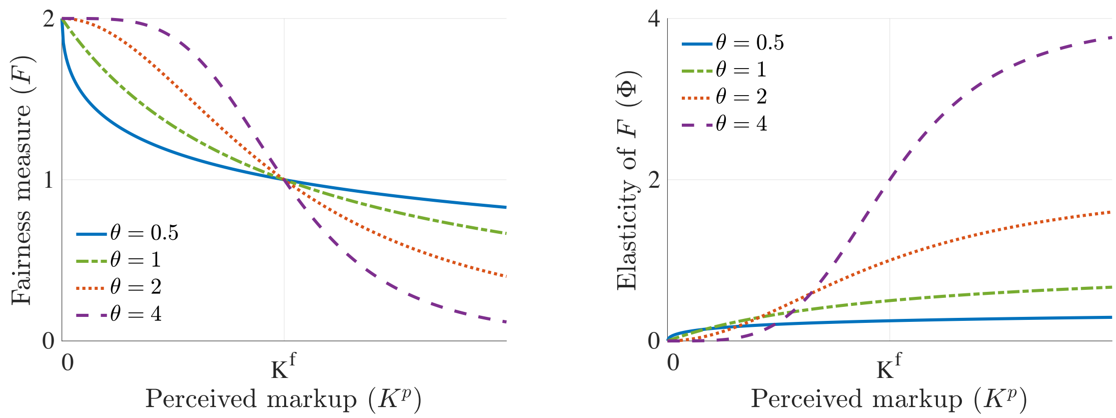


Figure 1. The Fairness Measure and Its Elasticity

The perceived markup determines the transaction's perceived fairness, which is measured by

$$F(K^p) = \frac{2}{1 + (K^p/K^f)^\theta}. \tag{2}$$

The parameter $\theta \geq 0$ governs the concern for fairness. When $\theta = 0$, the customer does not care about fairness: $F(K^p) = 1$ for any K^p. When $\theta > 0$, he does care about fairness: $F(K^p)$ is decreasing in K^p. The parameter $K^f > 0$ is a normalization constant such that $F(K^f) = 1$. The fairness measure $F(K^p)$ is positive, bounded, decreasing in the perceived markup K^p, with $F(0) = 2$, $F(K^f) = 1$, and $F(\infty) = 0$. In absolute value, the elasticity of the fairness measure with respect to the perceived markup is

$$\Phi(K^p) \equiv -\frac{d\ln(F)}{d\ln(K^p)} = \theta \frac{(K^p/K^f)^\theta}{1 + (K^p/K^f)^\theta}. \tag{3}$$

The elasticity is increasing in the perceived markup, with $\Phi(0) = 0$, $\Phi(K^f) = \theta/2$, and $\Phi(\infty) = \theta$. A useful result is that the elasticity of Φ is $d\ln(\Phi)/d\ln(K^p) = \theta - \Phi$. The fairness measure and its elasticity are plotted in Figure 1.

Two properties of the fairness measure F are central to our results: it is decreasing, and its elasticity (in absolute value) is increasing. Any fairness measure with these properties would yield the same results; we select the functional form (2) for its analytical tractability.

The quantity Y of the monopoly's good bought by the customer at a unit price P yields a fairness-adjusted consumption

$$Z = F(K^p(P))Y,$$

When the customer perceives the good to be priced at a markup above K^f—that is, when $P > K^f MC^p$—the fairness measure $F(K^p)$ is below one, and it is antagonized by consuming what it perceives as an overpriced good. This formulation is as if the customer lost a fraction $1 - F(K^p) > 0$ of each unit of the good bought at an unfair price, reducing the marginal utility of consumption. Analogously, when the customer perceives the good to be priced at a markup below K^f, the fairness measure exceeds one, and it enjoys heightened utility from consuming what it perceives as an underpriced good. When the customer perceives the good to be priced at a markup of K^f, the fairness measure equals one. As θ rises, customers become more upset when consuming an overpriced item and more content when consuming an underpriced item.

The representative customer has quasilinear utility

$$\frac{\varepsilon}{\varepsilon - 1} Z^{(\varepsilon-1)/\varepsilon} + M, \tag{4}$$

which depends on its fairness-adjusted consumption Z and money balances M. The parameter $\varepsilon > 1$ determines the concavity of the utility function.

The customer maximizes utility subject to the budget constraint

$$M + P \cdot Y = I, \tag{5}$$

where $I > 0$ is the customer's income. To maximize utility, the customer chooses consumption Y and money balances M given income I and price P.

Finally, the monopoly faces a linear cost function with marginal cost $MC > 0$. Hence, the total cost of producing quantity Y is $MC \times Y$. Shocks to the costs of the inputs used in production and to the production technology lead to changes in the parameter MC. In particular, a better technology leads to a lower marginal cost of production. Taking marginal cost MC as given, the monopoly chooses the price P and output Y to maximize profits $V = PY - MCY$ subject to the customer's demand for its product.

4.2. Optimal Pricing

We determine the optimal, profit-maximizing price for the monopoly. Given the budget constraint and utility function, the customer chooses Y to maximize

$$\frac{\varepsilon}{\varepsilon-1}(F\cdot Y)^{(\varepsilon-1)/\varepsilon}+I-P\cdot Y.$$

The first-order condition of the maximization is

$$F\cdot(F\cdot Y)^{-1/\varepsilon}=P.$$

This condition yields the demand curve faced by the firm:

$$Y^d(P)=F(K^p(P))^{\varepsilon-1}P^{-\varepsilon}. \tag{6}$$

The price affects demand through two channels. First, the traditional channel, captured by $P^{-\varepsilon}$: the price affects demand by determining customers' budget sets. Second, the fairness channel, captured by $F(K^p(P))^{\varepsilon-1}$: the price influences the perceived markup and thus the perceived fairness of the transaction; this affects the marginal utility of consumption and hence demand.

Given the demand curve (6), the monopoly chooses P to maximize profits $V=(P-MC)Y^d(P)$. The first-order condition of the maximization is

$$Y+(P-MC)\frac{dY^d}{dP}=0,$$

or equivalently,

$$P-(P-MC)\frac{-P}{Y}\cdot\frac{dY^d}{dP}=0.$$

We denote by

$$E\equiv-\frac{d\ln(Y^d)}{d\ln(P)}$$

the price elasticity of demand, in absolute value. The first-order condition then gives that

$$P=\frac{E}{E-1}MC. \tag{7}$$

Hence, to maximize profits, the monopoly sets its price at a markup $K = E/(E-1)$ over its marginal cost.

To characterize the profit-maximizing markup, we need to determine the price elasticity of demand, E. The firm takes into consideration how its price affects the budget of the customer as well as how its price influences the customer's inference about markups. In particular, the firm understands that the perceived marginal cost MC^p depends upon P in the perceived markup $K^p = P/MC^p$ that enters the demand $Y^d(P)$. Using (6), we obtain the price elasticity of demand:

$$E = \varepsilon + (\varepsilon - 1)\Phi(K^p)\left(1 - \frac{d\ln(MC^p)}{d\ln(P)}\right), \tag{8}$$

where the elasticity $\Phi(K^p)$ is given by (3). We have seen that the price affect demand through two channels: a standard, budget channel, and a fairness channel. These two channels appear in expression of the price elasticity. The first term ($\varepsilon > 0$) reflects the budget channel: a higher price makes the good relatively more expensive, which reduces demand. The second term ($(\varepsilon-1)\Phi(K^p)\left[1-(d\ln(MC^p)/d\ln(P))\right]$) reflects the fairness channel. It is useful to split this term into two subterms. The first subterm ($(\varepsilon-1)\Phi(K^p) > 0$) arises because a higher price mechanically raises the perceived markup and thus lowers the perceived fairness of the transaction, which reduces demand. The second subterm ($-(\varepsilon-1)\Phi(K^p)\left(d\ln(MC^p)/d\ln(P)\right) < 0$) arises because a higher price may also signal a higher marginal cost, which raises the perceived fairness of the transaction and thus demand.

We now analyze this equation to characterize the profit-maximizing markup in various situations. We focus on the markup charged by the monopoly because it governs the equilibrium of the model. Indeed, once we know the profit-maximizing markup K, together with the marginal cost MC, preference parameters, and belief parameters, we can directly derive the equilibrium values of all the variables: the price is $P = K \times MC$, the output is $Y = Y^d(K \times MC) = F(K^p(K \times MC))^{\varepsilon-1}(K \times MC)^{-\varepsilon}$, and the monopoly's profits are $V = Y \times MC \times (K-1) = F(K^p(K \times MC))^{\varepsilon-1} \times MC^{1-\varepsilon} \times (K-1)/K^{\varepsilon}$.

4.3. No Fairness Concerns

Before studying the more realistic and interesting case in which customers care about fairness, we briefly examine the case in which they do not care about fairness. This case will be a useful reference point when we study pricing with fairness concerns.

Without fairness concerns ($\theta = 0$), the fairness measure F is always one, its elasticity Φ is zero, and the price elasticity of demand E is constant, equal to ε (see equation (8)). In that case, the profit-maximizing markup takes a standard value of $\varepsilon/(\varepsilon - 1)$.

Since the markup does not depend on the marginal cost, changes in marginal cost are fully passed through into the price. We denote by

$$\sigma \equiv \frac{d\ln(P)}{d\ln(MC)}$$

the marginal-cost passthrough. This passthrough measures the percentage change in price when the marginal cost increases by one.percent. Since $P = K \cdot MC$, and here K is independent from MC, the passthrough is one. The following lemma summarizes the findings:

LEMMA 1. *When customers do not care about fairness ($\theta = 0$), the profit-maximizing markup is $K = \varepsilon/(\varepsilon - 1)$ and the marginal-cost passthrough is $\sigma = 1$.*

4.4. Observable Marginal Costs

With fairness concerns ($\theta > 0$), the results are quite different than without, but they depend on how customers infer marginal costs. We now consider several inference processes. Before analyzing the more realistic and interesting case in which marginal costs are unobservable, we briefly study pricing when marginal costs are observable. This situation will provide a useful point of comparison when we study unobservable marginal costs.

When marginal costs are observable to customers, the perceived marginal cost is the true marginal cost: $MC^p(P) = MC$. Hence, the perceived markup is the true markup: $K^p(P) = P/MC = K$. Equation (8) therefore implies that the price elasticity of demand is $E = \varepsilon + (\varepsilon - 1)\Phi(K) > \varepsilon$. When marginal costs are observable, the concern for fairness increases the price elasticity of the demand curve faced by the monopoly; thus, the profit-maximizing markup is lower than without fairness concerns. However, since the markup does not depend on marginal cost, changes in marginal cost are fully passed through into price so the passthrough remains one. The following lemma summarizes these results:

LEMMA 2. *When customers care about fairness ($\theta > 0$) but observe marginal costs, the profit-*

maximizing markup K is defined by

$$K = 1 + \frac{1}{\varepsilon - 1} \cdot \frac{1}{1 + \Phi(K)}, \tag{9}$$

implying that $K < \varepsilon/(\varepsilon - 1)$, and the marginal-cost passthrough is $\sigma = 1$. The markup is lower than in the absence of fairness concerns, but the passthrough is the same.

In the absence of fairness concerns, the price affects demand solely by determining customers' budget sets. With fairness concerns and observable marginal costs, the price also influences the perceived fairness of the transaction: when the purchase price is high relative to the marginal cost of production, customers deem the transaction to be less fair, which reduces customers' marginal utility from consuming the good. Hence, with fairness concerns and observable marginal costs, a high price also reduces demand by lowering the marginal utility of consumption. As a result, the monopoly's demand is more price elastic than without fairness concerns, and the profit-maximizing markup is accordingly lower.

4.5. Rational and Proportional Inference

We now turn to the more realistic and interesting situation where marginal costs are unobservable. Here, customers need to infer marginal costs from prices. We begin by analyzing the monopoly's pricing when customers rationally invert its price to uncover its hidden marginal cost.

The monopoly prices according to (7), which specifies that $P = K \cdot MC$ where $K = E/(E-1)$ is the profit-maximizing markup and MC is the monopoly's marginal cost. Equation (8) shows that the elasticity of demand E depends upon the function $P \mapsto MC^p(P)$, which gives customers' perception of the monopoly's marginal cost. Hence, we can write the profit-maximizing price as the following function of the marginal cost: $MC \mapsto P(MC) = MC \cdot E(MC^p)/(E(MC^p) - 1)$. To uncover the true marginal cost, customers must invert this price function. This is easy and yields a function that maps the profit-maximizing price to the true marginal cost:

$$P \mapsto MC(P) = P \frac{E(MC^p) - 1}{E(MC^p)}.$$

Correctly inverting the firm's price reveals the firm's true marginal cost, so $MC^p(P) = MC(P)$.

Therefore, to uncover the true marginal cost by observing the monopoly's price, rational customers need to solve the following functional equation:

$$MC(P) = P\frac{E(MC)-1}{E(MC)}. \tag{10}$$

Solving this functional equation yields the function $P \mapsto MC(P)$ that gives the true marginal cost associated with any price.

To solve the functional equation (10), rational customers guess that $MC(P) = P/K^b$, where K^b is a constant. Under this guess, $d\ln(MC^p)/d\ln(P) = d\ln(MC)/d\ln(P) = 1$ so (8) implies that $E = \varepsilon$. The functional equation can be rewritten as $P/K^b = P\cdot(\varepsilon-1)/\varepsilon$ for all P. By identification, we find that $K^b = \varepsilon/(\varepsilon-1)$. To conclude,

$$MC(P) = \frac{\varepsilon-1}{\varepsilon}P \tag{11}$$

is indeed a solution to (10). Rational customers thus form correct beliefs that

$$MC^p(P) = \frac{\varepsilon-1}{\varepsilon}P, \tag{12}$$

correctly perceiving the firm's markup to be $K = \varepsilon/(\varepsilon-1)$.

A rational customer recognizes that marginal cost is proportional to price and correctly estimates the factor of proportionality, K^b. Note, however, that the conclusion that $E = \varepsilon$, and the firm's markup $K = \varepsilon/(\varepsilon-1)$ by extension, did not depend upon customers correctly estimating the factor of proportionality. If customers were to use the wrong value of K^b—to infer proportionally, but not rationally—then the firm would still price the same as it would if customers did not care about fairness. Indeed, if customers infer proportionally, the perceived marginal cost is

$$MC^p(P) = \frac{P}{K^b}$$

for some $K^b \geq 1$. As $d\ln(MC^p)/d\ln(P) = d\ln(MC)/d\ln(P) = 1$, equation (8) implies that the price elasticity of demand is $E = \varepsilon$ and thus the profit-maximizing markup is $\varepsilon/(\varepsilon-1)$. Finally, since the markup does not depend on marginal costs with either rational or proportional inference, changes in marginal costs are fully passed through into prices, and the marginal-cost passthrough equals one. The following lemma summarizes these results:

LEMMA 3. *When customers care about fairness ($\theta > 0$), and rationally or proportionally infer marginal costs from prices, the profit-maximizing markup is $K = \varepsilon/(\varepsilon - 1)$, and the marginal-cost passthrough is $\sigma = 1$. The markup and passthrough are the same as in the absence of fairness concerns.*

Without fairness concerns, the price affects demand by determining customers' budget sets. With fairness concerns and hidden marginal cost, the price has two additional effects on demand. But with rational or proportional inference, these two effects cancel each other out, explaining why markup and passthrough are the same as without fairness concerns. The first effect is the same as with observable cost: a high price reduces demand by lowering the perceived fairness of the transaction and thus the marginal utility of consumption. The second effect is specific to the inference process when customers do not know the firm's marginal cost: a higher price signals a higher marginal cost, and a higher marginal cost raises the perceived fairness of the transaction and thus the marginal utility of consumption. With rational or proportional inference, the increase in the perceived marginal cost is as large as the observed price increase, so that only the effect of the price on demand through customers' budget sets remains.

4.6. Subproportional Inference

A customer that does not sufficiently introspect about the relationship between price and marginal cost will likely underappreciate the information conveyed by the price. We now analyze the market when customers stop short of rational inference by failing to appreciate that marginal costs rise proportionally to prices; instead, they make cost inferences that are subproportional.

We have seen how a rational customer can uncover marginal cost by inverting the firm's pricing rule. To treat cases in which the customer incompletely infers about marginal cost from price, we assume that it uses a simple belief-updating rule:

$$MC^p(P) = \left(MC^b\right)^{\chi} \left(\frac{P}{K^b}\right)^{1-\chi}. \tag{13}$$

The parameter $MC^b > 0$ denotes the customer's prior belief about the firm's marginal cost. The factor $K^b \geq 1$ represent the customer's perceived factor of proportionality between price and marginal cost. The parameter $\chi \in [0, 1]$ characterizes the sophistication of the customer's inferences. When $\chi = 0$, the customer adjusts her belief about marginal cost in proportion to the price set by the monopoly. In this case, the customer is sophisticated: she adjusts her belief about marginal cost as fast as a rational customer. The customer's prior belief about marginal cost play no role. As in the previous subsection, the customer can believe that marginal cost is a constant fraction of price but misjudge that fraction. When $\chi = 1$, the customer fails to update her belief about marginal cost at all from price. In this case, the customer is naive: she maintains her prior belief MC^b. When $\chi \in (0,1)$, the customer subproportionally adjusts her belief about marginal cost from price. The belief about marginal cost moves in the right direction, but only partially. Indeed, the customer's perceived marginal cost is a χ-weighted geometric average of her prior belief and the proportional belief P/K^b. The customer commits two errors in inference: she fails to sufficiently adjust her prior belief based on price, and also misunderstands the firm's behavior.

Under subproportional inference, customers perceive the monopoly's markup to be

$$K^p(P) = \left(K^b\right)^{1-\chi} \left(\frac{P}{MC^b}\right)^{\chi}. \tag{14}$$

The perceived markup is a geometric average with weight χ of the markup P/MC^b that naive customers would perceive and the markup K^b that sophisticated customers would perceive. When $\chi \in (0,1)$, customers appreciate that a higher price reflects a higher marginal cost, but they do not raise their estimate of the marginal cost sufficiently. Thus, the perceived markup is an increasing function of the observed price.

Since customers partially misattribute higher prices to higher markups, they see higher prices as less fair. Formally, under subproportional inference, an increase in P leads to an increase in $K^p(P)$ (as shown by (14)) and thus to a decrease in $F(K^p)$ (as shown by (2)). Furthermore, since the functions $K^p(P)$ and $F(K^p)$ are differentiable, customers enjoy a small price reduction as much as they dislike a small price increase: the demand curve faced by the monopoly has no kinks.

Although customers correctly perceive the markup as a real variable, subproportional inference ties their estimates to the nominal variable MC^b. In this way, subproportional inference induces a specific form of money illusion: the perceived markup is no longer independent of the price P; in fact, a higher price causes customers to perceive a higher markup. On the other hand, there is no money illusion with rational or proportional inference because the customer understands that a higher price reflects a higher marginal cost and that the markup is constant.

Despite its apparent arbitrary nature, the assumption of subproportional inference has close ties to game-theoretic models of erroneous, subproportional inference. The beliefs about marginal cost given by formula (13) with $\chi = 1$ resemble those given by the fully cursed equilibrium of Eyster and Rabin (2005) and the coarsest analogy-based equilibrium of Jehiel and Koessler (2008), when recasting our model as a Bayesian game. In a fully cursed or the coarsest analogy-based equilibrium, customers infer nothing about the exogenous parameter MC from the monopoly's decisions. Under this assumption, customers form beliefs about marginal costs that coincide with the formula (13) with $\chi = 1$. Furthermore, in any partially cursed equilibrium of Eyster and Rabin in which firms' actions can be inverted to reveal marginal costs, customers will form beliefs about marginal costs that are a χ-weighted arithmetic average of true and average marginal costs. Here, if $K^b = \varepsilon/(\varepsilon - 1)$, the log of the perceived marginal cost is the χ-weighted arithmetic average of prior belief and correct belief.

The combination of fairness and subproportional inference modifies the price elasticity of demand, E, in two important ways. Using (13), we rewrite (8):

$$E = \varepsilon + (\varepsilon - 1)\chi\Phi(K^p(P)), \tag{15}$$

where the perceived markup $K^p(P)$ is given by (14). We have seen that without fairness concerns ($\Phi = 0$), or with fairness concerns and proportional inference ($\chi = 0$), the price elasticity E is constant and equal to ε. But with fairness concerns ($\Phi > 0$) and subproportional inference ($\chi > 0$), things are different: the price elasticity E is always greater than ε; and price elasticity E is increasing in the price P, because $\Phi(K^p)$ and $K^p(P)$ are increasing in K^p and P.

The properties of the price elasticity E under fairness concerns and subproportional inference have direct implications for the markup charged the monopoly, because the profit-maximizing markup is $K = E/(E - 1)$. The following proposition formalizes these findings:

PROPOSITION 1. *When customers care about fairness ($\theta > 0$), and subproportionally infer marginal costs from prices ($\chi > 0$), the profit-maximizing markup K is defined by*

$$K = 1 + \frac{1}{\varepsilon - 1} \cdot \frac{1}{1 + \chi\Phi(K^p(K \cdot MC))}, \tag{16}$$

implying that $K < \varepsilon/(\varepsilon-1)$, and the marginal-cost passthrough is given by

$$\sigma = 1 \Big/ \left[1 + \frac{\chi^2 \Phi(\theta - \Phi)}{(1+\chi\Phi)\,(\varepsilon + (\varepsilon-1)\chi\Phi)}\right], \tag{17}$$

implying that $\sigma < 1$. The markup is lower than without fairness concerns or with proportional inference. And unlike without fairness concerns, with observable cost, or with proportional inference, the passthrough is below one.

The formal proof of the proposition appears in Appendix A, but the intuition is simple. When customers care about the fairness of prices but subproportionally infers the marginal cost of the firm from its price, customers become more price-sensitive. Indeed, an increase in the price increases the opportunity cost of consumption, as in the standard case without fairness, but it also decreases the enjoyment of consumption by increasing the perceived markup and thus reducing the marginal utility from consumption, which further reduces demand. This heightened price-sensitivity raises E above ε and lowers the markup below $\varepsilon/(\varepsilon-1)$.

Furthermore, after an increase in marginal cost, the monopoly find it optimal to charge a lower markup, which dampens the increase in price, and leads to a marginal-cost passthrough below 1. In fact, after an increase in price triggered by an increase in marginal cost, customers underappreciate the underlying increase in marginal cost because of subproportional inference. Hence, they attribute the higher price partly to a higher marginal cost and partly to a higher markup, which they find unfair. Since the perceived markup increases, the price elasticity of demand increases. In response, the monopoly reduces its markup, thus mitigating the price increase. While customers believe that transactions are less fair after the increase in marginal cost, they are mistaken: transactions are actually more fair. Here, prices exhibit a mild form of rigidity by moving less than proportionally to the marginal cost.

In an equilibrium where customers appraise the markup they face as fair, which through acclimation they may be particularly apt to do in the long run, the markup and passthrough admits a simpler form. This is because when $K^p = K^f$, then $\Phi = \theta/2$, which greatly simplifies expressions (16) and (17). To obtain comparative statics, we consider such equilibria. Then, using simple algebra, we obtain the following corollary of Proposition 1:

COROLLARY 1. *When customers care about fairness ($\theta > 0$), subproportionally infer marginal costs ($\chi > 0$), and are acclimated (this requires the belief parameters MC^b and K^b to be such* *that in equilibrium $K^p = K^f$ and $F(K^p) = 1$), the markup and passthrough are*

$$K = 1 + \frac{1}{\varepsilon - 1} \cdot \frac{1}{1 + \chi\theta/2} \tag{18}$$

$$\sigma = 1 \Bigg/ \left[1 + \frac{\chi^2\theta^2/4}{(1+\chi\theta/2)\,(\varepsilon + (\varepsilon-1)\chi\theta/2)}\right]. \tag{19}$$

The markup decreases with the competitiveness of the market (ε), concerns for fairness (θ), and inference error (χ). The passthrough increases with the competitiveness of the market (ε), but decreases with concerns for fairness (θ) and inference error (χ).

Although any amount of concern for fairness, however small, combined with any error in inference, short of proportional inference, lead to some price rigidity (a passthrough below 1), the corollary shows that more concern for fairness and a larger error in inference lead to more price rigidity (a lower passthrough). The corollary also shows that the passthrough is smaller in less-competitive markets, and that it even goes to one as the market becomes perfectly competitive ($\varepsilon \to \infty$). This implies that prices are more rigid in less-competitive markets, and that prices become flexible in perfectly competitive markets.

Another implication of the corollary is that more concern for fairness and a larger error in inference lead to a lower markup, exactly like a more competitive environment. Moreover, the markup goes to one as the market becomes perfectly competitive ($\varepsilon \to \infty$) or the concern for fairness infinitely large ($\theta \to \infty$).

4.7. Empirical Evidence

In many contexts, it has been observed that increases in cost are usually not entirely passed through into prices. Our model explains these phenomena (Proposition 1).

In international economics, the passthrough of the exchange rate into import prices is well below one. In their survey of the empirical literature, Goldberg and Knetter (1997) find that local-currency prices of foreign products do not respond fully to exchange rates. For the United States, the response varies by industry, but overall, it seems that a median estimate of the exchange-rate passthrough is 0.5. Furthermore, consistent with the mechanism in our model, they find that a significant share of the muted price response can be attributed to changes in the markups charged to consumers. Studies published since this survey have reinforced the findings, extending it to new countries and relying on richer datasets. For instance, using panel data for 1980–1993, Goldberg and Verboven (2001) find that the local-currency price of cars in Europe respond only incompletely to substantial exchange rate fluctuations. Another example comes from the United States. Using microdata on US import and export prices at the dock for the period 1994–2005, Gopinath and Rigobon (2008) find that even conditioning on a price change, exchange rate passthrough into US import prices is low, about 20%.

In industrial organization, the passthrough of shocks to marginal production costs is often below one, which leads to a reduction in markups when marginal costs rise and an increase when marginal costs fall. For instance, De Loecker et al. (2016) find that after trade liberalization in India, marginal costs fell significantly due to the input tariff liberalization, and prices fell as well, but the price declines were small relative to the declines in marginal costs. Furthermore, exactly as in our model, they find that the reason for the incomplete marginal-cost passthrough is that firms offset their reductions in marginal costs by raising markups. Another recent example comes from Nakamura and Zerom (2010), who use data on costs and prices for the coffee industry, and find that prices respond incompletely to changes in costs. They also find that after an increase in costs, markups fall significantly, as predicted by our model. Finally, using matched data on product-level prices and the producing firm's unit labor cost for Sweden, Carlsson and Skans (2012) find a moderate passthrough of current idiosyncratic marginal-cost changes into prices: about $1/3$.

And in public economics, the passthrough of some taxes into prices is incomplete, influencing the incidence of these taxes on firms and consumers. Recent reforms in value-added tax in European countries provide natural experiments that offer compelling evidence of low passthroughs. A first example comes from France. Benzarti and Carloni (2016) study a cut by 14 percentage points of the value-added tax applied to sit-down restaurants (the tax fell from 19.6 percent to 5.5 percent), which occurred in 2009. Using aggregate price data and a difference-in-differences strategy comparing sit-down restaurants to non-restaurant market services and non-restaurant small firms, they find that restaurants prices decreased by around 2 percent. Their results imply a low passthrough of $2/14 = 15\%$. Another example comes from Finland. Kosonen (2015) studies the impact of a reduction by 14 percentage points of the value-added tax on hairdressing services (from 22% to 8%). He finds that hairdressers cut their prices by an amount that corresponds to a passthrough of 50%. The tax was reduced in 2007, but the tax reform was undone in 2012, with the tax on hairdressing services returning to its previous level. Benzarti et al. (2017) study the impact of the tax increase and also find incomplete passthrough.

In addition to predicting incomplete marginal-cost passthrough, our model predicts that the passthrough is smaller in less-competitive economies, and that it even goes to one as the economy becomes perfectly competitive (Corollary 1). This property echoes the finding of Carlton (1986) that prices are more rigid in industries that are more concentrated. It is also consistent with the finding by Amiti, Itskhoki, and Konings (2014) that firms with high market power pass through changes in marginal costs driven by exchange-rate shocks much less than firms with low market power. In fact, they find that high-market-power firms set high markups and actively move them in response to changes in marginal costs, which limits the effect of exchange-rate shocks on export prices.

Our model also predicts that the passthrough is smaller in economies in which customers care more about fairness (also Corollary 1). This result seem to accord well with the results reported by Kackmeister (2007). First, he finds that the fairness of transactions matters less today than it did in 1890 due to weaker current personal relationships between retailers and customers. Second, he shows that retail prices were much more rigid in 1889–1891 than in 1997–1999. Under the presumption that fairness mattered much more in the past, the results in Poterba (1996) also support the result of the model: he finds that the passthrough of sales tax into prices in the United States was much lower in the 1920s and 1930s than it was in the postwar period.

Finally, our model predicts that when customers care about fairness but observe costs, the passthrough of marginal costs into prices is one, whereas the passthrough is strictly below one when costs are not observed (Lemma 2). Renner and Tyran (2004) provide evidence from a laboratory experiment that in customer markets, price rigidity after a temporary cost shock is much more pronounced when costs are observable than when they are not. Last, Kachelmeier, Limberg, and Schadewald (1991a,b) also find that in laboratory experiments that disclosing information on changes in marginal costs hastens price convergence relative to the convergence observed in markets with no disclosures.

4.8. Extension to Signaling

To study how firms strategically reveal cost information to customers, we add to our model the option to the firm of credibly revealing its cost to customers before choosing its price. In this case, the firms profits are $V^r = (P^r - MC)Y^r$, where the r superscript denotes the firm's decision to "reveal". When the firm reveals its marginal cost, then $K^p = K^r$. Using $P^r = K^r MC$ and substituting the expression for demand (6) yields

$$(20)\quad V^r = (K^r \cdot MC - MC) \cdot F(K^r)^{\varepsilon - 1} \cdot (K^r \cdot MC)^{-\varepsilon} = MC^{1-\varepsilon} \cdot (K^r - 1) \cdot (K^r)^{-\varepsilon} \cdot F(K^r)^{\varepsilon - 1}.$$

When the firm credibly reveal its marginal cost, the profit-maximizing markup is the same as when the marginal cost is observable, so K^r is given by (9).

When instead the firm conceals its marginal cost before choosing its price, we assume that the customer still uses the inference rule described by (13). This is reasonable because fully rational inference and fully naive inference take the same form as before, when there was no option to signal. Indeed, when the firm conceals, a rational customer can invert the price to uncover the marginal cost, just as it does absent the possibility of cost disclosure. And when the firm conceals, a fully naive customer infers nothing from the firm's disclosure or pricing decision. Accordingly, the inference rule remains the mixture of these two extreme cases. The firm's profits form concealing then are

$$(21)\quad V^c = (K^c \cdot MC - MC) \cdot F(K^p)^{\varepsilon - 1} \cdot (K^c \cdot MC)^{-\varepsilon} = MC^{1-\varepsilon} \cdot (K^c - 1) \cdot (K^c)^{-\varepsilon} \cdot F(K^p)^{\varepsilon - 1},$$

where the superscript c denotes "conceal," the perceived markup is

$$K^p(K^c, MC) = (K^b)^{1-\chi} \left(\frac{K^c \cdot MC}{MC^b} \right)^{\chi},$$

as in (14), and the profit-maximizing markup is given by (16), as when the marginal cost is not observable.

While the profits when the monopoly reveals are independent of customers' beliefs, the perceived markup, K^p, is an important determinant of the profits when the monopoly conceals. A higher K^p means a lower fairness measure $F(K^p)$ and a lower markup K^c, and therefore lower profits. Hence the monopoly may choose to conceal or reveal, depending on customers' beliefs:

LEMMA 4. *Assume that customers care about fairness ($\theta > 0$) and subproportionally infer marginal costs ($\chi > 0$). Consider the decision of the monopoly to conceal or reveal marginal cost depending on customers' beliefs, parameterized by K^b and MC^b. The monopoly's decision solely depends on $\lambda \equiv \left(K^b\right)^{1-\chi} / \left(MC^b\right)^{\chi}$. There exists a threshold λ_0 such the firm optimally conceals if $\lambda < \lambda_0$ and reveals if $\lambda > \lambda_0$. Equivalently, there exists a threshold K_0^p on the perceived markup such the firm optimally conceals if $K^p < K_0^p$ and reveals if $K^p > K_0^p$.*

The formal proof of the lemma is in Appendix A, but this intuition is simple. The monopoly optimally follows a threshold rule, concealing costs when the perceived markup is low and revealing costs when the perceived markup would have been high. Because lower perceived markup lead to higher and less elastic demand—which means higher profits—a monopoly facing customers who tend to perceive low markups has much less incentive to reveal its cost and its markup than a monopoly facing customers who tend to perceive high markups.

The previous lemma shows that depending on parameter values, a monopoly may choose to conceal or reveal its cost. To obtain sharper predictions, we focus on a situation where customers appraise the markup they face as fair, which they may be particularly likely to do in the long run, once they have adapted to the environment.[7] Being in an equilibrium in which customers are neither angry nor happy imposes constraints on the fairness and belief parameters. We take the parameters ε, θ, and χ as given. For customers to find the markup fair when the firm reveals its cost, it must be that $F(K^r) = 1$, which requires $K^r = K^f$ and therefore

$$K^f = 1 + \frac{1}{\varepsilon - 1} \cdot \frac{1}{1 + \theta/2}. \tag{22}$$

As customers also perceive the markup to be fair if the firm conceals, the parameters MC^b and K^b must be such that $K^p = K^f$. As showed in Appendix A, there is a unique value of $\lambda = \left(K^b\right)^{1-\chi} / \left(MC^b\right)^{\chi}$ such that in equilibrium $K^p = K^f$, where K^f is given by (22). When customers are acclimated, they perceive the same markup whether the firm conceals or reveals its cost.

[7]As noted by Kahneman, Knetsch, and Thaler (1986, pp. 730–731), "Psychological studies of adaption suggest that any stable state of affairs tends to become accepted eventually, at least in the sense that alternatives to it no longer come to mind. Terms of exchange that are initially seen as unfair may in time acquire the status of a reference transaction. . . . [People] adapt their views of fairness to the norms of actual behavior."

We now study whether the monopoly chooses to conceal or reveal when customers are in such acclimated situation. We find that the monopoly always prefers to conceal:

PROPOSITION 2. *Assume that customers care about fairness ($\theta > 0$) and are acclimated (K^f is given by (22) and MC^b and K^b are such that in equilibrium $K^p = K^f$). If customers make some inference ($\chi < 1$), then the monopoly always chooses to conceal its marginal cost: $V^c > V^r$. If customers do not make any inference ($\chi = 1$), then the monopoly is indifferent between concealing and revealing its marginal cost: $V^c = V^r$*

The proof of the proposition is in Appendix A. The proposition says that if the monopoly had to choose between concealing and revealing its cost when customers are acclimated, which is likely to happen in the long run once customers have adapted to the markups and find them fair, then the monopoly would always choose to conceal its cost. Indeed, once customers are acclimated, they find transaction equally fair, whether the firm reveals or conceals, and the level of demand is the same in both situations. However, the demand is less elastic when the firm conceals: an increase in price signals some increase in cost, and triggers a smaller increase in perceived marginal cost as when the firm reveals. As the monopoly faces a more inelastic demand when it conceals its cost, it is able to extract higher profits.

At the limit where customers do not make any inference about marginal costs, however, the demand is as elastic whether the firm conceals or reveals, and the firm makes as much profits whether it conceals or reveals.

Proposition 2 shows that when customers are acclimated, it is more profitable for the monopoly to conceal its cost. Finally, we examine whether, starting from this situation, the monopoly may choose to reveal its cost in response to an increase or decrease in cost. We find that the monopoly will reveal its cost for a large-enough increase in marginal cost:

PROPOSITION 3. *Assume that customers care about fairness ($\theta > 0$) and are acclimated to some marginal cost $\overline{MC}$ (K^f is given by (22) and MC^b and K^b are such that in equilibrium $K^p = K^f$). At $MC = \overline{MC}$, the monopoly optimally conceals its cost. Then if customers subproportionally infer marginal costs ($\chi \in (0,1)$), there exists a threshold $MC_0 > \overline{MC}$ such that the firm optimally conceals any marginal cost $MC < MC_0$ and reveals any marginal cost $MC > MC_0$. If customers do not make any inference ($\chi = 1$), the threshold satisfies $MC_0 = \overline{MC}$, such that the firm reveals any cost increase but conceals any cost decrease. And if customers proportionally infer marginal costs ($\chi = 0$), the firm never reveals its marginal cost.*

The proof of this proposition is in Appendix A, but there is a simple logic for the result. We consider that the monopoly conceals its cost and that customers have adapted to the situation. Then we examine what happens if the marginal cost changes—either increases or decreases. A firm with a high marginal cost will tend to charge high prices. As the customer fails to adequately update beliefs about marginal cost from price, if the firm conceals its marginal cost, it will be wrongly perceived to use a high markup and regarded as unfair. On the other hand, a firm with a low marginal cost that conceals it will be wrongly perceived to use a low markup and regarded as fair. The former clearly has more incentive to reveal than the latter.

Starting from an equilibrium in which customers are acclimated and firms have the ability to signal their marginal costs, what happens to the marginal-cost passthrough? Let's focus on customers making subproportional inference. Before the cost shock, the monopoly conceals. If the marginal cost falls, the monopoly keeps concealing, so the passthrough is given by (19), which is less than one. This means that in response to a decrease in cost, prices are somewhat rigid. If the marginal cost rises but remains below MC_0, the monopoly keeps concealing, so the passthrough is also given by (19). This means that in response to a small increase in cost, prices are also somewhat rigid. Finally, if the marginal cost rises above MC_0, the monopoly switches from concealing to revealing. The original price is $\overline{P} = K^c \cdot \overline{MC}$ and the final price is $P = K^r \cdot MC$ so the marginal-cost passthrough is strictly less than one when $K^r < K^c$. As showed by (22) and (18), since $\chi < 1$, $K^r = K^f < K^c$, and the passthrough is indeed less than one even though the monopoly switches to revealing its costs. Hence prices are also somewhat rigid even in response to a large increase in cost. Depending on parameter values, the price rigidity may be more or less pronounced in response to a large cost increase, but of course as the marginal cost becomes infinitely large, the firm will eventually reveal its cost and the passthrough will converge to one.

In the special case in which customers make proportional inference, firms always conceal, and the passthrough is always one: hence prices are flexible. And in the special case in which customers do not make any inference, firms conceal cost decreases but reveal cost increases, so prices are downwardly rigid but upwardly flexible.

Our model thus predicts that in general a monopoly would not want to reveal its costs (Proposition 2). This could explain why we rarely see firms reveal their costs to customers. Our model also predicts that in response to a large-enough increase in production costs (but not a decrease in production costs), a monopoly will reveal its costs (Proposition 3). Indeed, there is evidence to this effect: while we have never observed a firm advertise a decrease in production costs, we frequently observe firms advertising cost increase. In fact, Okun (1981, p. 153) observed that "In many industries, when firms raise their prices, they routinely issue announcements to their customers, insisting that higher costs have compelled them to do so."

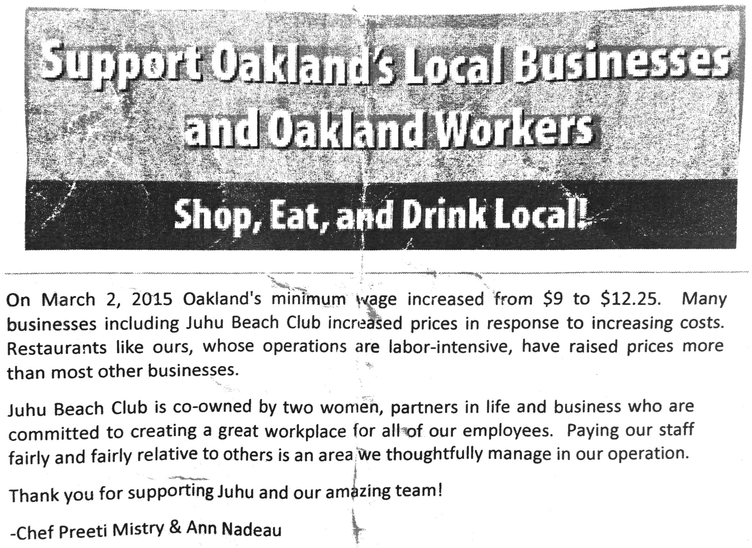
Figure 2, panel A, presents examples of firms that reveal their costs in response to a substantial increase in labor costs. The two signs in the figure were posted in restaurants in Oakland and Berkeley in California following the large increase in minimum wage enacted in these cities in March 2015. The minimum wage increased by more than 30%, leading many businesses to increase prices. Interestingly, many businesses felt compelled to explain why prices rose.

Figure 2, panel B, shows that firms go to great lengths to document large increases in production costs. The figure comprises two displays posted side-by-side in a bakery in Ithaca, NY. The first reproduces several graphs from the New York Times to substantiate the claim. These graphs plot the price of wheat, of soybeans, and of corn over time. The second explains that the increase in the wheat price translated into an increase in the price of flour, a key ingredient for bagels. The bakery promises to "drop the surcharge" when wheat prices return to normal.

A last implication of the model with signaling is that the response of prices to cost decreases and costs increases, especially large increases, may be asymmetric. As soon as the cost increase is large enough to make the firm reveal its cost, the price response will be different from the response to a cost decrease of the same amplitude. In particular, as the cost increase becomes large, the passthrough will become closer to one—that is, prices will be close to flexible. In that situation, prices respond more strongly to large cost increases than to small cost increases or cost decreases.

5. Dynamic General-Equilibrium Model

We now embed our pricing model into a simple New Keynesian model. When customers care about the fairness of prices and subproportionally infer marginal costs from prices, the markup charged by monopolistic firms is not constant but depends on the rate of inflation. This property has several important implications, including the nonneutrality of money.



Support Oakland's Local Businesses and Oakland Workers

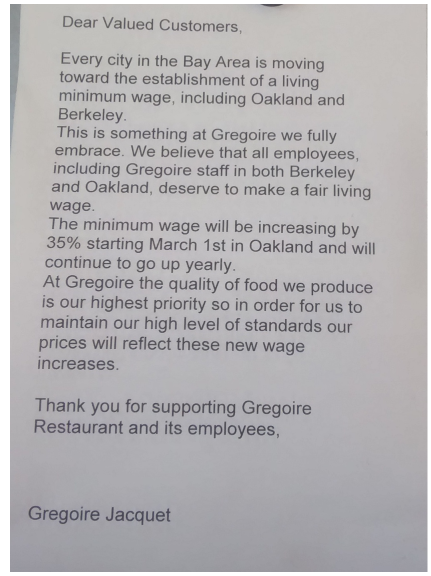
Shop, Eat, and Drink Local!

On March 2, 2015 Oakland's minimum wage increased from $9 to $12.25. Many businesses including Juhu Beach Club increased prices in response to increasing costs. Restaurants like ours, whose operations are labor-intensive, have raised prices more than most other businesses.

Juhu Beach Club is co-owned by two women, partners in life and business who are committed to creating a great workplace for all of our employees. Paying our staff fairly and fairly relative to others is an area we thoughtfully manage in our operation.

Thank you for supporting Juhu and our amazing team!

-Chef Preeti Mistry & Ann Nadeau



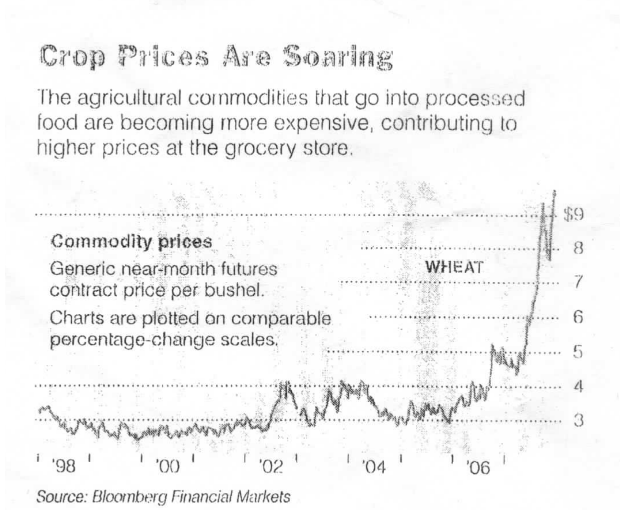
Dear Valued Customers,

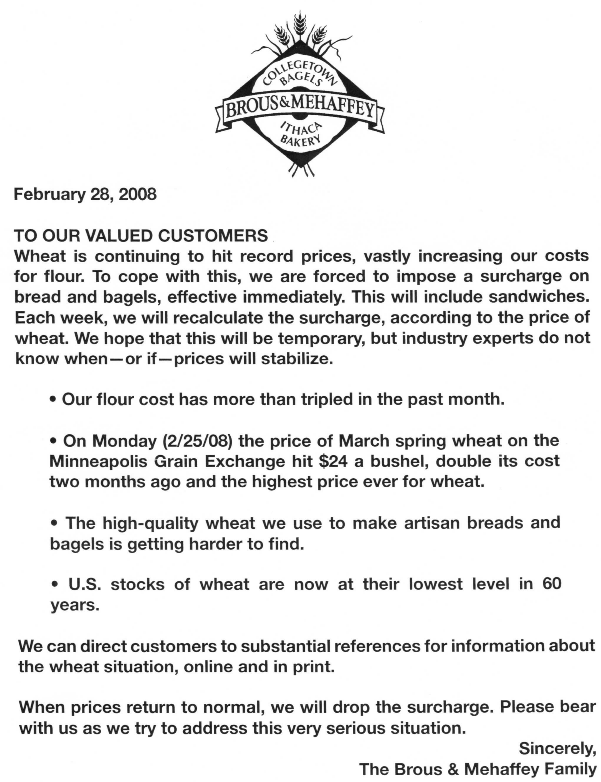
Every city in the Bay Area is moving toward the establishment of a living minimum wage, including Oakland and Berkeley.
This is something at Gregoire we fully embrace. We believe that all employees, including Gregoire staff in both Berkeley and Oakland, deserve to make a fair living wage.
The minimum wage will be increasing by 35% starting March 1st in Oakland and will continue to go up yearly.
At Gregoire the quality of food we produce is our highest priority so in order for us to maintain our high level of standards our prices will reflect these new wage increases.

Thank you for supporting Gregoire Restaurant and its employees,

Gregoire Jacquet

A. Large increases in minimum wage





February 28, 2008

TO OUR VALUED CUSTOMERS
Wheat is continuing to hit record prices, vastly increasing our costs for flour. To cope with this, we are forced to impose a surcharge on bread and bagels, effective immediately. This will include sandwiches. Each week, we will recalculate the surcharge, according to the price of wheat. We hope that this will be temporary, but industry experts do not know when—or if—prices will stabilize.

- **Our flour cost has more than tripled in the past month.**
- **On Monday (2/25/08) the price of March spring wheat on the Minneapolis Grain Exchange hit $24 a bushel, double its cost two months ago and the highest price ever for wheat.**
- **The high-quality wheat we use to make artisan breads and bagels is getting harder to find.**
- **U.S. stocks of wheat are now at their lowest level in 60 years.**

We can direct customers to substantial references for information about the wheat situation, online and in print.

When prices return to normal, we will drop the surcharge. Please bear with us as we try to address this very serious situation.

Sincerely,
The Brous & Mehaffey Family

B. Large increase in wheat prices

Figure 2. Examples of Firms Revealing Large Cost Increases

Sources: Panel A: pictures taken at restaurants in Oakland, CA, and Berkeley, CA, in 2015 by Pascal Michaillat. Panel B: picture taken at a bakery in Ithaca, NY, in 2008 by Daniel Benjamin.

5.1. Assumptions

The model is dynamic and set in discrete time. The economy is composed of a continuum of households indexed by $j \in [0,1]$ and a continuum of firms indexed by $i \in [0,1]$. Households supply labor services, consume goods, and hold riskless nominal bonds. Firms use labor services to produce goods. Since the goods produced by firms are imperfect substitutes for one another, and the labor services supplied by households are also imperfect substitutes, each firm exercises some monopoly power on the goods market, and each household exercises some monopoly power on the labor market.

Fairness Concerns. We introduce concerns about the fairness of prices as in Section 4 but generalize the setup to allow for a continuum of firms and goods.

We assume that each firm's technology and hence its marginal cost are unobservable to other firms and households. When a household purchases good i at price P_i, it infers that firm i's nominal marginal cost of production is $MC_i^p(P_i)$. Having inferred the marginal cost, the household deduces that the markup charged by firm i is $K_i^p(P_i) = P_i / MC_i^p(P_i)$. This perceived markup determines the perceived fairness of the transaction with firm i, measured by

$$F_i(K_i^p) = \frac{2}{1 + \left(K_i^p / K_i^f\right)^{\theta_i}}. \tag{23}$$

The parameters K_i^f and θ_i may be specific to good i. In absolute value, the elasticity of F_i with respect to K_i^p is

$$\Phi_i(K_i^p) \equiv -\frac{d\ln(F_i)}{d\ln(K_i^p)} = \theta_i \frac{\left(K_i^p / K_i^f\right)^{\theta_i}}{1 + \left(K_i^p / K_i^f\right)^{\theta_i}}.$$

An amount Y_{ij} of good i bought by household j at a unit price P_i yields a fairness-adjusted consumption $Z_{ij} = F_i(K_i^p(P_i))Y_{ij}$. Then, household j's fairness-adjusted consumption of the different goods aggregates into a consumption index

$$Z_j = \left(\int_0^1 Z_{ij}^{(\varepsilon-1)/\varepsilon} di\right)^{\varepsilon/(\varepsilon-1)}, \tag{24}$$

where $\varepsilon > 1$ is the elasticity of substitution between different goods. The index describes the household's love of variety; as $\varepsilon \to \infty$, goods become perfect substitutes.

Finally, we introduce the fairness-adjusted price index

$$Q = \left[\int_0^1 \left(\frac{P_i}{F_i(K_i^p(P_i))} \right)^{1-\varepsilon} di \right]^{1/(1-\varepsilon)}. \tag{25}$$

The fairness-adjusted price index is useful because it gives the price of one unit of Z_j.

Inference about Marginal Costs. An advantage of the dynamic model over the static model is to provide a natural candidate for the nominal anchor that households use when they infer firms' nominal marginal costs. In the static model the nominal anchor is just a parameter (MC^b). In the dynamic model, we use the current perception of nominal marginal cost as anchor. Formally, households' perception of firm i's nominal marginal cost evolves according to the following law of motion:

$$MC_i^p(t) = \left(e^{\pi^b} MC_i^p(t-1) \right)^{\chi} \left(\frac{P_i(t)}{K^b} \right)^{1-\chi}. \tag{26}$$

In the law of motion, π^b is the inflation rate used to continuously update perceived marginal costs, $P_i(t)/K_i^b$ is the nominal marginal cost of firm i under proportional inference, and $\chi \in [0,1]$ measures the sophistication of households' inference. With $\chi = 0$, then $MC_i^p(t) = P_i(t)/K_i^b$ so households set their beliefs about marginal costs in proportion to observed prices. With $\chi = 1$, then $MC_i^p(t)$ grows at a constant rate π^b so households fail to update their beliefs about marginal costs. With $\chi \in (0,1)$, households partially adjust their beliefs in the direction of the true nominal marginal cost.

Following the same logic as in the static model of Section 4, we can show that with rational inference the nominal marginal cost remains $MC_i(P_i(t)) = P_i(t) \cdot (\varepsilon - 1)/\varepsilon$; furthermore, rational households are able to perceive this cost following the same strategy as in the static model.[8] Hence, rational inference is a special case of (26) with $\chi = 0$ and $K_i^b = \varepsilon/(\varepsilon - 1)$.

[8]The key is that under rational inference, the firm's optimization problem reduces to a collection of static optimization problems: at each time t, the firm maximizes the current flow of profits. The firm's problem is therefore the same as in the static model of Section 4, and rational households can follow the same strategy of solving a functional equation at each time t.

Households. Households work, own the firms, spend part of their income on consumption, and save part of their income using riskless nominal bonds. Households derive utility from consuming goods and disutility from working. The utility depends on the fairness-adjusted consumption index Z_j and the amount N_j of labor supplied. Household j's utility at time 0 is

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t\left(\ln(Z_j)-\frac{N_j(t)^{1+\eta}}{1+\eta}\right)\right] \tag{27}$$

where $\mathbb{E}_0$ is the expectation conditional on period-0 information, $\beta > 0$ is the time discount factor, and $\eta > 0$ measures the curvature of the disutility from labor.

Households sell or buy one-period bonds. Household j holds $B_j(t)$ bonds in period t. Bonds purchased in period t have a price $X(t)$, mature in period $t+1$, and pay one unit of money at maturity. The bonds are traded on a perfectly competitive market. The price of bonds is determined by monetary policy.

Household j's budget constraint in period t is

$$\int_0^1 P_i(t)Y_{ij}(t)di + X(t)B_j(t) = W_j(t)N_j(t) + B_j(t-1) + V_j(t), \tag{28}$$

where $V_j(t)$ are dividends from ownership of firms. In addition, household j is subject to a solvency constraint preventing Ponzi schemes: $\lim_{T\to\infty}\mathbb{E}_t\left[B_j(T)\right] \geq 0$ for all t.

Household j maximizes the utility (27) by choosing sequences for the nominal wage of labor service j, the amount of labor service j supplied, the amounts of consumption of goods $i \in [0,1]$, and the amount of bonds held, $\left\{W_j(t), N_j(t), \left[Y_{ij}(t)\right]_{i=0}^{1}, B_j(t)\right\}_{t=0}^{\infty}$. The maximization is subject to the flow budget constraint (28), to the solvency condition, and to the constraint imposed by firms' demand for labor service j. The household takes as given the initial endowment of bonds $B_j(-1)$, and the sequences for prices and dividends, $\left\{X(t), [P_i(t)]_{i=0}^{1}, V_j(t)\right\}_{t=0}^{\infty}$.

Firms. Firm i hires labor to produce output using the production function

$$Y_i = A_i(t)N_i^{\alpha}, \tag{29}$$

where Y_i is its output of good i, $A_i(t)$ is its technology level, $\alpha < 1$ is the extent of diminishing marginal returns to labor, and

$$N_i = \left(\int_0^1 N_{ij}^{(\nu-1)/\nu} dj\right)^{\nu/(\nu-1)} \tag{30}$$

is an employment index. In the employment index, N_{ij} is the quantity of labor service j hired by firm i, and $\nu > 1$ is the elasticity of substitution between different labor services. The level of technology $A_i(t)$ is exogenous, possibly stochastic, and is unobservable to households—making the firm's marginal cost unobservable.

Firm i chooses sequences for the price of good i, the output of good i, and the amounts of labor services employed, $\left\{P_i(t), Y_i(t), \left[N_{ij}(t)\right]_{j=0}^{1}\right\}_{t=0}^{\infty}$, in order to maximize the present-discounted value of profits

$$\mathbb{E}_0 \left[\sum_{t=0} \Gamma(t) \left(P_i(t)Y_i(t) - \int_0^1 W_j(t)N_{ij}(t)dj\right)\right], \tag{31}$$

where

$$\Gamma(t) \equiv \beta^t \frac{Q(0)}{Q(t)} \cdot \frac{Z(0)}{Z(t)} \tag{32}$$

is the stochastic discount factor for nominal payoffs in period t. The maximization is subject to the production constraint (29), to the demand for good i, and to the law of motion of the perceived marginal cost, given by (26). All the firm's profits are rebated to households.

Monetary Policy. The nominal interest rate is determined by monetary policy, which follows an interest-rate rule:

$$i(t) = i_0(t) + \mu\pi(t), \tag{33}$$

where the intercept $i_0(t) > 0$ gives the nominal interest rate when inflation is zero and $\mu > 0$ gives the response of monetary policy to inflation. The intercept $i_0(t)$ is exogenous and possible stochastic.

5.2. Optimal Pricing

We now characterize the optimal, profit-maximizing pricing for firms. Once we have characterized optimal pricing, it is easy to completely describe the equilibrium. In the next subsections, the derivations are mostly standard and relegated to Appendix B.

To maximize their utility, households make two decisions: first, they choose how to divide their wealth across goods and bonds; second, they determine the wage for their labor service. Integrating over all households, we find that the demand for good i is given by

$$Y_i^d(t, P_i(t), MC_i^p(t-1)) = Z(t) \cdot F\left(\left[K^b\right]^{1-\chi}\left[\frac{P_i(t)}{e^{\pi^b} \cdot MC_i^p(t-1)}\right]^{\chi}\right)^{\varepsilon-1} \cdot \left(\frac{P_i(t)}{Q(t)}\right)^{-\varepsilon}. \tag{34}$$

where $Z(t) \equiv \int_0^1 Z_j(t)dj$ describes the level of aggregate demand. The demand increases with aggregate demand, Z, and decreases with the price of good i, P_i. The equation can be written as $Z_i^d \equiv F \cdot Y_i^d = Z \cdot [(P_i/F)/Q]^{-\varepsilon}$. As the price of one unit of Z_i is P_i/F and the price of one unit of Z is Q, the relative price of Z_i is $(P_i/F)/Q$. Hence, this alternative formulation says that the demand for Z_i equals aggregate demand Z times the relative price of Z_i to the power of $-\varepsilon$. This is the standard expression for demand curves in this type of models.

We also find that it is optimal for household j to smooth fairness-adjusted consumption over time according to an Euler equation:

$$X(t) = \beta \mathbb{E}_t\left[\frac{Q(t)Z_j(t)}{Q(t+1)Z_j(t+1)}\right] \tag{35}$$

The analysis will focus on symmetric equilibria: all households receive the same dividends; all firms share a common technology; all households post the same wage; and all firms set the same price. In such an equilibrium, all the parameters and variables are the same for all households and firms, so we will drop the subscripts i and j on parameters and variables. In particular, in a symmetric equilibrium, $Z_j(t) = F(t)Y(t)$ and $Q(t) = P(t)/F(t)$. In such an equilibrium, the Euler equation simplifies to

$$X(t) = \beta \mathbb{E}_t\left[\frac{P(t)Y(t)}{P(t+1)Y(t+1)}\right]. \tag{36}$$

This is the standard consumption Euler equation.

Next, the demand for labor service j from firms is

$$N_j^d(t, W_j(t)) = N(t) \cdot \left(\frac{W_j(t)}{W(t)}\right)^{-\nu}, \tag{37}$$

where

$$W(t) \equiv \left(\int_0^1 W_j(t)^{1-\nu} dj\right)^{1/(1-\nu)} \tag{38}$$

is the nominal wage index and $N(t) \equiv \int_0^1 N_i(t) di$ is aggregate employment. The labor demand increases with aggregate employment but decreases with the relative wage of labor service j, W_j/W. Given labor demand (37), household j sets its wage $W_j(t)$ to maximize utility. The optimal wage satisfies

$$\frac{W_j(t)}{Q(t)} = \frac{\nu}{\nu-1} N_j(t)^{\eta} Z_j(t). \tag{39}$$

As the wage of labor service j is W_j and the price of one unit of fairness-adjusted consumption is Q, the real wage of labor service j is W_j/Q. Hence, household j sets its real wage at a markup of $\nu/(\nu-1) > 1$ over its marginal rate of substitution between leisure and fairness-adjusted consumption, $N_j^{\eta} Z_j$. In the symmetric case, $Z_j(t) = F(t)Y(t)$ and $Q(t) = P(t)/F(t)$, so (39) simplifies to

$$\frac{W(t)}{P(t)} = \frac{\nu}{\nu-1} N(t)^{\eta} Y(t). \tag{40}$$

To maximize profits, firms also make two decisions: first, they choose how much of each labor service to hire; second, they determine the price of their good. Integrating over all firms, we find that the demand for labor service j is given by (37).

Next, we turn to firm i's' pricing. Let E_i be the price elasticity of the demand for good i, in absolute value:

$$E_i(t) = -\frac{\partial \ln(Y_i^d)}{\partial \ln(P_i)} = \varepsilon + (\varepsilon - 1)\chi \Phi(K_i^p(t)),$$

where the elasticity Φ is given by (3). Although the demand is not the same as in the static model, the expression for E_i remains the same (see (15)). In the static model the profit-maximizing markup is given by $K_i = E_i/(E_i - 1)$. In the dynamic model, however, we will see that the profit-maximizing markup is not necessarily given by $E_i/(E_i-1)$: since E_i does not capture the effect of P_i on future perceived marginal costs and thus future demands.

When firm i charges a price $P_i(t)$ and faces a nominal marginal cost $MC_i(t)$, then the markup charged by firm i is

$$K_i(t) = \frac{P_i(t)}{MC_i(t)}. \tag{41}$$

Then we define the quasi elasticity $D_i(t) > 1$ by

$$D_i(t) = \frac{K_i(t)}{K_i(t)-1},$$

where $K_i(t)$ is defined by (41). In the static model, when the price is optimal, $D_i(t) = E_i(t)$; in the dynamic model, this is not necessarily the case. In fact, in the dynamic model, the gap between $D_i(t)$ and $E_i(t)$ indicates how much the slow adjustment of customers' beliefs matters. When firms change their price, they affect perceived marginal costs today and in the future (through (26)). Thus, the price today affects demands in the future. This effect is not captured by $E_i(t)$ but is indeed captured by $D_i(t)$, since the profit-maximizing markups accounts for it.

Indeed, to maximize profits, firms should set prices such that

$$\beta \mathbb{E}_t \left[\frac{E(t+1)-(1-\chi)\varepsilon}{D(t+1)} \right] + (1-\chi\beta) = \frac{E(t)}{D(t)}. \tag{42}$$

This forward-looking equation gives the quasi elasticity $D(t)$ when prices are optimal, and thus the profit-maximizing markup $K(t) = D(t)/(D(t)-1)$. This equation holds in a symmetric equilibrium; Appendix B shows that the equation admits a slightly more complicated expression in an equilibrium that is not symmetric.

Having described firms' pricing, we can recover all other equilibrium variables. To link employment to the goods-market markup, we compute marginal costs in a symmetric equilibrium. The nominal marginal cost is the nominal wage divided by the marginal product of labor: $MC(t) = W(t)/\left(\alpha A N(t)^{\alpha-1}\right)$. In a symmetric equilibrium, equation (29) becomes

$$Y(t) = A(t)N(t)^{\alpha}. \tag{43}$$

Using (40) and (43), we obtain

$$\frac{MC(t)}{P(t)} = \frac{\nu}{(\nu-1)\alpha} N(t)^{1+\eta}. \tag{44}$$

The nominal marginal cost increases with employment because the real wage increases with employment and the production function has diminishing marginal returns to labor. The nominal marginal cost also increases with the labor-market markup, $\nu/(\nu-1)$. In a symmetric equilibrium, the goods-market markup is the price over the marginal cost: $K(t) = P(t)/MC(t)$. Thus, we reformulate (44):

$$N(t)^{1+\eta} = \alpha \frac{\nu-1}{\nu} \cdot \frac{1}{K(t)}. \tag{45}$$

This equation implies that the goods-market market directly govern employment. Then, employment determines output and the real wage through (40) and (43). Finally, we compute profits in a symmetric equilibrium. Nominal profits in period t are turnover minus wage bill: $V(t) = P(t)Y(t) - W(t)N(t)$. Moreover,

$$\frac{1}{K(t)} = \frac{MC(t)}{P(t)} = \frac{W(t)/P(t)}{\alpha A(t) N(t)^{\alpha-1}} = \frac{W(t)/P(t)}{\alpha\,(Y(t)/N(t))}.$$

Hence real profits are governed by the goods-market markup:

$$\frac{V(t)}{P(t)} = Y(t) \cdot \left[1 - \frac{\alpha}{K(t)}\right]. \tag{46}$$

5.3. Steady-State Equilibrium

We describe the steady-state equilibrium. We focus on a symmetric equilibrium. In the steady-state equilibrium, all real variables are constant and all nominal variables grow at a constant rate $\overline{\pi}$ (the steady-state inflation rate). It is convenient to manipulate all the variables in log form. We use the following notation: for a variable $X(t)$, we denote the log of $X(t)$ by $x(t) \equiv \ln(X(t))$, and the steady-state values of $X(t)$ and $x(t)$ by $\overline{X}$ and $\overline{x}$. Following common practice, we also introduce three new variables. We define the inflation rate between t and $t+1$ as $\pi(t+1) \equiv \ln(P(t+1)/P(t))$. If $P(t+1)$ and $P(t)$ are close enough, then $\pi(t+1) \approx (P(t+1) - P(t))/P(t)$, which is another common way of defining inflation. We define the nominal interest between t

and $t+1$ as $i(t) \equiv -\ln(X(t))$. If $X(t) \approx 1$ (that is, if the interest rate is small), then $i(t) \approx (1-X(t))/X(t)$, which is the yield of a bond purchased at time t, and is another common way of defining the interest rate. Both $\pi(t+1)$ and $i(t)$ describe what happens between periods t and $t+1$, but we index the inflation rate with $t+1$ and the interest rate with t because the inflation rate is realized in period $t+1$ while the interest rate is known in period t. Finally, we define the time discount rate as $\rho \equiv -\ln(\beta)$.

Since $Y(t) = Y(t+1)$ in steady state, (36) implies

$$\bar{i} = \overline{\pi} + \rho. \tag{47}$$

Hence, in steady state, the nominal interest rate is the time discount rate plus the inflation rate. In other words, the real interest rate (the nominal interest rate minus the inflation rate) equals the time discount rate: $\overline{r} \equiv \bar{i} - \overline{\pi} = \rho$. This is typical.

Equation (47) combined with the monetary policy rule (33) implies that

$$\overline{\pi} = \frac{\rho - \overline{i_0}}{\mu - 1}. \tag{48}$$

Hence the steady-state inflation rate is determined by the intercept of the monetary-policy rule, $\overline{i_0}$. Inflation is higher when the intercept of the interest-rate rule is lower. This is also typical.

Then, (26) shows that in steady state the perceived markup is determined by inflation:

$$\overline{k^p} = k^b + \frac{\chi}{1-\chi}\left(\overline{\pi} - \pi^b\right). \tag{49}$$

Households perceive higher markups when inflation is higher. The response of the perceived markup to inflation is stronger when inference is less rational (high χ). The perceived markup is closer to the proportional-inference markup k^b when inference is more rational (low χ) and when the mechanical updating rate π^b is closer to the inflation rate $\overline{\pi}$.

In steady state, equation (42) implies that

$$(1-\chi\beta)\overline{D} = (1-\beta)\overline{E} + (1-\chi)\beta\varepsilon.$$

Since $\overline{E} = \varepsilon + (\varepsilon - 1)\chi\Phi(\overline{k}^p)$, we obtain

(50) $$\overline{D} = \varepsilon + (\varepsilon - 1)\frac{(1-\beta)\chi}{1-\beta\chi}\Phi(\overline{k}^p).$$

As the profit-maximizing markup satisfies $\overline{K} = \overline{D}/(\overline{D}-1)$, equation (50) yields the equilibrium relationship between the goods-market markup and the rate of inflation in steady state:

PROPOSITION 4. *Without fairness concerns ($\theta = 0$), or with proportional inference ($\chi = 0$), the steady-state goods-market markup is $\overline{K} = \varepsilon/(\varepsilon - 1)$. But with fairness concerns ($\theta > 0$) and subproportional inference ($\chi > 0$), the steady-state goods-market markup is*

(51) $$\overline{K} = 1 + \frac{1}{\varepsilon - 1} \cdot \frac{1}{1 + \frac{(1-\beta)\chi}{1-\beta\chi}\Phi(K^p(\overline{\pi}))},$$

where the elasticity Φ is given by (3), the perceived markup $K^p(\overline{\pi})$ by (49), and steady-state inflation $\overline{\pi}$ by (48). This implies that $\overline{K} < \varepsilon/(\varepsilon - 1)$ and that $\overline{K}$ is decreasing in $\overline{\pi}$. However, if households always use steady-state inflation to update their beliefs ($\pi^b = \overline{\pi}$), then the steady-state goods-market markup becomes independent of steady-state inflation:

(52) $$\overline{K} = 1 + \frac{1}{\varepsilon - 1} \cdot \frac{1}{1 + \frac{(1-\beta)\chi}{1-\beta\chi}\Phi(K^b)}.$$

Equation (51) is the counterpart to equation (16) in the static model. The two equations have the same structure. Since $\chi \mapsto (1-\beta)\chi/(1-\beta\chi)$ is increasing from 0 to 1 when χ increases from 0 to 1, for any $\chi \in [0,1]$, the static model with inference parameter $\chi^s = (1-\beta)\chi/(1-\beta\chi)$ achieves the same allocation as the steady state of the dynamic model with inference parameter χ.

From the steady-state markup $\overline{k} = \ln(\overline{K})$, we are able to infer employment, consumption, and the real wage. First, we use (45) to express employment as a function of the goods-market markup:

(53) $$(1+\eta)\overline{n} = \ln(\alpha) - \ln\left(\frac{\nu}{\nu - 1}\right) - \overline{k}.$$

Then, the production constraint (43) links output to employment:

$$\overline{y} = \overline{a} + \alpha \overline{n} \tag{54}$$

Further, the wage-setting equation (40) links real wage to employment and output:

$$\overline{w} - \overline{p} = \ln\left(\frac{\nu}{\nu - 1}\right) + \eta \overline{n} + \overline{y}. \tag{55}$$

Finally, real profits are given by (46):

$$\overline{v} - \overline{p} = \overline{y} + \ln\left(1 - \frac{\alpha}{\overline{K}}\right). \tag{56}$$

This completes the characterization of the steady-state equilibrium.

Combining the characterization of the steady state and Proposition 4, we characterize the effect of steady-state inflation on real variables:

PROPOSITION 5. *Without fairness concerns ($\theta = 0$), or with proportional inference ($\chi = 0$), or if households always use steady-state inflation to update their beliefs ($\pi^b = \overline{\pi}$), then the steady-state goods-market markup is independent of inflation. Thus money is superneutral: steady-state inflation has no effect on steady-state employment, output, fairness measure, real wages, and real profits.*

PROPOSITION 6. *With fairness concerns ($\theta > 0$) and subproportional inference ($\chi > 0$), the steady-state goods-market markup is decreasing in steady-state inflation. Thus money is not superneutral: in steady state, higher inflation leads to higher employment, higher output, lower fairness measure, higher real wages, but lower real profits when $K < 1 + \alpha + \eta$.*

Proposition 5 immediately follows from what we have done above. Proposition 6 also directly follows from that, except for the response of real profits to inflation, which is analyzed in Appendix A. The effect of inflation on real profits depends on parameter values. In the case $K < 1 + \alpha + \eta$, real profits fall when inflation is higher. This is the case that seems the most relevant in practice: since macroeconomists conventionally estimate K to be between 1.05 and 1.3, α to be between 0.66 and 1, and η to be positive.

The two propositions explain when money is superneutral. The superneutrality of money is the property that the steady-state inflation rate has no influence on the steady-state levels of real variables McCallum and Nelson (2010, p. 102). In the model, an increase in steady-state inflation is engineered by reducing the intercept of the interest-rate rule, $\bar{i}_0$ (see equation (48)). We find that without fairness concerns, with proportional inference, or if households use steady-state inflation to update their beliefs, then money is superneutral. On the other hand, if households care about fairness and infer subproportionally (with a fixed π^b), then money is not superneutral. In that case, after an increase in steady-state inflation, households underappreciate the increase in nominal marginal costs, so they attribute the higher prices partly to higher nominal marginal costs and partly to higher markups, which they find unfair. Since the perceived fairness of the transactions on the goods market decreases, the elasticity of the demand for goods increases. In response, firms reduce their markups. We have showed that in equilibrium, employment is a decreasing function of the markup; therefore, a lower markup implies higher employment, which in turn implies higher output. After an increase in inflation, households mistakenly believe that transactions on the goods market are less fair, but transactions are in fact more fair (since markups are lower), and firms actually suffer lower real profits.

The long-run Phillips curve links steady-state inflation to steady-state employment. Propositions 5 tells us that without fairness concerns ($\theta = 0$), or with proportional inference ($\chi = 0$), or if households always use steady-state inflation to update their beliefs ($\pi^b = \overline{\pi}$), the long-run Phillips curve is vertical: employment is independent of inflation. But as showed by Proposition 6, with fairness concerns ($\theta > 0$) and subproportional inference ($\chi > 0$), the long-run Phillips curve is upward-sloping: higher inflation leads to higher employment. We now describe the long-run Phillips curve more precisely:

PROPOSITION 7. *The long-run Phillips curve relates steady-state inflation $\overline{\pi}$ to log steady-state employment $\overline{n}$. It admits the following expression:*

$$\overline{n} = \frac{1}{1+\eta}\left[\ln(\alpha) - \ln\left(\frac{\nu}{\nu-1}\right)\right] - \frac{1}{1+\eta}\ln\left(1 + \frac{1}{\varepsilon-1}\cdot\frac{1}{1+\frac{(1-\beta)\chi}{1-\beta\chi}\Phi(K^p(\overline{\pi}))}\right).$$

The long-run Phillips curve is increasing from

$$\overline{n} = \frac{1}{1+\eta}\left[\ln(\alpha) - \ln\left(\frac{\nu}{\nu-1}\right)\right] - \frac{1}{1+\eta}\ln\left(\frac{\varepsilon}{\varepsilon-1}\right)$$

when $\overline{\pi} \to -\infty$ to

$$\overline{n} = \frac{1}{1+\eta}\left[\ln(\alpha) - \ln\left(\frac{\nu}{\nu-1}\right)\right] - \frac{1}{1+\eta}\ln\left(1 + \frac{1}{\varepsilon-1}\cdot\frac{1}{1+\frac{(1-\beta)\chi}{1-\beta\chi}\theta}\right).$$

when $\overline{\pi} \to +\infty$. The slope of the long-run Phillips curve is

$$\frac{d\overline{n}}{d\overline{\pi}} = \frac{\varepsilon-1}{1+\eta}\cdot\frac{(\overline{K}-1)^2}{\overline{K}}\cdot\frac{1-\beta}{1-\beta\chi}\cdot\frac{\chi^2}{1-\chi}\cdot\overline{\Phi}\cdot(\theta-\overline{\Phi}). \tag{57}$$

For any $K > K^f$, the slope is decreasing in the inflation rate; the slope converges to 0 when $\overline{\pi} \to +\infty$.

With fairness concerns and misinference, the long-run Phillips curve is not vertical so that steady-state inflation affects employment in the long run. This mechanism complements another mechanism, discussed by Tobin (1972) and formalized by Akerlof, Dickens, and Perry (1996) and Benigno and Ricci (2011): that steady-state inflation erodes real wages and thus reduces unemployment in the presence of downward nominal wage rigidity. Our mechanism is different than the traditional mechanism, since it operates on the goods market instead of the labor market. Furthermore, it is not based on rigidity of wages but on the fact that customers do not fully understand the effect of inflation in their inference about hidden marginal costs. However, the source of wage rigidity could be fairness concerns of workers, coupled with some money illusion (Akerlof, Dickens, and Perry 1996). The psychological origin of the two mechanisms could therefore be similar.

The long-run Phillips curve is vertical both when deflation is infinite and when inflation is infinite. It is flatter for finite rates of inflation. This implies that steady-state inflation has the strongest effect on employment for small rates of inflation. As the rates of inflation become large (in absolute value), the effect on employment vanishes. The expression of the slope of the Phillips curve given by (57) gives the percentage increase in employment when inflation increases by one percentage point, which is broadly the same as the decrease in unemployment, measured in percentage point, when inflation increases by one percentage point.

In addition to comparative statics with respect to inflation, we can also compute comparative statics with respect to technology, A. The results are the same in all the cases considered in Propositions 5 and 6, because the goods-market markup is always independent of technology.

Consequently, output, real wages, and real profits are proportional to technology. Employment and fairness measure are independent of technology.

5.4. Equilibrium Dynamics

We now analyze equilibrium dynamics. It is convenient to work with the deviations of the log variables from their steady-state values. We use the following notation: for a variable $X(t)$, we denote the log-deviation of $X(t)$ from its steady-state value by $\widehat{x}(t) \equiv x(t) - \overline{x}$. The only exceptions are inflation and interest rates: we denote the deviation (not log-deviation) of inflation and interest rates from their steady-state values by $\widehat{\pi}(t) \equiv \pi(t) - \overline{\pi}$, and $\widehat{i_0}(t) \equiv i_0(t) - \overline{i_0}$.

The first equation of the dynamical system describing the equilibrium is the law of motion of the perceived markup, which derives from the inference mechanism (26):

$$\widehat{k^p}(t) = \chi \left[\widehat{\pi}(t) + \widehat{k^p}(t-1)\right]. \tag{58}$$

This equation shows that the perceived markup today tend to be high if inflation is high and if the perceived markup was high in the past. Past beliefs matter because people use them as baseline to form their current beliefs. Inflation matters because people are not able to fully incorporate the effect of inflation on nominal marginal costs.

The second equation is the *dynamic IS equation*, obtained by combining the Euler equation (36) with the monetary-policy rule (33):

$$\alpha\widehat{n}(t) + \mu\widehat{\pi}(t) = \alpha\mathbb{E}_t\left[\widehat{n}(t+1)\right] + \mathbb{E}_t\left[\widehat{\pi}(t+1)\right] - \widehat{i_0}(t) - \widehat{a}(t) + \mathbb{E}_t\left[\widehat{a}(t+1)\right]. \tag{59}$$

Here the dynamic IS equation involves the log-deviation of employment, $\widehat{n}$; but it usually involves the output gap, which is the gap between the actual level of output and the level of output when the markup is at its long-run level (in the New Keynesian model, this is also the level of output when prices are flexible). Using equation (43), we find that the log of output and the log of employment are related by $y(t) = a(t) + \alpha n(t)$. Moreover, when the markup is at its long-run level, employment also is at its long-run level, so that the log of the natural level of output is $y^n(t) = a(t) + \alpha\overline{n}$, where long-run employment $\overline{n}$ is given by (53). Thus, the output gap $y(t)-y^n(t)$ is directly determined by the log-deviation of employment, $\widehat{n}(t)=n(t)-\overline{n}$:

$$y(t)-y^n(t)=\alpha\widehat{n}(t). \tag{60}$$

The output gap is negative whenever employment is below its long-run level.

The last equation is the *short-run Phillips curve*, obtained from the optimal pricing equation (42):

$$(1-\beta\chi)\widehat{k^p}(t)-\Lambda_1\widehat{n}(t)=\beta\chi\mathbb{E}_t\left[\widehat{\pi}(t+1)\right]-\Lambda_2\mathbb{E}_t\left[\widehat{n}(t+1)\right].$$

where

$$\begin{aligned}\Lambda_1 &\equiv (1+\eta)\frac{\varepsilon+(\varepsilon-1)\chi\overline{\Phi}}{(\theta-\overline{\Phi})\chi\overline{\Phi}}\left[1+\frac{(1-\beta)\chi}{1-\beta\chi}\overline{\Phi}\right]\\ \Lambda_2 &\equiv (1+\eta)\beta\frac{\varepsilon+(\varepsilon-1)\overline{\Phi}}{(\theta-\overline{\Phi})\overline{\Phi}}\left[1+\frac{(1-\beta)\chi}{1-\beta\chi}\overline{\Phi}\right].\end{aligned}$$

Using (58), we rewrite the short-run Phillips curve:

$$(1-\beta\chi)\chi\left[\widehat{k^p}(t-1)+\widehat{\pi}(t)\right]-\Lambda_1\widehat{n}(t)=\beta\chi\mathbb{E}_t\left[\widehat{\pi}(t+1)\right]-\Lambda_2\mathbb{E}_t\left[\widehat{n}(t+1)\right]. \tag{61}$$

Just as the long-run Phillips curve relates inflation to employment, the short-run Phillips curve relates inflation and and its expected value to the log-deviation of employment and its expected value. This is an expectation-augmented Phillips curve: it involves not only current inflation and employment but also foward-looking elements: the expectations of inflation and employment. This is typical in modern macroeconomic models, such as the New Keynesian model (see Galí 2008, p. 49). In addition, this Phillips curve also include a backward-looking element: $\widehat{k^p}(t-1)$. This backward-looking elements appears here because customers' perception of marginal costs is backward-looking: the perceived marginal cost is an average of the past perceived marginal cost and the marginal cost that a rational customer would perceive. In a simple New Keynesian model, the Phillips curve does not feature backward-looking elements; but earlier Phillips curves used to have such elements.

Using (58), we can write $\widehat{k^p}(t-1)$ as a function of past inflation:

$$\widehat{k^p}(t)=\sum_{i=0}^{+\infty}\chi^{i+1}\widehat{\pi}(t-i).$$

Combining this result with the expression of the short-run Phillips curve offers an alternative formulation of the Phillips curve that highlights the backward-looking inflation components:

$$(1-\beta\chi)\chi\sum_{i=0}^{+\infty}\chi^{i}\widehat{\pi}(t-i)-\Lambda_1\widehat{n}(t)=\beta\chi\mathbb{E}_t\left[\widehat{\pi}(t+1)\right]-\Lambda_2\mathbb{E}_t\left[\widehat{n}(t+1)\right].$$

Thus, unlike the basic New Keynesian Phillips curve, which is purely forward-looking, the short-run Phillips curve in our model combines backward-looking and forward-looking inflation components. This Phillips curve also differs from that obtained by Mankiw and Reis (2002) in their sticky-information model: their Phillips curve does not involve past inflations (say, $\pi(t-3)$) but past expectations of future inflation (say, $\mathbb{E}_{t-3}\left[\pi(t+1)\right]$).

6. Conclusion

In many contexts, prices are somewhat rigid—they only partially respond to changes in marginal costs. In turn, price rigidity has numerous implications for how shocks propagate in the economy and how policies affect the economy. To explain price rigidity, this paper presents a model of monopolistic pricing in which customers care about the fairness of prices: customers derive more utility from a good priced at a low markup than at a high markup. This assumption is motivated by copious evidence that firms stabilize prices out of fairness for their customers, and that customers are very concerned about fairness and consider a fair price to be a fair markup over marginal cost.

We find that preferences for fairness alone cannot explain price rigidity, however. When marginal costs are observable, or when marginal costs are hidden but customers infer them rationally from prices, prices are flexible: the passthrough of marginal costs into prices is one.

But as soon as we assume that customers care about fairness and underinfer hidden marginal costs from prices, our model generates some price rigidity: the passthrough of marginal costs into prices is strictly less than one. The assumption of underinference is natural since laboratory evidence indicates that people do not usually draw sufficient inference from their observations. The logic for the result is simple. When prices rise following an increase in marginal costs, customers underappreciate the increase in marginal costs and partially misattribute higher prices to higher markups. As they perceive transactions as less fair, the price elasticity of their demand for goods rises, and firms respond by reducing markups. Hence, the passthrough of marginal costs into prices is less than one.

One area where our model of price rigidity could be especially useful is in the study of optimal monetary policy, in both closed and open economy. The vast majority of the macroeconomic models used to study optimal monetary policy rely on the assumption of infrequent pricing from Calvo (1983). The Calvo model of pricing does not provide a theory of price rigidity: it is only a modeling device to introduce price rigidity in macroeconomic models. Nevertheless, Calvo pricing is immensely popular because it offers a tractable way to introduce price rigidity in general equilibrium. There exist models of pricing that are more realistic than the Calvo model; but they have not been nearly as successful because they are much less tractable. Given that the complexity of our model is comparable to that of the Calvo model, and that our microfoundations accord well with evidence collected by survey of firms and customers, it seems that our model could offer a way forward. Building on reasonable microfoundations is especially important to study optimal monetary policy because the choice of microfoundations determines the effects of monetary policy on social welfare in the model; these effects in turn determine the outcome of the policy analysis.

References

Akerlof, George A. 1982. "Labor Contracts as Partial Gift Exchange." *Quarterly Journal of Economics* 97 (4): 543–569.

Akerlof, George A., William T. Dickens, and George L. Perry. 1996. "The Macroeconomics of Low Inflation." *Brookings Papers on Economic Activity* 1996 (1): 1–76.

Akerlof, George A., and Janet L. Yellen. 1990. "The Fair Wage-Effort Hypothesis and Unemployment." *Quarterly Journal of Economics* 105 (2): 255–283.

Alvarez, Luis J., and Ignacio Hernando. 2005. "Price Setting Behaviour of Spanish Firms: Evidence from Survey Data." ECB Working Paper 538.

Amirault, David, Carolyn Kwan, and Gordon Wilkinson. 2006. "Survey of Price-Setting Behaviour of Canadian Companies." Bank of Canada Working Paper 06-35.

Amiti, Mary, Oleg Itskhoki, and Jozef Konings. 2014. "Importers, Exporters, and Exchange Rate Disconnect." *American Economic Review* 104 (7): 1942–1978.

Apel, Mikael, Richard Friberg, and Kerstin Hallsten. 2005. "Microfoundations of Macroeconomic Price Adjustment: Survey Evidence from Swedish Firms." *Journal of Money, Credit and Banking* 37 (2): 313–338.

Atkeson, Andrew, and Ariel Burstein. 2008. "Pricing-to-Market, Trade Costs, and International Relative Prices." *American Economic Review* 98 (5): 1998–2031.

Aucremanne, Luc, and Martine Druant. 2005. "Price-Setting Behaviour in Belgium: What Can Be Learned from an Ad Hoc Survey?." ECB Working Paper 448.

Ball, Laurence, and David Romer. 1990. "Real Rigidities and the Non-Neutrality of Money." *Review of Economic Studies* 57 (2): 183–203.

Benigno, Pierpaolo, and Luca Antonio Ricci. 2011. "The Inflation-Output Trade-Off with Downward Wage Rigidities." *American Economic Review* 101 (4): 1436–1466.

Benzarti, Youssef, and Dorian Carloni. 2016. "Who Really Benefits from Consumption Tax Cuts? Evidence from a Large VAT Reform in France." http://dx.doi.org/10.2139/ssrn.2629380.

Benzarti, Youssef, Dorian Carloni, Jarkko Harju, and Tuomas Kosonen. 2017. "What Goes Up May Not Come Down: Asymmetric Incidence of Value-Added Taxes." http://doriancarloni.weebly.com/uploads/6/1/5/6/61560343/asymmetry_v15.pdf.

Bergin, Paul R., and Robert C. Feenstra. 2001. "Pricing-to-market, staggered contracts, and real exchange rate persistence." *Journal of international Economics* 54 (2): 333–359.

Bieger, Thomas, Isabelle Engeler, and Christian Laesser. 2010. "In What Condition is a Price Increase Perceived as Fair? An Empirical Investigation in the Cable Car Industry." In *20th Annual CAUTHE Conference*, 1–12. Hobart, Tasmania: School of Management, University of Tasmania.

Blinder, Alan S., Elie R. D. Canetti, David E. Lebow, and Jeremy B. Rudd. 1998. *Asking about Prices*. New York: Russell Sage Foundation.

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

Carillo, Juan, and Thomas Palfrey. 2011. "No Trade." *Games and Economic Behavior* 71 (1): 66–87.

Carlsson, Mikael, and Oskar Nordström Skans. 2012. "Evaluating Microfoundations for Aggregate Price Rigidities: Evidence from Matched Firm-Level Data on Product Prices and Unit Labor Cost." *American Economic Review* 102 (4): 1571–1595.

Carlton, Dennis W. 1986. "The Rigidity of Prices." *American Economic Review* 76 (4): 637–658.

Charness, Gary, and Matthew Rabin. 2002. "Understanding Social Preferences with Simple Tests." *Quarterly Journal of Economics* 117 (3): 817–869.

De Loecker, Jan, Pinelopi K. Goldberg, Amit K. Khandelwal, and Nina Pavcnik. 2016. "Prices, Markups and Trade Reform." *Econometrica* 84 (2): 445–510.

Dornbusch, Rudiger. 1985. "Exchange rates and prices." *American Economic Review* 77 (1): 93–107.

Dufwenberg, Martin, Paul Heidhues, Georg Kirchsteiger, Frank Riedel, and Joel Sobel. 2011. "Other-Regarding Preferences in General Equilibrium." *Review of Economic Studies* 78 (2): 613–639.

Eichenbaum, Martin, and Jonas D.M. Fisher. 2007. "Estimating the Frequency of Price Re-Optimization in Calvo-Style Models." *Journal of monetary Economics* 54 (7): 2032–2047.

Esponda, Ignacio, and Emanuel Vespa. 2014. "Hypothetical Thinking and Information Extraction in the Laboratory." *American Economic Journal: Microeconomics* 6 (4): 180–202.

Eyster, Erik, and Matthew Rabin. 2005. "Cursed Equilibrium." *Econometrica* 73 (5): 1623–1672.

Fabiani, Silvia, Martine Druant, Ignacio Hernando, Claudia Kwapil, Bettina Landau, Claire Loupias, Fernando Martins, Thomas Matha, Roberto Sabbatini, Harald Stahl, and Ad Stokman. 2006. "What Firms' Surveys Tell Us about Price-Setting Behavior in the Euro Area." *International Journal of Central Banking* 3 (2): 3–47.

Fehr, Ernst, and S. Gachter. 2000. "Fairness and Retaliation: The Economics of Reciprocity." *Journal of Economic Perspectives* 14 (3): 159–181.

Fehr, Ernst, Lorenz Goette, and Christian Zehnder. 2009. "A Behavioral Account of the Labor Market:

The Role of Fairness Concerns." *Annual Review of Economics* 1 (1): 355–384.

Fehr, Ernst, Alexander Klein, and Klaus M. Schmidt. 2007. "Fairness and Contract Design." *Econometrica* 75 (1): 121–154.

Fehr, Ernst, and Klaus M. Schmidt. 1999. "A Theory of Fairness, Competition, and Cooperation." *Quarterly Journal of Economics* 114 (3): 817–868.

Fraichard, Julien. 2006. "Le Commerce en 2005." http://www.insee.fr/fr/ffc/docs_ffc/ref/comfra06bb.pdf.

Frey, Bruno S., and Werner W. Pommerehne. 1993. "On the Fairness of Pricing—An Empirical Survey Among the General Population." *Journal of Economic Behavior & Organization* 20 (3): 295–307.

Gabaix, Xavier. 2014. "A Sparsity-Based Model of Bounded Rationality." *Quarterly Journal of Economics* 129 (4): 1661–1710.

Gabaix, Xavier. 2016. "A Behavioral New Keynesian Model." NBER Working Paper 22954.

Galí, Jordi. 2008. *Monetary Policy, Inflation, and the Business Cycle*. Princeton, NJ: Princeton University Press.

Gennaioli, Nicola, and Andrei Shleifer. 2010. "What Comes to Mind." *Quarterly Journal of Economics* 125 (4): 1399–1433.

Gielissen, Robert, Chris E. Dutilh, and Johan J. Graafland. 2008. "Perceptions of Price Fairness: An Empirical Research." *Business & Society* 47 (3): 370–389.

Goldberg, Pinelopi K., and Michael M. Knetter. 1997. "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature* 35 (3): 1243–1272.

Goldberg, Pinelopi K., and Frank Verboven. 2001. "The Evolution of Price Dispersion in the European Car Market." *Review of Economic Studies* 68 (4): 811–848.

Gopinath, Gita, and Oleg Itskhoki. 2010. "Frequency of Price Adjustment and Pass-Through." *Quarterly Journal of Economics* 125 (2): 675–727.

Gopinath, Gita, and Roberto Rigobon. 2008. "Sticky Borders." *Quarterly Journal of Economics* 123 (2): 531–575.

Hall, R. L., and C. J. Hitch. 1939. "Price Theory and Business Behaviour." *Oxford Economic Papers* 2: 12–45.

Hall, Simon, Mark Walsh, and Anthony Yates. 2000. "Are UK Companies' Prices Sticky?." *Oxford Economic Papers* 52 (3): 425–446.

Hoeberichts, Marco, and Ad Stokman. 2006. "Pricing Behaviour of Dutch Companies: Main Results from a Survey." ECB Working Paper 607.

Holt, Charles A., and Roger Sherman. 1994. "The Loser's Curse." *American Economic Review* 84 (3): 642–652.

Jehiel, Philippe, and Frédéric Koessler. 2008. "Revisiting Games of Incomplete Information with Analogy-Based Expectations." *Games and Economic Behavior* 62 (2): 533–557.

Jones, Douglas N., and Patrick C. Mann. 2001. "The Fairness Criterion in Public Utility Regulation: Does Fairness Still Matter?" *Journal of Economic Issues* 35 (1): 153–172.

Kachelmeier, Steven J., Stephen T. Limberg, and Michael S. Schadewald. 1991a. "Fairness in Markets: A Laboratory Investigation." *Journal of Economic Psychology* 12 (3): 447–464.

Kachelmeier, Steven J., Stephen T. Limberg, and Michael S. Schadewald. 1991b. "A Laboratory Market Examination of the Consumer Price Response to Information about Producers' Costs and Profits."

Accounting Review 66 (4): 694–717.

Kackmeister, Alan. 2007. “Yesterday’s Bad Times Are Today’s Good Old Times: Retail Price Changes Are More Frequent Today Than in the 1890s.” *Journal of Money, Credit and Banking* 39 (8): 1987–2020.

Kagel, John, and Dan Levin. 2002. *Common Value Auctions and the Winner’s Curse*. Princeton, NJ: Princeton University Press.

Kahneman, Daniel, Jack L. Knetsch, and Richard Thaler. 1986. “Fairness as a Constraint on Profit Seeking: Entitlements in the Market.” *American Economic Review* 76 (4): 728–41.

Kalapurakal, Rosemary, Peter R. Dickson, and Joel E. Urbany. 1991. “Perceived Price Fairness and Dual Entitlement.” In *Advances in Consumer Research*, edited by Rebecca H. Holman and Michael R. Solomon, vol. 18, 788–793. Provo, UT: Association for Consumer Research.

Kaplan, Steven Laurence. 1996. *The Bakers of Paris and the Bread Question: 1700-1755*. Durham, NC: Duke University Press.

Kimball, Miles S. 1995. “The Quantitative Analytics of the Basic Neomonetarist Model.” *Journal of Money, Credit and Banking* 27 (4): 1241–1277.

Klenow, Peter J., and Jonathan L. Willis. 2016. “Real rigidities and nominal price changes.” *Economica* 83 (331): 443–472.

Konow, James. 2001. “Fair and Square: The Four Sides of Distributive Justice.” *Journal of Economic Behavior & Organization* 46 (2): 137–164.

Kosonen, Tuomas. 2015. “More and Cheaper Haircuts after VAT Cut? On the Efficiency and Incidence of Service Sector Consumption Taxes.” *Journal of Public Economics* 131: 87–100.

Kwapil, Claudia, Joseph Baumgartner, and Johann Scharler. 2005. “The Price-Setting Behaviour of Austrian Firms: Some Survey Evidence.” ECB Working Paper 464.

Loupias, Claire, and Roland Ricart. 2004. “Price Setting in France: New Evidence from Survey Data.” ECB Working Paper 448.

Lunnemann, Patrick, and Thomas Y. Matha. 2006. “New Survey Evidence on the Pricing Behavior of Luxembourg Firms.” ECB Working Paper 617.

Mankiw, N. Gregory, and Ricardo Reis. 2002. “Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve.” *Quarterly Journal of Economics* 117 (4): 1295–1328.

Martins, Fernando. 2005. “The Price Setting Behaviour of Portuguese Firms: Evidence From Survey Data.” ECB Working Paper 562.

Maxwell, Sarah. 1995. “What Makes a Price Increase Seem “Fair”?” *Pricing Strategy & Practice* 3 (4): 21–27.

McCallum, Bennett T., and Edward Nelson. 2010. “Money and Inflation: Some Critical Issues.” In *Handbook of Monetary Economics*, edited by Benjamin M. Friedman and Michael Woodford, vol. 3A, chap. 3: Elsevier.

Melitz, Marc J., and Gianmarco I. P. Ottaviano. 2008. “Market Size, Trade, and Productivity.” *Review of Economic Studies* 75 (1): 295–316.

Miller, Judith A. 1999. *Mastering the Market. The State and the Grain Trade in Northern France, 1700–1860*. Cambridge: Cambridge University Press.

Mullainathan, Sendhil, Joshua Schwartzstein, and Andrei Shleifer. 2008. “Coarse Thinking and Persuasion.” *Quarterly Journal of Economics* 123 (2): 577–619.

Nakamura, Emi, and Dawit Zerom. 2010. "Accounting for Incomplete Pass-Through." *Review of Economic Studies* 77 (3): 1192–1230.

Okun, Arthur M. 1975. "Inflation: Its Mechanics and Welfare Costs." *Brookings Papers on Economic Activity* 6 (2): 351–402.

Okun, Arthur M. 1981. *Prices and Quantities: A Macroeconomic Analysis*. Washington, DC: Brookings Institution.

Poterba, James M. 1996. "Retail Price Reactions to Changes in State and Local Sales Taxes." *National Tax Journal* 49 (2): 165–176.

Rabin, Matthew. 1993. "Incorporating Fairness into Game Theory and Economics." *American Economic Review* 83 (5): 1281–1302.

Renner, Elke, and Jean-Robert Tyran. 2004. "Price Rigidity in Customer Markets." *Journal of Economic Behavior & Organization* 55 (4): 575–593.

Rotemberg, Julio J. 2005. "Customer Anger at Price Increases, Changes in the Frequency of Price Adjustment and Monetary Policy." *Journal of Monetary Economics* 52 (4): 829–852.

Rotemberg, Julio J. 2011. "Fair Pricing." *Journal of the European Economic Association* 9 (5): 952–981.

Samuelson, William F., and Max H. Bazerman. 1985. "The Winner's Curse in Bilateral Negotiations." In *Research in Experimental Economics*, edited by Vernon L. Smith, vol. 3, 105–137. Greenwich, CT: JAI Press.

Schmidt, Klaus M. 2011. "Social Preferences and Competition." *Journal of Money, Credit and Banking* 43 (5): 207–231.

Shafir, Eldar, Peter Diamond, and Amos Tversky. 1997. "Money Illusion." *Quarterly Journal of Economics* 112 (2): 341–374.

Shiller, Robert J. 1997. "Why Do People Dislike Inflation?." In *Reducing Inflation: Motivation and Strategy*, edited by Christina D. Romer and David H. Romer, chap. 1. Chicago: University of Chicago Press.

Shiller, Robert J., Maxim Boycko, and Vladimir Korobov. 1991. "Popular Attitudes Towards Free Markets: The Soviet Union and the United States Compared." *American Economic Review* 81 (3): 385–400.

Tobin, James. 1972. "Inflation and Unemployment." *American Economic Review* 62 (1/2): 1–18.

Tversky, Amos, and Daniel Kahneman. 1973. "Availability: A Heuristic for Judging Frequency and Probability." *Cognitive Psychology* 5 (2): 207–232.

Tversky, Amos, and Daniel Kahneman. 1974. "Judgment under Uncertainty: Heuristics and Biases." *Science* 185 (4157): 1124–1131.

Urbany, Joel E., Thomas J. Madden, and Peter R. Dickson. 1989. "All's Not Fair in Pricing: An Initial Look at the Dual Entitlement Principle." *Marketing Letters* 1 (1): 17–25.

Warhaftig, Itamar. 1987. "Consumer Protection: Price and Wage Levels." In *Crossroads: Halacha and the Modern World*, vol. 1, 49–69. Alon Shvut-Gush Etzion, Israel: Zomet Institute.

Weizsäcker, Georg. 2010. "Do We Follow Others when We Should? A Simple Test of Rational Expectations." *American Economic Review* 100 (5): 2340–2360.

Xia, Lan, Kent B. Monroe, and Jennifer L. Cox. 2004. "The Price Is Unfair! A Conceptual Framework of Price Fairness Perceptions." *Journal of Marketing* 68 (4): 1–15.

Zajac, Edward E. 1985. "Perceived Economic Justice: The Example of Public Utility Regulation." In

Cost Allocation: Methods, Principles, Applications, edited by H. Peyton Young, 119–154. Amsterdam: North Holland.

Appendix A. Proofs

Most of the results stated in the paper are directly derived in the main text. Only a few results have not been established in the main text, because their proof is longer. We prove them here.

Proof of Proposition 1

We first derive the expression for the profit-maximizing markup K, given by (16). This expression directly follows from the result that $K = E/(E-1)$ and from the expression (15) for E. Since $K^p(P)$ is strictly increasing in P, $\Phi(K^p)$ is strictly increasing in K^p, and $\chi > 0$, the right-hand side of (16) is strictly decreasing in K; it is also strictly positive for $K \geq 0$. Hence, (16) always has a unique solution, so that K is well-defined and unique.

Next we derive the expression for the marginal-cost passthrough σ. Equation (15) gives the price elasticity of demand as a function of the perceived markup: $E(K^p)$. Thus the profit-maximizing markup is a function of the perceived markup: $K(K^p) = E(K^p)/(E(K^p)-1)$. Finally, (14) gives the perceived markup as a function of the price: $K^p(P)$. The price therefore satisfies $P = K(K^p(P)) \cdot MC$. Taking logs and differentiating, we obtain

$$\sigma = \frac{d\ln(P)}{d\ln(MC)} = 1 + \frac{d\ln(K)}{d\ln(K^p)} \cdot \frac{d\ln(K^p)}{d\ln(P)} \cdot \frac{d\ln(P)}{d\ln(MC)}.$$

Using $d\ln(K^p)/d\ln(P) = \chi$ and $d\ln(P)/d\ln(MC) = \sigma$, we reshuffle the above equation and obtain

$$\sigma = 1 \Bigg/ \left(1 - \chi \frac{d\ln(K)}{d\ln(K^p)}\right). \tag{A1}$$

Using (15) and (3), we obtain the following elasticity:

$$\frac{d\ln(E)}{d\ln(K^p)} = \frac{E-\varepsilon}{E} \cdot \frac{d\ln(\Phi)}{d\ln(K^p)} = \frac{E-\varepsilon}{E}(\theta - \Phi).$$

Since $K(K^p) = E(K^p)/(E(K^p)-1)$, the elasticities of K and E are related:

$$\frac{d\ln(K)}{d\ln(K^p)} = \left(1 - \frac{E}{E-1}\right)\frac{d\ln(E)}{d\ln(K^p)} = -\frac{1}{E-1} \cdot \frac{d\ln(E)}{d\ln(K^p)}.$$

Combining the last two equations yields

$$-\frac{d\ln(K)}{d\ln(K^p)} = \frac{E-\varepsilon}{(E-1)E}(\theta-\Phi) = \frac{\chi\Phi(\theta-\Phi)}{[1+\chi\Phi][\varepsilon+(\varepsilon-1)\chi\Phi]}.$$

Using this last equation and (A1), we obtain (17).

Proof of Lemma 4

The profits V^r if the monopoly reveals its marginal cost are independent of the belief parameters K^b and MC^b since customers do not need to make any inference when the firm reveals its cost.

On the other hand, the belief parameters K^b and MC^b determine the profits V^c if the monopoly conceals its marginal cost. In fact, in any equilibrium in which the firm conceals, the profits can be written as a function of the perceived markup K^p, which acts as a sufficient statistic summarizing the effect of K^b and MC^b on profits. Using (21), we write equilibrium profits as a function of K^p:

$$V^c(K^p) = MC^{1-\varepsilon}\cdot[K^c(K^p)-1]\cdot K^c(K^p)^{-\varepsilon}\cdot F(K^p)^{\varepsilon-1},$$

where

$$K^c(K^p) = 1+\frac{1}{(\varepsilon-1)(1+\chi\Phi(K^p))}.$$

Since $F(K^p)$ is decreasing in K^p and $\varepsilon>1$, then $F(K^p)^{\varepsilon-1}$ is decreasing in K^p.

The function $(K-1)K^{-\varepsilon}$ is increasing in K on $[1,\varepsilon/(\varepsilon-1)]$ and decreasing on $[\varepsilon/(\varepsilon-1),\infty)$. Since $K^c\in(1,\varepsilon/(\varepsilon-1))$, then $(K^c-1)(K^c)^{-\varepsilon}$ is increasing in K^c. Furthermore, since Φ is increasing in K^p, then $K^c(K^p)$ is decreasing in K^p. To conclude, $[K^c(K^p)-1]\cdot K^c(K^p)^{-\varepsilon}$ is decreasing in K^p.

Overall, $V^c(K^p)$ is decreasing in K^p. It has the following limits. When $K^p=0$, $F(0)=2$ and $\Phi(0)=0$ so $K^c(0)=\varepsilon/(\varepsilon-1)$. Since $F(K^r)<2$ and $K^r<\varepsilon/(\varepsilon-1)$, following the same arguments as above, $V^c(0)>V^r$. When $K^p\to\infty$, $F(\infty)=0$ and $\Phi(\infty)=\theta$ so $K^c(\infty)=1+1/[(\varepsilon-1)(1+\theta)]$. Accordingly, $V^c(\infty)=0$ so $V^c(\infty)<V^r$. We infer that there is a threshold K^p_0 such that for any $K^p<K^p_0$, $V^c(K^p)>V^r$, and for any $K^p>K^p_0$, $V^c(K^p)<V^r$.

We now reformulate this result in terms of the underlying belief parameters. Using (14), we write the perceived markup as $K^p(\lambda)=\lambda\cdot P(\lambda)^\chi$ where $\lambda\equiv\left(K^b\right)^{1-\chi}/\left(MC^b\right)^\chi$ and $P(\lambda)$ is implicitly defined by

$$P(\lambda) = K^c(\lambda \cdot P(\lambda)^\chi) \cdot MC.$$

The elasticity of K^p with respect to λ is

$$\frac{d\ln(K^p)}{d\ln(\lambda)} = 1 + \chi \frac{d\ln(P)}{d\ln(\lambda)}.$$

The elasticity of P with respect to λ satisfies

$$\frac{d\ln(P)}{d\ln(\lambda)} = \frac{d\ln(K^c)}{d\ln(K^p)} \left(1 + \chi \frac{d\ln(P)}{d\ln(\lambda)}\right)$$
$$\frac{d\ln(P)}{d\ln(\lambda)} = \frac{\frac{d\ln(K^c)}{d\ln(K^p)}}{1 - \chi \frac{d\ln(K^c)}{d\ln(K^p)}}.$$

Combining these two results, we infer that

$$\frac{d\ln(K^p)}{d\ln(\lambda)} = \frac{1}{1 - \chi \frac{d\ln(K^c)}{d\ln(K^p)}} = \sigma,$$

where we use (A1) to introduce the passthrough σ. Since $\sigma > 0$, $K^p(\lambda)$ is strictly increasing in λ. Furthermore, since K^c is bounded between 1 and $\varepsilon/(\varepsilon - 1)$, then $P(\lambda)$ is bounded between MC and $[\varepsilon/(\varepsilon - 1)] \cdot MC$ for any λ, which implies that $K^p(0) = 0$ and $\lim_{\lambda \to \infty} K^p(\lambda) = \infty$. Accordingly, the mapping $K^p(\lambda)$ is an increasing bijection from $[0, \infty)$ to $[0, \infty)$. This means that we can reformulate the results above in terms of λ instead of K^p.

Proof of Proposition 2

We first compute profits when the firm reveals its cost. Since $K^r = K^f$, $F(K^r) = 1$, and equation (20) implies that profits are

$$V^r = MC^{1-\varepsilon} \cdot (K^r - 1) \cdot (K^r)^{-\varepsilon}.$$

Since $K^r = K^f$, $\Phi(K^r) = \theta/2$, and equation (9) implies that the profit-maximizing markup is

$$K^r = 1 + \frac{1}{(\varepsilon - 1)(1 + \theta/2)}.$$

Following the same logic, and using equations (21) and (16), we can compute the profits and profit-maximizing markup when the firm conceals its cost:

$$V^c = MC^{1-\varepsilon} \cdot (K^c - 1) \cdot (K^c)^{-\varepsilon}$$
$$K^c = 1 + \frac{1}{(\varepsilon - 1)(1 + \chi\theta/2)}.$$

If $\chi = 1$, then $K^c > K^r$ and $V^c = V^r$. But for any $\theta > 0$ and $\chi < 1$, then $K^c > K^r$. Since the function $(K-1)K^{-\varepsilon}$ is strictly increasing in K for $K \in [1, \varepsilon/(\varepsilon-1)]$, the result that $K^c > K^r$ implies that $V^c > V^r$: it is more profitable to conceal marginal costs.

Proof of Proposition 3

Consider that the marginal cost is at some initial value $\overline{MC}$. Customers are acclimated to this marginal cost such that $K^r = K^f = K^p$. We have seen in Proposition 2 that in this situation, it is optimal for the firm to conceal its cost. Hence, $V^c(\overline{MC}) > V^c(\overline{MC})$. We now study what happens when the marginal cost MC departs from the initial value $\overline{MC}$.

We study the ratio of profits V^c/V^r. We have seen that at $MC = \overline{MC}$, $V^c/V^r > 1$. We determine how the ratio evolves when MC departs from $\overline{MC}$. Since V^c is given by equation (21) and V^r by equation (20), we have

$$\frac{V^c}{V^r} = \frac{\gamma(K^c)}{\gamma(K^r)} \cdot \frac{F(K^p)}{F(K^r)}.$$

where $\gamma(K) = (K-1)/K^{\varepsilon}$, K^c satisfies (16), K^p is given by (14), and K^r is given by (9). The auxiliary function $\gamma(K)$ is strictly increasing for $K \in [1, \varepsilon/(\varepsilon-1)]$.

When MC increases, the following happens. First, K^r does not change so $F(K^r)$ and $\gamma(K^r)$ remain unchanged. Second, P also increases because the passthrough of marginal costs into prices (σ) is positive; then, as P increases, K^p increases. Third, the increase in K^p leads $F(K^p)$ to fall. Fourth, the increase in K^p leads $\Phi(K^p)$ to rise, K^c to fall, and $\gamma(K^c)$ to fall. To conclude, when MC increases, V^c/V^r decreases.

A first implication is that for all $MC < \overline{MC}$, then $V^c/V^r > 1$: it remains more profitable to conceal when marginal costs fall.

In addition, when $MC \to \infty$, then $P \to \infty$ (since $P \geq MC$), so $K^p \to \infty$, and $F(K^p) \to 0$.

This implies that when $MC \to \infty$, then $V^c/V^r \to 0$. Since $V^c/V^r > 1$ for $MC = \overline{MC}$, V^c/V^r is strictly decreasing in MC, and $V^c/V^r \to 0$ when $MC \to \infty$, then there is a unique MC_0 such that $V^c/V^r > 1$ for any $MC < MC_0$ and $V^c/V^r < 1$ for any $MC > MC_0$. It is more profitable to reveal if and only if marginal costs are above MC_0.

Proof of Proposition 6

We consider a symmetric steady-state equilibrium. Equation (51), the fact that $K^p(\pi)$ is increasing in π, and the fact that $\Phi(K^p)$ is decreasing in K^p, imply that the goods-market markup is decreasing in inflation. Then, equation (53) implies that employment is increasing in inflation. Next, equation (54) implies that output is increasing in inflation. It follows from these results and (55) that the real wage is increasing in inflation.

The last step is to compute the response of real profits to inflation. To do that, we compute the elasticity of real profits to the goods-market markup. Equation (54) implies that $d\bar{y}/d\bar{n} = \alpha$ and equation (53) implies that $d\bar{n}/d\bar{k} = -1/(1+\eta)$ so $d\bar{y}/d\bar{k} = -\alpha/(1+\eta)$. Equation (56) yields

$$\frac{d(\bar{v}-\bar{p})}{d\bar{k}} = \frac{d\bar{y}}{d\bar{k}} + \frac{\alpha}{K-\alpha},$$

which implies

$$\frac{d(\bar{v}-\bar{p})}{d\bar{k}} = \alpha \cdot \left(\frac{1}{K-\alpha} - \frac{1}{1+\eta}\right). \tag{A2}$$

Hence, $d(\bar{v}-\bar{p})/d\bar{k} > 0$ if and only if $1/(K-\alpha) > 1/(1+\eta)$, which is equivalent to $K < 1+\alpha+\eta$. Higher inflation leads to lower goods-market markup, and when $K < 1+\alpha+\eta$, to lower real profits.

Appendix B. Dynamic General-Equilibrium Model: Derivations

We derive various results pertaining to the dynamic general-equilibrium model of Section 5.

Optimal Pricing

Monopolistic firms set prices to maximize profits. We describe their optimal pricing strategy here. We start by deriving the demand faced by firms. To do that, we analyze the behavior of households.

Household j chooses

$$\left\{W_j(t), N_j(t), \left[Y_{ij}(t)\right]_{i=0}^{1}, B_j(t)\right\}_{t=0}^{\infty}$$

to maximize (27) subject to the budget constraint (28), the labor-demand constraint $N_j(t) = N_j^d(t, W_j(t))$, and a solvency condition. Labor demand $N_j^d(t, W_j(t))$ gives the quantity of labor that firms would hire from household j in period t at a nominal wage $W_j(t)$. The household takes

$$\left\{X(t), [F_i(t)]_{i=0}^{1}, [P_i(t)]_{i=0}^{1}, V_j(t)\right\}_{t=0}^{\infty}$$

as given. To solve household j's problem, we set up the Lagrangian:

$$\begin{aligned}\mathscr{L}_j = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Bigg[& \ln(Z_j(t)) - \frac{N_j(t)^{1+\eta}}{1+\eta} \\ & + \mathscr{A}_j(t) \left\{ W_j(t)N_j(t) + B_j(t-1) + V_j(t) - X(t)B_j(t) - \int_0^1 P_i(t)Y_{ij}(t)di \right\} \\ & + \mathscr{B}_j(t) \left\{ N_j^d(t, W_j(t)) - N_j(t) \right\} \Bigg]\end{aligned}$$

where $\mathscr{A}_j(t)$ is the Lagrange multiplier on the budget constraint in period t and $\mathscr{B}_j(t)$ is the Lagrange multiplier on the labor-demand constraint in period t.

We first compute the first-order conditions with respect to $Y_{ij}(t)$. We know that

$$\begin{aligned}\frac{\partial Z_{ij}}{\partial Y_{ij}} &= F_i \\ \frac{\partial Z_j}{\partial Z_{ij}} &= \left(\frac{Z_{ij}}{Z_j}\right)^{-1/\varepsilon} di.\end{aligned}$$

Hence, the first-order conditions with respect to $Y_{ij}(t)$ are

$$\left(\frac{Z_{ij}(t)}{Z_j(t)}\right)^{-1/\varepsilon} \frac{F_i(t)}{Z_j(t)} = \mathscr{A}_j(t)P_i(t). \tag{A3}$$

Manipulating and integrating the conditions (A3) over $i \in [0,1]$, then using the definitions of Z_j

and Q given by (24) and (25), we obtain

(A4)
$$\mathscr{A}_j(t)Q(t) = \frac{1}{Z_j(t)}.$$

Combining (A3) and (A4), we obtain the optimal consumption of good i for household j:

$$Y_{ij}(t) = \left(\frac{P_i(t)/F_i(t)}{Q(t)}\right)^{-\varepsilon} \frac{Z_j(t)}{F_i(t)}.$$

Integrating the consumption of good i over all households yields the output of good i:

$$Y_i(t) = Z(t) \cdot F\left(\frac{P_i(t)}{MC_i^p(t)}\right)^{\varepsilon-1} \cdot \left(\frac{P_i(t)}{Q(t)}\right)^{-\varepsilon}.$$

Last, substituting $MC_i^p(t)$ by expression (26), we obtain the demand for good i:

$$Y_i^d(t, P_i(t), MC_i^p(t-1)) = Z(t) \cdot F\left(\left[K^b\right]^{1-\chi}\left[\frac{P_i(t)}{e^{\pi^b} \cdot MC_i^p(t-1)}\right]^{\chi}\right)^{\varepsilon-1} \cdot \left(\frac{P_i(t)}{Q(t)}\right)^{-\varepsilon}.$$

The derivatives of the function Y_i^d are

$$-\frac{\partial \ln(Y_i^d)}{\partial \ln(P_i)} = \varepsilon + (\varepsilon-1)\chi\Phi(K_i^p) \equiv E_i(t)$$
$$\frac{\partial \ln(Y_i^d)}{\partial \ln(MC_i^p)} = (\varepsilon-1)\chi\Phi(K_i^p) = E_i(t) - \varepsilon.$$

where Φ is minus the elasticity of F, and is characterized by (3). The variable $E_i(t) > \varepsilon$ is the absolute value of the price elasticity of the demand for good i.

The first-order condition with respect to $B_j(t)$ is

$$X(t)\mathscr{A}_j(t) = \beta\mathbb{E}_t\left[\mathscr{A}_j(t+1)\right].$$

Using equation (A4), we obtain

$$X(t) = \beta\mathbb{E}_t\left[\frac{Q(t)Z_j(t)}{Q(t+1)Z_j(t+1)}\right]$$

Since the wage set by household j depends on firms' demand for its labor, we turn to firms' problems before returning to the household's problem. Firm i chooses

$$\left\{P_i(t), Y_i(t), \left[N_{ij}(t)\right]_{j=0}^{1}\right\}_{t=0}^{\infty}$$

to maximize (31) subject to the production constraint (29), the demand constraint (34), and to the law of motion of beliefs (26). The firm takes

$$\left\{A_i(t), \left[W_j(t)\right]_{j=0}^{1}\right\}_{t=0}^{\infty}$$

as given. To solve firm i's problem, we set up the Lagrangian:

$$\begin{aligned}\mathscr{L}_i = \mathbb{E}_0 \sum_{t=0}^{\infty} \Gamma(t) \Bigg[& P_i(t)Y_i(t) - \int_0^1 W_j(t)N_{ij}(t)dj \\ & + \mathscr{C}_i(t)\left\{Y_i^d(t, P_i(t), MC_i^p(t)) - Y_i(t)\right\} + \mathscr{D}_i(t)\left\{A_i(t)N_i(t)^{\alpha} - Y_i(t)\right\} \\ & + \mathscr{E}_i(t)\left\{\left[e^{\pi^b} \cdot MC_i^p(t-1)\right]^{\chi}\left(\frac{P_i(t)}{K^b}\right)^{1-\chi} - MC_i^p(t)\right\}\Bigg]\end{aligned}$$

where $\mathscr{C}_i(t)$ is the Lagrange multiplier on the demand constraint in period t, $\mathscr{D}_i(t)$ is the Lagrange multiplier on the production constraint in period t, and $\mathscr{E}_i(t)$ is the Lagrange multiplier on the law of motion of the perceived marginal cost in period t.

Using the fact that

$$\frac{\partial N_i(t)}{\partial N_{ij}(t)} = \left(\frac{N_{ij}(t)}{N_i(t)}\right)^{-1/\nu} dj,$$

we find that the first-order conditions with respect to $N_{ij}(t)$ for all j are

$$W_j(t) = \alpha \mathscr{D}_i(t)A_i(t)N_i(t)^{\alpha-1}\left(\frac{N_{ij}(t)}{N_i(t)}\right)^{-1/\nu}. \tag{A5}$$

Manipulating and integrating the conditions (A5) over $j \in [0,1]$, then using the definitions of N_i and W given by (30) and (38), we obtain

$$\mathscr{D}_i(t) = \frac{W(t)}{\alpha A_i(t)N_i(t)^{\alpha-1}}. \tag{A6}$$

Combining (A5) and (A6), we obtain the quantity of labor that firm i hires from household j:

$$N_{ij}(t) = \left(\frac{W_j(t)}{W(t)}\right)^{-\nu} N_i(t).$$

Integrating the quantities $N_{ij}(t)$ over all firms i yields the labor demand faced by household j:

$$N_j^d(t, W_j(t)) = \left(\frac{W_j(t)}{W(t)}\right)^{-\nu} N(t).$$

Having determined the demand for labor service j, we finish solving the problem of household j. The first-order conditions with respect to $N_j(t)$ and $W_j(t)$ are

$$\begin{aligned} N_j(t)^\eta &= \mathscr{A}_j(t) W_j(t) - \mathscr{B}_j(t) \\ \mathscr{A}_j(t) N_j(t) &= -\mathscr{B}_j(t) \frac{dN_j^d}{dW_j}. \end{aligned}$$

Combining these conditions, and using the fact that the elasticity of $N_j^d(t, W_j)$ with respect to W_j is $-\nu$, we find that

$$\begin{aligned} \mathscr{B}_j(t) &= \frac{N_j(t)^\eta}{\nu - 1} \\ W_j(t) &= \frac{\nu}{\nu - 1} \cdot \frac{N_j(t)^\eta}{\mathscr{A}_j(t)}. \end{aligned}$$

Using (A4), we find that household j sets its wage according to

$$\frac{W_j(t)}{Q(t)} = \frac{\nu}{\nu - 1} N_j(t)^\eta Z_j(t).$$

Next, we finish solving the problem of firm i. The first-order condition with respect to $Y_i(t)$ yields $P_i(t) = \mathscr{C}_i(t) + \mathscr{D}_i(t)$. Using (A6), we obtain

$$\mathscr{C}_i(t) = P_i(t) \left(1 - \frac{W(t)/P_i(t)}{A_i(t) \alpha N_i(t)^{\alpha - 1}}\right).$$

Firm i's nominal marginal cost is

$$MC_i(t) = \frac{W(t)}{A_i(t) \alpha N_i(t)^{\alpha - 1}}. \tag{A7}$$

Hence, the first-order condition implies

$$\mathscr{C}_i(t) = P_i(t)\left(1 - \frac{MC_i(t)}{P_i(t)}\right).$$

With the quasi elasticity $D_i(t) = K_i(t)/(K_i(t)-1)$, we rewrite the first-order condition as

$$\mathscr{C}_i(t) = \frac{P_i(t)}{D_i(t)}. \tag{A8}$$

The first-order condition with respect to $P_i(t)$ is

$$0 = Y_i(t) + \mathscr{C}_i(t)\frac{\partial Y_i^d}{\partial P_i(t)} + (1-\chi)\mathscr{E}_i(t)\frac{MC_i^p(t)}{P_i(t)},$$

which implies

$$0 = 1 - \frac{\mathscr{C}_i(t)}{P_i(t)}E_i(t) + (1-\chi)\frac{\mathscr{E}_i(t)}{Y_i(t)K_i^p(t)}.$$

Combining this equation (A8) yields

$$\frac{E_i(t)}{D_i(t)} - 1 = (1-\chi)\frac{\mathscr{E}_i(t)}{Y_i(t)K_i^p(t)}. \tag{A9}$$

Finally, the first-order condition with respect to $MC_i^p(t)$ is

$$0 = \mathbb{E}_t\left[\frac{\Gamma(t+1)}{\Gamma(t)}\mathscr{C}_i(t+1)\frac{\partial Y_i^d}{\partial MC_i^p}\right] + \chi\mathbb{E}_t\left[\frac{\Gamma(t+1)}{\Gamma(t)}\mathscr{E}_i(t+1)\frac{MC_i^p(t+1)}{MC_i^p(t)}\right] - \mathscr{E}_i(t).$$

Multiplying this equation by $MC_i^p(t)/P_i(t)$, we get

$$0 = \mathbb{E}_t\left[\frac{\Gamma(t+1)}{\Gamma(t)P_i(t)}\mathscr{C}_i(t+1)Y_i(t+1)(E_i(t+1)-\varepsilon) + \chi\frac{\Gamma(t+1)}{\Gamma(t)P_i(t)}\mathscr{E}_i(t+1)MC_i^p(t+1)\right] - \mathscr{E}_i(t)\frac{MC_i^p(t)}{P_i(t)}.$$

We now focus on a symmetric equilibrium, where $P_i(t) = P(t)$, $Z(t) = F(t)Y(t)$, and $Q(t) = P(t)/F(t)$. Using the definition of $\Gamma(t)$, given by (32), we find that in such equilibrium,

$$\frac{\Gamma(t+1)}{\Gamma(t)P_i(t)} = \beta\frac{Q(t)}{Q(t+1)P(t)}\cdot\frac{Z(t)}{Z(t+1)} = \frac{\beta}{P(t+1)}\cdot\frac{Y(t)}{Y(t+1)}.$$

Hence, the equation becomes

$$0=\beta\mathbb{E}_t\left[\mathscr{C}(t+1)\frac{Y(t)}{P(t+1)}(E(t+1)-\varepsilon)+\chi\mathscr{E}(t+1)\frac{Y(t)}{Y(t+1)}\cdot\frac{MC^p(t+1)}{P(t+1)}\right]-\mathscr{E}(t)\frac{MC^p(t)}{P(t)}.$$

Using (A8) and $K^p(t)=P(t)/MC^p(t)$, and dividing by $Y(t)$, we now obtain

$$0=\beta\mathbb{E}_t\left[\frac{E(t+1)-\varepsilon}{D(t+1)}+\chi\frac{\mathscr{E}(t+1)}{Y(t+1)K^p(t+1)}\right]-\frac{\mathscr{E}(t)}{Y(t)K^p(t)}.$$

Finally, multiplying by $1-\chi$ and using (A9), we get

$$0=\beta\mathbb{E}_t\left[(1-\chi)\frac{E(t+1)-\varepsilon}{D(t+1)}+\chi\frac{E(t+1)}{D(t+1)}-\chi\right]-\frac{E(t)}{D(t)}+1.$$

Rearranging the terms, we finally obtain

$$\beta\mathbb{E}_t\left[\frac{E(t+1)-(1-\chi)\varepsilon}{D(t+1)}\right]=\frac{E(t)}{D(t)}-(1-\chi\beta).$$

This forward-looking equation gives the quasi elasticity $D(t)$ and thus the optimal markup $K(t)$.

Log-Linear Equilibrium Conditions

We log-linearize the equilibrium conditions. These log-linear equations are first-order approximations that are accurate as long as the economy is close to the steady-state equilibrium.

First, we log-linearize the Euler equation (36):

$$y(t)=\mathbb{E}_t\left[y(t+1)\right]-\left(i(t)-\mathbb{E}_t\left[\pi(t+1)\right]-\rho\right).$$

Combining this log-linear equation with the monetary-policy rule (33) yields

$$y(t)=\mathbb{E}_t\left[y(t+1)\right]+\mathbb{E}_t\left[\pi(t+1)\right]-\mu\pi(t)+(\rho-i_0(t)),$$

In steady state, $\rho-\overline{i_0}=\mu\overline{\pi}-\overline{\pi}$ (see equation (48)). Subtracting $\overline{y}$ on both sides of the equation, and substracting $\rho-\overline{i_0}+\overline{\pi}-\mu\overline{\pi}$ on the right-hand side, we rewrite the equation as

(A10) $$\widehat{y}(t)+\mu\widehat{\pi}(t)=\mathbb{E}_t\left[\widehat{y}(t+1)\right]+\mathbb{E}_t\left[\widehat{\pi}(t+1)\right]-\widehat{i_0}(t).$$

Then we log-linearize equation (45):

$$\widehat{k}(t) = -(1+\eta)\widehat{n}(t). \tag{A11}$$

We also log-linearize equation (43):

$$\widehat{y}(t) = \widehat{a}(t) + \alpha\widehat{n}(t). \tag{A12}$$

Combining (A11) and (A12), we finally obtain

$$\widehat{y}(t) = \widehat{a}(t) - \frac{\alpha}{1+\eta}\widehat{k}(t). \tag{A13}$$

This equation shows that the fluctuations of output are driven both by the exogenous fluctuations of technology and the endogenous fluctuations of the goods-market markup. Combining the equation with (A10) yields

$$-\frac{\alpha}{1+\eta}\widehat{k}(t) + \mu\widehat{\pi}(t) = -\frac{\alpha}{1+\eta}\mathbb{E}_t\left[\widehat{k}(t+1)\right] + \mathbb{E}_t\left[\widehat{\pi}(t+1)\right] - \widehat{i_0}(t) - \widehat{a}(t) + \mathbb{E}_t\left[\widehat{a}(t+1)\right].$$

Next, we take logs of (26). In a symmetric equilibrium, we find that

$$mc^p(t) = -(1-\chi)k^b + \chi\pi^b + (1-\chi)p(t) + \chi mc^p(t-1).$$

Since $k^p(t) = p(t) - mc^p(t)$ and $p(t) = p(t-1) + \pi(t)$, the law of motion of $k^p(t)$ is

$$k^p(t) = (1-\chi)k^b + \chi\left[(\pi(t) - \pi^b) + k^p(t-1)\right]. \tag{A14}$$

In steady state, $(1-\chi)\overline{k^p} = (1-\chi)k^b + \chi\left(\overline{\pi} - \pi^b\right)$. Subtracting this equation from (A14) yields

$$\widehat{k^p}(t) = \chi\left[\widehat{\pi}(t) + \widehat{k^p}(t-1)\right]. \tag{A15}$$

The next step is to log-linearize the expression for the price elasticity of demand: $E(t) =$

$\varepsilon + (\varepsilon - 1)\chi\Phi(K^p(t))$. In log-linear form, we obtain

$$\widehat{e}(t) = \frac{\overline{E} - \varepsilon}{\overline{E}} \cdot \frac{d\ln(\Phi)}{d\ln(K^p)} \widehat{k^p}(t).$$

Furthermore, the elasticity of Φ with respect to K^p is

$$\frac{d\ln(\Phi)}{d\ln(K^p)} = \theta - \Phi. \tag{A16}$$

Thus, we have $\widehat{e}(t) = \Omega_0 \widehat{k^p}(t)$ where

$$\Omega_0 = \frac{\overline{E} - \varepsilon}{\overline{E}} \left(\theta - \overline{\Phi}\right) = \frac{(\varepsilon - 1)\chi\overline{\Phi}}{\varepsilon + (\varepsilon - 1)\chi\overline{\Phi}} (\theta - \overline{\Phi}).$$

Next, $D = K/(K-1)$, so in log-linear form, $\widehat{d}(t) = -\Omega_1 \widehat{k}(t)$, where

$$\Omega_1 = \overline{D} - 1 = (\varepsilon - 1)\left[1 + \frac{(1-\beta)\chi}{1 - \beta\chi} \overline{\Phi}\right].$$

Finally, we log-linearize (42):

$$\widehat{e}(t) - \widehat{d}(t) = \Omega_3 \mathbb{E}_t \left[\widehat{e}(t+1)\right] - \Omega_2 \mathbb{E}_t \left[\widehat{d}(t+1)\right],$$

where

$$\Omega_3 = \left[\frac{\overline{E} - (1 - \chi\beta)\overline{D}}{\overline{E}}\right] \left[\frac{\overline{E}}{\overline{E} - (1-\chi)\varepsilon}\right] = \beta$$
$$\Omega_2 = \frac{\overline{E} - (1 - \chi\beta)\overline{D}}{\overline{E}} = \beta\chi \cdot \frac{\varepsilon + (\varepsilon - 1)\overline{\Phi}}{\varepsilon + (\varepsilon - 1)\chi\overline{\Phi}}$$

Combining these results, we obtain

$$\Omega_0 \widehat{k^p}(t) + \Omega_1 \widehat{k}(t) = \beta\Omega_0 \mathbb{E}_t \left[\widehat{k^p}(t+1)\right] + \Omega_1\Omega_2 \mathbb{E}_t \left[\widehat{k}(t+1)\right],$$

which can be rewritten, using (A15), as

$$(1 - \beta\chi)\widehat{k^p}(t) + \frac{\Omega_1}{\Omega_0} \widehat{k}(t) = \beta\chi \mathbb{E}_t \left[\widehat{\pi}(t+1)\right] + \frac{\Omega_1\Omega_2}{\Omega_0} \mathbb{E}_t \left[\widehat{k}(t+1)\right].$$

After some algebra, this equation takes a simpler form:

$$(1-\beta\chi)\widehat{k^p}(t)+\Lambda_1\widehat{k}(t)=\beta\chi\mathbb{E}_t\left[\widehat{\pi}(t+1)\right]+\Lambda_2\mathbb{E}_t\left[\widehat{k}(t+1)\right].$$

where

$$\Lambda_1=\frac{\Omega_1}{\Omega_0}=\frac{\varepsilon+(\varepsilon-1)\chi\overline{\Phi}}{(\theta-\overline{\Phi})\chi\overline{\Phi}}\left[1+\frac{(1-\beta)\chi}{1-\beta\chi}\overline{\Phi}\right]$$

$$\Lambda_2=\frac{\Omega_1\Omega_2}{\Omega_0}=\beta\frac{\varepsilon+(\varepsilon-1)\overline{\Phi}}{(\theta-\overline{\Phi})\overline{\Phi}}\left[1+\frac{(1-\beta)\chi}{1-\beta\chi}\overline{\Phi}\right].$$