This paper proposes a theory of pricing consistent with two well-documented patterns: customers care about fairness, and firms take these concerns into account when they set prices. The theory assumes that customers find a price unfair when it carries a high markup over cost, and that customers dislike unfair prices. Since markups are not observable, customers must extract them from prices. The theory assumes that customers infer less than rationally: when a price rises after an increase in marginal cost, customers partially misattribute the higher price to a higher markup—which they find unfair. Firms anticipate this response and trim their price increases, which reduces the passthrough of marginal costs into prices below one: prices are somewhat rigid. Embedded in a New Keynesian model—as a replacement of Calvo pricing—our theory produces monetary nonneutrality. When monetary policy loosens and inflation rises, customers misperceive markups as higher and feel unfairly treated; firms mitigate the perceived unfairness of prices by reducing their markups, which in general equilibrium leads to higher output.
1. Introduction

Empirical evidence suggests that prices are somewhat rigid: neither are they exactly fixed, nor do they fully respond to shocks. Price rigidity is important, as it determines the effects of taxes, of tariffs and exchange-rate movements, of changes in wages and commodity prices, and of monetary policy. Empirical evidence also suggests that firms show restraint when setting prices to avoid alienating customers, who balk at paying prices that they regard as unfair. Numerous models have been developed to explain price rigidity; but these models almost never include fairness considerations.\(^1\) This paper aims to develop a theory of pricing that organizes the facts better: the theory incorporates the concerns for fairness observed among firms and their customers; and it uses them to generate the price rigidity observed in the data.

The first element of our theory is that customers dislike paying prices marked up heavily over marginal costs because they find these prices unfair, and that firms understand this. This assumption draws upon evidence from numerous surveys of consumers and firms, our own survey of French bakers, and religious and legal texts (section 2). We formalize this assumption by weighting each unit of consumption in the utility function by a fairness factor that is high if the good consumed is purchased through a transaction perceived to be fair, and low if it is purchased through a transaction perceived to be unfair. The fairness factor is a function of the markup that customers perceive firms to charge for the good: it is decreasing in the perceived markup (since higher markups seem less fair) and concave (since people tend to respond more strongly to increases in markups than to decreases).

Because customers do not observe firms’ marginal costs but need them to assess the markup charged by firms, customers’ perceptions of fairness depend upon their estimates of marginal costs. The second element of our theory is that customers update their beliefs about firms’ marginal costs less than rationally: they form beliefs that lie somewhere between their prior beliefs and rational beliefs. This assumption draws upon evidence that during inflationary periods people seem to underinfer increases in nominal costs, and more generally that people tend to infer less than they should about others’ private information from others’ actions (also section 2).

We begin our analysis by embedding these psychological elements into a model of monopoly pricing (section 3). For the monopoly, the profit-maximizing price features a markup over marginal cost. This markup is a decreasing function of the price elasticity of demand. We assume a standard utility function such that if customers did not care about fairness, the price elasticity of

\(^1\) Fairness has received more attention in other contexts: Akerlof (1982), Akerlof and Yellen (1990), and Benjamin (2015) add fairness to labor-market models; Rabin (1993), Fehr and Schmidt (1999), and Charness and Rabin (2002) to game-theoretic models; and Fehr, Klein, and Schmidt (2007) to contract-theoretic models. For surveys of the economic literature on fairness, see Fehr and Gachter (2000), Sobel (2005), and Fehr, Goette, and Zehnder (2009).
demand would be constant, and the monopoly’s markup would be constant. With such constant markup, prices would be flexible: they would move proportionally to marginal costs. If customers care about fairness but rationally invert price to uncover the hidden marginal cost, the same pricing rule is an equilibrium. The reason is that when price increases by \( x \)%, customers infer that marginal cost has increased by \( x \)%, and therefore that the markup has not changed. Since the price change does not change the perceived markup, the price elasticity of demand does not change, and neither does the markup.

Once fairness concerns and misinference are combined, however, pricing changes. First, fairness concerns and misinference lead the monopoly to reduce its markup. Indeed, under these assumptions, demand decreases in price not only due through the standard channel, but also through a fairness channel. When customers see a higher price, they attribute it partially to a higher marginal cost and partially to a higher markup—which they find unfair. Thus the higher price lowers their marginal utility of consumption and further decreases demand. This renders demand more elastic than it would be otherwise, leading the monopoly to set a lower markup.

Second, fairness concerns and misinference give rise to price rigidity. After an increase in price spurred by higher marginal cost, customers underappreciate the increase in marginal cost and partially misattribute higher prices to higher markup. Since the fairness factor is decreasing and concave in the perceived markup, it is more elastic at higher perceived markups. This property translates to the demand curve, which is more price elastic at higher perceived markups. Hence, after the cost increase, the monopoly chooses to reduce its markup. As a result, the price increases less than proportionally to the underlying marginal cost: the passthrough of marginal costs into prices falls short of one. This mild form of price rigidity is consistent with the response of prices to marginal-cost shocks estimated in several empirical studies.

Theories of price rigidity are a key input into macroeconomic models. To illustrate how our theory can be embedded into such a model, and develop its implications, we substitute it for Calvo (1983) pricing in a New Keynesian model (section 4). In this dynamic model, customers form beliefs about current marginal costs by averaging their past beliefs with rational inference from current prices. The model yields three realistic properties. First, monetary policy is nonneutral: it affects output and employment. This property arises through the same channel as in the monopoly model: expansionary monetary policy increases prices and nominal marginal costs; customers partially misattribute higher prices to higher markups, which they perceive as unfair; as a result, the price elasticities of the goods demands rise; firms respond by reducing markups, thus stimulating the economy. Second, the Phillips curve is hybrid: it links current employment not only to current and expected future inflation but also to past inflation. This property emerges because beliefs about marginal costs are backward-looking, forcing firms to account for both
future and past inflation when they set prices. Third, when we calibrate the parameters that
govern fairness concerns and misinference to match evidence on passthrough, simulating the
model yields reasonable impulse responses to monetary-policy shocks. In particular, the impulse
responses of output and employment are hump-shaped.

Our macroeconomic model is also consistent with survey evidence that inflation angers
people—who attribute it to the greed of businesses—and that people appreciate deflation. In our
model, when there is inflation, people partially misattribute higher prices to higher markups, so
they find transactions less fair, which reduces their utility. By symmetry, deflation leads people to
believe that markups are lower and transactions more fair, which raises their utility.

Related literature. The finding that fairness concerns lead to price rigidity is reminiscent of
the result obtained by Rotemberg (2005). He assumes that customers care about firms’ altruism,
which they re-evaluate following every price change. Customers buy a normal amount from a
firm unless they can reject the hypothesis that the firm is altruistic, in which case they withhold
all demand in order to lower the firm’s profits. Firms react to the discontinuity in demand
by refraining from passing on small cost increases, creating price stickiness. We depart 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 obtain closed-form expressions for the markup and
passthrough, and to embed our pricing theory into a macroeconomic model.

In fact, our approach to fairness differs from the popular social-preference approach, developed
by Rabin (1993) and Fehr and Schmidt (1999), and used by Rotemberg. The social-preference
approach models people as caring about one another’s material payoffs, whether positively or
negatively. Then, a consumer who feels unfairly treated by a firm might withhold demand to
hurt the firm’s profits. In our model, by contrast, because customers simply do not savor unfairly
priced goods, they withhold demand irrespective of whether it harms the firm. An advantage of
our approach, which appears clearly in our macroeconomic application, is that fairness continues
to matter in general equilibrium. This is not the case with many social preferences: when people’s
utility can be written as a separable function of their own and other people’s allocations, social
preferences do not affect general-equilibrium prices or allocations (Dufwenberg et al. 2011; Sobel
2007). For example, consider a model in which consumers disdain profit-making, but have
preferences over their own consumption goods that do not vary with the level of profits. As much
as a consumer might dislike that a firm earns high profits, she can do little to prevent it in a large

Rotemberg (2011) further explores the implications of fairness for pricing, focusing on other phenomena such as
price discrimination.
market—where prices and others’ allocations are taken as given. Therefore, consumers have no incentive to distort their consumption away from that affordable bundle which maximizes their preferences over their own consumption.

Finally, our assumption of misinference shares some similarities with models of failure of contingent thinking. The game-theoretic concepts of cursed equilibrium developed by Eyster and Rabin (2005) and analogy-based expectations developed by Jehiel and Koessler (2008) propose mechanisms through which people may fail to account for the information that equilibrium prices reveal about 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 price changes reflect changes in cost and those where they reflect changes in markup. The misinference could also 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 might also embody a form of the availability heuristic documented by Tversky and Kahneman (1973): 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. 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).

2. **Empirical evidence supporting the assumptions**

This section presents microevidence in support of the assumptions underlying our theory. First, we show that people care about the fairness of prices, and that they assess a price to be fair when it carries a low markup over marginal cost. Second, we document that people misinfer marginal costs from prices and thus systematically misperceive markups. Finally, we show that firms account for customers’ fairness concerns when they set prices.

2.1. **Customers’ concern for fairness**

Our theory assumes that people deem a price to be fair when it entails a low markup over marginal costs. Here we review evidence supporting this assumption.

**Price increases due to higher demand.** Our assumption implies that people will find price increases unjustified by cost increases to be unfair. In a survey of Canadian residents, Kahneman, Knetsch, and Thaler (1986, p. 729) document 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.” Among 107 respondents, only 18% regard this pricing as acceptable, whereas 82% regard it as unfair.

Subsequent studies confirm and refine Kahneman, Knetsch, and Thaler’s results. For example, in a survey of 1,750 households in Switzerland and Germany, Frey and Pommerehne (1993, pp. 297–298) confirm that customers dislike a price increase that involves an increase in markup; so too do Shiller, Boycko, and Korobov (1991, p. 389) in a comparative survey of 391 respondents in Russia and 361 in the United States.

One concern about the snow-shovel evidence is that people may find the price increase unfair simply because it occurs during a period of hardship. To address this question, Maxwell (1995) asks 72 students at a Florida university about price increases following an ordinary increase in demand as well as those following a hardship-driven increase in demand. While more find price increases in the hardship environment unfair (86% versus 69%), a substantial majority in each case perceive the price increase as unfair.

**Price increases due to higher costs.** Conversely, our fairness assumption suggests that customers tolerate price increases following cost increases so long as the markup remains constant. Kahneman, Knetsch, and Thaler (1986, pp. 732–733) also identify this pattern: “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.” Among 101 respondents, 79% regard the pricing as acceptable, and only 21% find it unfair. In a survey of 307 Dutch individuals, Gielissen, Dutilh, and Graafland (2008, table 2) also find that price increases following cost increases are fair, while those following demand increases are not.

**Price decreases allowed by lower costs.** Our assumption equally implies that it is unfair for firms not to pass along cost decreases. Kahneman, Knetsch, and Thaler (1986, p. 734) find milder support for this reaction. 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, despite the elevated markup.

Subsequent studies, however, find that people do expect the price to fall after a cost reduction. Kalapurakal, Dickson, and Urbany (1991) conduct 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, in survey of US respondents, Konow (2001, table 6) finds that if a factory that sells a table at $150 locates a supplier charging $20 less for materials, the new fair price is $138, well below $150.

**Norms about markups.** Religious and legal texts written over the ages display a long history of norms regarding markups—which suggests that people deeply care about markups. For example, Talmudic law specifies that the highest fair and allowable markup when trading essential items is 20% of the production cost, or one-sixth of the final price (Friedman 1984, p. 198).

Another example comes from 18th-century France, where local authorities fixed bread prices by publishing “fair” prices in official decrees. In the city of Rouen, for instance, the official bread prices took the costs of grain, rent, milling, wood, and labor into account, and granted a “modest profit” to the baker (Miller 1999, p. 36). Thus, officials 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 the cost of bread and the rationale for any price rise into minute detail (https://perma.cc/GQ28-sJMFC).

Two more examples come from regulation in the United States. First, return-on-cost regulation for public utilities—which limits the markups charged by utilities—has been justified not only on efficiency grounds but also on fairness grounds (for example, Zajac 1985; Jones and Mann 2001). Second, most US states have anti-price-gouging legislation that limits the prices that firms can charge in periods of upheaval (for example, a hurricane). But by exempting price increases justified by higher costs, this legislation only outlaws price increases caused by higher markups (Rotemberg 2009, pp. 74–77).

**Fairness and willingness to pay.** Finally, we assume that customers who purchase a good at an unfair price derive less utility from consuming it; as a result, unfair pricing reduces customers’ willingness to pay. Substantial evidence documents that unfair prices make customers angry, and more generally that unfair outcomes trigger feelings of anger (Rotemberg 2009, pp. 60–64). A small body of evidence suggests that customers indeed reduce purchases when they feel
unfairly treated. In a telephone survey of 40 US consumers, Urbany, Madden, and Dickson (1989) explore—by looking at a 25-cent ATM surcharge—whether a price increase justified by a cost increase is perceived as more fair than an unjustified one, and whether fairness perceptions affect customers’ propensity to buy. While 58% of respondents judge the introduction of the surcharge fair when justified by a cost increase, only 29% judge it fair when not justified (table 1, panel B). Moreover, those people who find the surcharge unfair are indeed more likely to switch banks (52% versus 35%, see table 1, panel C). Similarly, Piron and Fernandez (1995) present survey and laboratory evidence that customers who find a firm’s actions unfair tend to reduce their purchases with that firm.

2.2. Misinference of marginal costs

Customers do not observe firms’ marginal costs. Consequently, their perception of the fairness of firms’ prices depends upon their estimates of marginal costs. If all customers in our model were rational, and firms understood this, then firms would set prices proportional to marginal cost, and consumers would rationally infer marginal costs proportional to price. We introduce two substantive departures from that rational benchmark. First, consumers underinfer marginal cost from price: they form beliefs that depend upon some anchor, which may be their prior expectation of marginal cost. Second, insofar as consumers do update their beliefs about marginal cost from price, they engage in a form of proportional thinking by estimating marginal costs that are proportional to price. We dub this pair of assumptions subproportional inference. We now review evidence in support of these assumptions.

Underinference in general. Numerous experimental studies establish that people underinfer other people’s information from those other people’s actions. Samuelson and Bazerman (1985), Holt and Sherman (1994), Carillo and Palfrey (2011), and others provide evidence in the context of bilateral bargaining with asymmetric information that bargainers underappreciate the 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 meta-study of social-learning experiments, Weizsacker (2010) finds that subjects behave as if they underinfer their predecessors’ private information from their actions. In a voting experiment, Esponda and Vespa (2014) show that people underinfer others’ private information from their votes. Subproportional inference includes such underinference.

Underinference about prices. Shafir, Diamond, and Tversky (1997) report survey evidence that points at underinference in the context of pricing. They presented 362 people in New Jersey
with the following thought experiment: “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: 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 then before (p. 355). Our model makes this prediction. While consumers who update subproportionally recognize that higher prices signal higher marginal costs, they stop short of rational inference. Consequently, consumers perceive markups to be higher when prices are higher. These consumers deem today’s transaction less fair, so they have a lower willingness to pay for the armchair.

A survey conducted by Shiller (1997) confirms that when consumers see higher prices, they systematically believe that markups are higher. Among 120 respondents in the United States, 85% 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 perceived culprits are “manufacturers,” “store owners,” and “businesses,” whose transgressions include “greed” and “corporate profits” (p. 25). In the presence of higher prices, many people indeed infer that firms have increased their profit margins, which angers them.

**Underinference about inflation and deflation.** In our model, customers dislike inflation because it leads them to perceive higher markups; symmetrically, they enjoy deflation because it leads them to perceive lower markups. An opinion poll conducted by the Bank of Japan between 2001 and 2017 paints this pattern (table 1). During this period, Japan alternated between inflation and deflation. Yet people held diametrically opposed views toward inflation and deflation. Of the 18,000 respondents who perceived a decrease in the price of the goods they purchased, 43% saw it as a favorable development, while 22% saw it as an unfavorable development; but of the 68,000 respondents who perceived a price increase, only 3% saw it as a favorable development, while 84% saw it as an unfavorable development.

**Proportional thinking.** Finally, a small body of evidence documents that people think proportionally, even in settings that do not call for proportional thinking. Thaler (1980) and Tversky and Kahneman (1981) demonstrate that people’s willingness to invest time in lowering the price of a good by a fixed dollar amount depends negatively upon the good’s price; rather than care about
Opinions about price movements in Japan, 2001–2017

Table 1. Opinions about perceived price change

<table>
<thead>
<tr>
<th>Perceived price change</th>
<th>Number of respondents</th>
<th>Opinion about perceived price change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prices have gone down</td>
<td>18,257</td>
<td>Favorable 43.0% Neutral 34.2% Unfavorable 21.9%</td>
</tr>
<tr>
<td>Prices have gone up</td>
<td>68,491</td>
<td>Favorable 2.5% Neutral 13.0% Unfavorable 83.7%</td>
</tr>
</tbody>
</table>

Data come from the 60 waves of the Opinion Survey on the General Public’s Mindset and Behavior conducted by the Bank of Japan between September 2001 and December 2017. Although the survey is administered since 1993, survey results are available online only since 2001; the table is based on these online results. The survey was conducted nearly every quarter with a random sample of 4,000 adults living in Japan. The average response rate was 57.2%. Respondents answered the following question: “How do you think prices (defined as overall prices of goods and services you purchase) have changed compared with one year ago?” (question 10, 11, 12, or 13, depending on the survey). Respondents who answered “prices have gone down significantly” or “prices have gone down slightly” are described on the first row of the table. Respondents who answered “prices have gone up significantly” or “prices have gone up slightly” are described on the second row of the table. The rest of the respondents, who answered “prices have remained almost unchanged,” do not feature in the table. Those who answered that prices had gone down then answered “How would you describe your opinion of the price decline?” (question 10, 11, 12, 13, or 15, depending on the survey). The third column gives the share of those respondents who answered “rather favorable,” the fourth column the share who answered “neither favorable nor unfavorable,” and the fifth column the share who answered “rather unfavorable.” Those who answered that prices had gone up then answered “How would you describe your opinion of the price rise?” (question 10, 11, 12, or 13, depending on the survey, and only after June 2004). The third, fourth, and fifth column give the share of those respondents who answered “rather favorable,” “neither favorable nor unfavorable,” and “rather unfavorable.” Detailed survey results are available at http://www.boj.or.jp/en/research/o_survey/index.htm/.

In our model, in response to their customers’ concern for fairness, firms pay great attention to fairness when setting prices. This seems to hold true in the real world: firms identify fairness to be a major concern in price-setting.

2.3 Firms’ concern for fairness

In our model, in response to their customers’ concern for fairness, firms pay great attention to fairness when setting prices. This seems to hold true in the real world: firms identify fairness to be a major concern in price-setting.

Surveys of firms. Following Blinder et al. (1998), researchers have surveyed more than 12,000 firms across developed economies about their pricing practices (table 2). The typical study asks managers to evaluate the relevance of different pricing theories from the economics literature to explain their own pricing, in particular price rigidity. Amongst the theories that the managers deem most important, some version of fairness invariably appears, often called “implicit contracts” and described as follows: “firms tacitly agree to stabilize prices, perhaps out of fairness to customers.” Indeed, fairness appeals to firms more than any other theory, with a median rank of 1 and a mean
Table 2. Description of firm surveys about pricing

<table>
<thead>
<tr>
<th>Survey</th>
<th>Country</th>
<th>Period</th>
<th>Number of firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apel, Friberg, and Hallsten (2005)</td>
<td>Sweden (SE)</td>
<td>2000</td>
<td>626</td>
</tr>
<tr>
<td>Kwapil, Baumgartner, and Scharler (2005)</td>
<td>Austria (AT)</td>
<td>2004</td>
<td>873</td>
</tr>
<tr>
<td>Aucremanne and Druant (2005)</td>
<td>Belgium (BE)</td>
<td>2004</td>
<td>1,979</td>
</tr>
<tr>
<td>Lunnemann and Matha (2006)</td>
<td>Luxembourg (LU)</td>
<td>2004</td>
<td>367</td>
</tr>
<tr>
<td>Hoeberichts and Stokman (2006)</td>
<td>Netherlands (NL)</td>
<td>2004</td>
<td>1,246</td>
</tr>
<tr>
<td>Martins (2005)</td>
<td>Portugal (PT)</td>
<td>2004</td>
<td>1,370</td>
</tr>
<tr>
<td>Alvarez and Hernando (2005)</td>
<td>Spain (ES)</td>
<td>2004</td>
<td>2,008</td>
</tr>
<tr>
<td>Olafsson, Petursdottir, and Vignisdottir (2011)</td>
<td>Iceland (IS)</td>
<td>2008</td>
<td>262</td>
</tr>
</tbody>
</table>

rank of 1.9 (table 3). The second most popular explanation for price rigidity takes the form of nominal contracts—prices do not change because they are fixed by contracts: it has a median rank of 3 and a mean rank of 2.6. Two common macroeconomic theories of price rigidity—menu costs and information delays—do not resonate at all with firms, who rank them amongst the least popular theories, with mean and median ranks above 9.

Firms also understand that customers bristle at unfair markups. According to Blinder et al. (1998, pp. 153–157), 64% of firms say that customers do not tolerate price increases after demand increases, while 71% of firms say that customers do tolerate price increase after cost increases. Firms seem to agree that the norm for fair pricing revolves around a constant markup over marginal cost. 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 in discussions with business people that “empirically, the typical standard of fairness involves cost-oriented pricing with a markup.”

Survey of French bakers. 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.\(^3\) We sampled bakeries in cities and villages around Grenoble,
Survey respondents 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 as follows (with wording varying 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); chart 14 in Nakagawa, Hattori, and Takagawa (2000); table 8 in Amirault, Kwan, and Wilkinson (2006); table 5 in Kwapiil, 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); table 5 in Alvarez and Hernando (2005); chart 26 in Langbraaten, Nordbo, and Wulfsberg (2008); and table 17 in Olafsson, Petursdottir, and Vignisdottir (2011).

<table>
<thead>
<tr>
<th>Theory</th>
<th>US</th>
<th>GB</th>
<th>SE</th>
<th>JP</th>
<th>CA</th>
<th>AT</th>
<th>BE</th>
<th>FR</th>
<th>LU</th>
<th>NL</th>
<th>PT</th>
<th>ES</th>
<th>NO</th>
<th>IS</th>
<th>Median</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implicit contracts</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Nominal contracts</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Coordination failure</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>9</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3.5</td>
<td></td>
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**Table 3. Ranking of pricing theories in firm surveys**
Aix-en-Provence, Paimpol, and Paris. Overall, the interviews show that bakers are guided by norms of fairness when they adjust prices in order to preserve customer loyalty. In particular, cost-based pricing is widely used. Bakers raise the price of bread only in response to increases in the cost of flour (generally at the end of harvest in September), utilities, or wages. Bakers also refuse to increase prices in response to increased demand. Several bakers explained that they do not 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) because it would be unfair—and hence anger and drive away customers.

3. Monopoly model

We extend a simple model of monopoly pricing to include fairness concerns and subproportional inference, along the lines described in section 2. In this extended model, the markup charged by the monopoly is lower. Furthermore, the markup responds to marginal-cost shocks, generating some price rigidity: prices are not completely fixed, but they respond less than one-for-one to marginal costs. Last, we allow the monopoly to credibly disclose its cost, and we study how it sets its price and strategically reveals information about cost.

3.1. Assumptions

A monopoly sells a good to a representative customer. The monopoly cannot price-discriminate, so each unit of the good sells at the same price $P$. The customer cares about fairness and appraises transactional fairness by assessing the markup charged by the monopoly. Since the customer does not observe the marginal cost of production, she needs to infer it from the price. We assume that the perceived marginal cost is given by a belief function $MC^P(P)$. For simplicity, we restrict $MC^P(P)$ to be deterministic. Having inferred the marginal cost, the customer deduces that the markup charged by the monopoly is

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

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 of 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).
The perceived markup determines the fairness of the transaction through a fairness function \( F(K^p) > 0 \). The functions \( MC^p(P) \) and \( F(K^p) \) are both assumed to be continuously differentiable.

A customer who buys \( Y \) at price \( P \) experiences the fairness-adjusted consumption

\[
Z = F(K^p(P)) \times Y,
\]

which enters a quasilinear utility function:

\[
\frac{\epsilon}{\epsilon - 1} Z^{(\epsilon-1)/\epsilon} + M.
\]

The variable \( M \) designates money balances, and the parameter \( \epsilon > 1 \) governs the concavity of the utility function. The customer also faces a budget constraint:

\[
M + P \times Y = I,
\]

where \( I > 0 \) is income.\(^4\) Then, given \( F \) and \( P \), the customer chooses \( M \) and \( Y \) to maximize utility subject to the budget constraint.

Finally, the monopoly has constant marginal cost \( MC > 0 \). It chooses \( P \) and \( Y \) to maximize profits \((P - MC) \times Y\) subject to customers’ demand for its good.

### 3.2. Behavior of customers and monopoly

First, we determine customers’ demand for the monopoly good. The customer chooses \( Y \) to maximize

\[
\frac{\epsilon}{\epsilon - 1} (F \times Y)^{(\epsilon-1)/\epsilon} + I - P \times Y.
\]

The first-order condition is

\[
F^{(\epsilon-1)/\epsilon} \times Y^{-1/\epsilon} = P,
\]

which yields the demand curve

\[(1) \quad Y^d(P) = \frac{P^{-\epsilon}}{F(K^p(P))^{\epsilon-1}}.\]

The price affects demand through two channels: the typical substitution effect, captured by \( P^{-\epsilon} \); and the fairness channel, captured by \( F(K^p(P))^{\epsilon-1} \). The fairness channel appears because the price influences the perceived markup and thus the fairness of the transaction, which in turn

\(^4\)In this static setup, money balances allow customers to spend their income on something else than the monopoly’s output; in the dynamic setup of section 4, customers instead save part of their income in government bonds.
affects the marginal utility of consumption and consequently demand.

Then we determine the optimal price for the monopoly. The monopoly chooses $P$ to maximize $(P - MC) \times Y^d(P)$. The first-order condition is

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

The price elasticity of demand, normalized to be positive, is

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

The first-order condition then yields

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

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

To learn more about the monopoly’s markup, we compute the elasticity $E$. Using (1), we find

$$E = \epsilon + (\epsilon - 1) \phi \left[ 1 - \frac{d \ln(MC^p)}{d \ln(P)} \right],$$

where $\phi = -d \ln(F)/d \ln(K^p)$ is the elasticity of the fairness function with respect to the perceived markup, normalized to be positive. The first term, $\epsilon$, describes the standard substitution effect. The second term, $(\epsilon - 1) \phi \left[ 1 - d \ln(MC^p)/d \ln(P) \right]$, represents the fairness channel and splits into two subterms. The first subterm, $(\epsilon - 1) \phi$, appears because a higher price mechanically raises the perceived markup and thus reduces fairness. The second subterm, $-(\epsilon - 1) \phi \left[ d \ln(MC^p)/d \ln(P) \right]$, appears because a higher price conveys information about the marginal cost and thus influences perceived markup and fairness. We now use (3) to compute the monopoly’s markup in various situations.

### 3.3. No fairness concerns

Before studying the more realistic case with fairness concerns, we examine the benchmark case in which customers do not care about fairness.

**Definition 1.** Customers who do not care about fairness have a fairness function $F(K^p) = 1$.

Without fairness concerns, the fairness function is constant, so its elasticity is $\phi = 0$. According to (3), the price elasticity of demand is therefore constant, equal to $\epsilon$. This implies that the optimal
markup for the monopoly takes a standard value of \( \varepsilon/(\varepsilon - 1) \).

Since the markup is independent of marginal cost, changes in marginal cost are fully passed through into the price; that is, prices are flexible. Formally, the marginal-cost passthrough is

\[
\sigma = \frac{d \ln(P)}{d \ln(MC)},
\]

which measures the percentage change in price when the marginal cost increases by one percent. The passthrough takes the value of one because \( P = \varepsilon MC/(\varepsilon - 1) \).

The following lemma summarizes the monopoly’s pricing:

**Lemma 1.** When customers do not care about fairness, irrespective of the beliefs \( MC^p(P) \), the monopoly sets the markup to \( K = \varepsilon/(\varepsilon - 1) \), and the marginal-cost passthrough is \( \sigma = 1 \).

### 3.4. Rational inference

Next, we analyze another benchmark case in which customers care about fairness but rationally invert the price to uncover the hidden marginal cost. In this case, the model takes the form of a simple signaling game in which the monopoly learns its marginal cost and chooses a price, before customers observe the monopoly’s price—but not its marginal cost—and formulate demand. Let \([0, MC^h] \subset \mathbb{R}_+\) be the set of all possible marginal costs for the monopoly. The monopoly knows its marginal cost \( MC \in [0, MC^h] \), but customers do not; instead, customers have non-atomistic prior beliefs over \([0, MC^h] \).

We look for a perfect Bayesian equilibrium (PBE) of this game having the property that the monopoly chooses different prices for different marginal costs, which allows a rational customer who knows the monopoly’s equilibrium strategy and observes the price to deduce marginal cost (separating equilibrium). A PBE comprises three elements: a pure strategy for the monopolist, which is a mapping \( P : [0, MC^h] \to \mathbb{R}_+ \) that selects a price for every possible value of marginal cost; a belief function for customers, which is a mapping \( MC^p : \mathbb{R}_+ \to [0, MC^h] \) that determines a marginal cost for every possible price; and a pure strategy for customers, which is a mapping \( Y^d : \mathbb{R}_+ \to \mathbb{R}_+ \) that selects a quantity purchased for every possible price. We now show that there exists a PBE in which the monopolist’s strategy is \( P(MC) = \varepsilon MC/(\varepsilon - 1) \); customers’ belief function is \( MC^p(P) = (\varepsilon - 1)P/\varepsilon \) if

\[
P \in \mathcal{P} \equiv \left[ 0, \frac{\varepsilon}{\varepsilon - 1}MC^h \right],
\]

and \( MC^p(P) = 0 \) otherwise; and customers’ strategy is \( Y^d(P) = P^{\varepsilon} F(P/MC^p(P))^{\varepsilon - 1} \). In such PBE, customers correctly infer marginal costs from prices on the equilibrium path \( P \in \mathcal{P} \), and
they infer the worst when they observe a price off the equilibrium path ($P \notin \mathcal{P}$)—namely that the firm has zero marginal cost and thus infinitely high markup.

The argument proceeds in three steps. First, given their beliefs, customers’ strategy is indeed optimal, as we have showed in (1). Second, given the monopolist’s strategy, customers’ beliefs are indeed correct for any price on the equilibrium path. Third, given customers’ beliefs and strategy, the monopolist’s strategy is optimal. Indeed, given customers’ beliefs for $P \in \mathcal{P}$, we have $d \ln(MC^p)/d \ln(P) = 1$. Then, according to (3) (which is implied by customers’ strategy), the price elasticity of demand for any price on $\mathcal{P}$ is $E = \varepsilon$. Hence, (2) implies that it is optimal for the monopolist to charge a price $P = \varepsilon MC/(\varepsilon - 1)$. It remains to show that the monopoly has no incentive to deviate from the equilibrium markup $\varepsilon/(\varepsilon - 1)$, regardless of its marginal cost.

The following lemma records the findings:

**Lemma 2.** When customers rationally infer marginal costs, irrespective of the fairness function, there is a PBE in which the monopoly uses the markup $K = \varepsilon/(\varepsilon - 1)$, and customers learn marginal cost from price. In this PBE, the marginal-cost passthrough is $\sigma = 1$. Hence, in this PBE, the markup and passthrough are the same as without fairness concerns.

The lemma shows that if customers care about fairness but rationally infer marginal costs, fairness does not necessarily play a role. The intuition is the following. Without fairness concerns, the price affects demand only by changing customers’ budget sets. With fairness concerns, the price affects demand through a second channel, by changing the perceived markup. In this equilibrium, however, after observing any price chosen by the monopoly, rational customers perceive the same markup $\varepsilon/(\varepsilon - 1)$. The second channel closes, so the monopoly indeed sets the standard markup $\varepsilon/(\varepsilon - 1)$. Since the markup does not depend on marginal cost, changes in marginal cost are fully passed through into prices—prices are flexible again.

Actually, fairness continues to play no role if instead of inferring rationally, customers infer proportionally: they perceive a marginal cost $MC^p(P) = P/K^p$, with a wrong value of $K^p$. Here too, since $d \ln(MC^p)/d \ln(P) = 1$, equation (3) indicates that the price elasticity of demand is $\varepsilon$. Therefore the monopoly sets the standard markup of $\varepsilon/(\varepsilon - 1)$.

### 3.5. Fairness concerns and subproportional inference

We turn to the case in which customers care about fairness and misinfer markups from prices.
Definitions. To describe this case, we impose some structure on the fairness and belief functions.

Definition 2. Customers who care about fairness have a fairness function $F(K_p)$ that is positive, strictly decreasing, and weakly concave on $[0, K^h]$, where $F(K^h) = 0$ and $K^h > \epsilon/(\epsilon - 1)$.

The assumption that the fairness function strictly decreases in the perceived markup captures the pattern that customers find higher markups less fair and derive displeasure from unfair transactions. The assumption that the fairness function is weakly concave means that an increase in perceived markup causes a utility loss of equal magnitude (if $F$ is linear) or of greater magnitude (if $F$ is strictly concave) than the utility gain caused by an equal-sized decrease in perceived markup. We have not found direct evidence on this assumption, but it seems natural that people are at least as outraged over a price increase as they are happy about a price decrease of the same magnitude. These assumptions lead to the following properties:

Lemma 3. When customers care about fairness, the elasticity of the fairness function,

$$\phi(K_p) = -\frac{d \ln(F)}{d \ln(K_p)}$$

is strictly positive and strictly increasing on $(0, K^h)$, with $\lim_{K_p \to 0} \phi(K_p) = 0$ and $\lim_{K_p \to K^h} \phi(K_p) = +\infty$. As an implication, the superelasticity of the fairness function,

$$\chi = \frac{d \ln(\phi)}{d \ln(K_p)},$$

is strictly positive on $(0, K^h)$.

Proof. By definition, $\phi(K_p) = -K_p F'(K_p)/F(K_p)$. Using the properties of the fairness function listed in definition 2, $F(K_p) > 0$ and $F'(K_p) < 0$, so $\phi(K_p) > 0$. The properties also indicate that $F > 0$ is decreasing in $K_p$, and that $F' < 0$ is decreasing in $K_p$ (as $F$ is concave in $K_p$). Thus, both $1/F > 0$ and $-F' > 0$ are increasing in $K_p$, which implies that $\phi$ is strictly increasing in $K_p$. Finally, the properties indicate that $F(K^h) = 0$ while $K^h > 0$ and $F'(K^h) < 0$, so that $\lim_{K_p \to K^h} \phi(K_p) = +\infty$. The result about $\chi$ follows immediately, since $\chi = K_p \phi'(K_p)/\phi(K_p)$, $\phi'(K_p) > 0$, and $\phi(K_p) > 0$.

A key property in the lemma is that the superelasticity of the fairness function is positive—meaning that the fairness function is more elastic at higher perceived markups. This property directly follows from the assumptions in definition 2 as a positive, decreasing, and linear function always has positive superelasticity; this is even truer if the function is concave instead of linear. This property will play an important role because it will render the monopoly’s demand curve more price elastic at higher prices.
DEFINITION 3. Customers who update subproportionally use the belief-updating rule

\[ MC^p(P) = \left( MC^b \right)^{\gamma} \left( \frac{\epsilon - 1}{\epsilon} P \right)^{1-\gamma}, \]

where

\[ MC^b > \frac{\epsilon - 1}{\epsilon} \left( K^h \right)^{-1/\gamma} MC, \]

is a prior point belief about marginal cost, and \( \gamma \in (0, 1] \) governs the extent to which beliefs anchor on that prior belief.

We have seen that people do not sufficiently introspect about the relationship between price and marginal cost, which leads them to underinfer the information conveyed by the price, and that they tend to think proportionally. The inference rule (4) geometrically averages underinference with proportional inference, so it encompasses these two types of error.

First, customers underinfer marginal costs from price by clinging to their prior belief \( MC^b \). The parameter \( \gamma \in (0, 1] \) measures the degree of such underinference. When \( \gamma = 1 \), customers do not update at all about marginal cost based on price; they naively maintain their prior belief \( MC^b \), irrespective of the price they observe. When \( \gamma \in (0, 1) \), customers do infer something from the price, but not enough.

Moreover, insofar as they infer something, they infer that marginal cost is proportional to price, given by \( (\epsilon - 1)P/\epsilon \). Such proportional inference represents a second error: underinference pertains to how much customers infer, whereas proportional inference describes what customers infer in as much as they do infer. The updating rule has the property that in the limit as \( \gamma = 0 \), customers infer rationally. Indeed, when \( \gamma = 0 \), the monopoly optimally sets the markup \( \epsilon/(\epsilon - 1) \), which makes \( (\epsilon - 1)P/\epsilon \) the marginal cost at price \( P \), and proportional inference agrees with rational inference. When \( \gamma \in (0, 1) \), however, the monopoly does not find it optimal to mark up proportionally, and proportional inference becomes an error.\(^5\)

\(^5\)Eyster, Rabin, and Vayanos (2019) propose an alternative to rational-expectations equilibrium in which traders underinfer one another’s private information from market prices. In a “cursed expectation equilibrium” of a static model in which traders endowed with private information trade a risky asset, each trader forms an expectation about the value of the asset equal to a geometric average of her expectation conditional upon her private signal alone and her expectation conditional upon both her private signal and the market price. Traders’ expectations therefore take the form of a weighted average of “naive beliefs” and correct beliefs. The updating rule in this paper has one important difference and one important similarity to that solution concept. The two rules differ to the extent that consumers in our model average naive beliefs with a particular form of incorrect beliefs (proportional inference); in order to include rational updating as a limit case, we calibrate the updating rule to match correct equilibrium beliefs for the case in which all consumers are rational. We adopt this approach for its analytic tractability and suspect that the main qualitative results of the paper would go through if people averaged their prior expectation of marginal cost...
Last, we impose (5) such that the perceived markup falls below $K^h$ when the firm prices at marginal cost; this is necessary for the equilibrium to exist.

Plugging the inference rule (4) into $K^p = P/MC^p$, we obtain the following lemma:

**Lemma 4.** When customers update subproportionally, they perceive the monopoly’s markup to be

$$K^p(P) = \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\gamma} \left( \frac{P}{MC^b} \right)^{\gamma},$$

which is an increasing function of the observed price $P$.

Customers appreciate that higher prices signal higher marginal costs. But by underappreciating the strength of the relationship between price and marginal cost, customers partially misattribute higher prices to higher markups. Consequently, they regard higher prices as less fair. As the functions $K^p(P)$ and $F(K^p)$ are differentiable, customers enjoy an infinitesimal price reduction as much as they dislike an infinitesimal price increase; therefore, the monopoly’s demand curve has no kinks, unlike in pricing theories based on loss aversion (Heidhues and Koszegi 2008).

**Results.** Combining (3) and (4), we find that the price elasticity of demand satisfies

$$E = \epsilon + (\epsilon - 1)\gamma \phi(K^p).$$

We have seen that without fairness concerns ($\phi = 0$), or with rational inference ($\gamma = 0$), the price elasticity of demand is constant, equal to $\epsilon$. That result changes here. Since $\gamma > 0$, the price elasticity of demand (7) is always greater than $\epsilon$. Moreover, since $\phi(K^p)$ is increasing in $K^p$ and $K^p(P)$ in $P$, the price elasticity of demand is increasing in $P$. These properties have implications for the markup charged by the monopoly.

**Proposition 1.** When customers care about fairness and update subproportionally, the monopoly’s markup is implicitly defined by

$$K = 1 + \frac{1}{\epsilon - 1} \cdot \frac{1}{1 + \gamma \phi(K^p(K \times MC))},$$

which implies that $K \in (1, \epsilon/((\epsilon - 1)))$. Furthermore, the marginal-cost passthrough is given by

$$\sigma = 1 \left\{ 1 + \frac{\gamma^2 \phi \chi}{(1 + \gamma \phi) [\epsilon + (\epsilon - 1)\gamma \phi]} \right\},$$

with rational expectations about marginal cost. The two rules share the similarity that neither one lends itself to interpretation as someone’s beliefs given a simple wrong theory of how other people’s actions depend upon their private information.
which implies that $\sigma \in (0, 1)$. Hence, the markup is lower than without fairness concerns or with rational inference; and unlike without fairness concerns or with rational inference, the marginal-cost passthrough is incomplete.

The proof appears in appendix A, but the intuition is simple. First, when customers care about fairness but underinfer marginal costs, they become more price-sensitive. Indeed, an increase in the price increases the opportunity cost of consumption—as in the case without fairness—and also increases the perceived markup, which reduces the marginal utility of consumption and therefore demand. This heightened price-sensitivity raises the price elasticity of demand above $\epsilon$ and pushes the markup below $\epsilon/(\epsilon - 1)$.

Second, after an increase in marginal cost, the monopoly optimally lowers its markup. This occurs because customers underappreciate the increase in marginal cost that accompanies a higher price. Since the perceived markup increases, the price elasticity of demand increases. In response, the monopoly reduces its markup, which mitigates the price increase. Thus, our model generates incomplete passthrough of marginal cost into price—a mild form of price rigidity. Furthermore, customers err in believing that transactions are less fair when the marginal cost increases: transactions actually become more fair.

**Comparison with empirical evidence.** The result that prices do not fully respond to marginal-cost shocks accords with empirical evidence. First, using matched data on product-level prices and producers’ unit labor cost for Sweden, Carlsson and Skans (2012) find a moderate passthrough of idiosyncratic marginal-cost changes into prices: about 0.3. Second, using production data for Indian manufacturing firms, De Loecker et al. (2016, table 7) find that following trade liberalization in India, marginal costs fell significantly due to the import tariff liberalization, yet prices failed to fall in step: they estimate passthroughs between 0.3 and 0.4. Third, using production and cost data for Mexican manufacturing firms, Caselli, Chatterjee, and Woodland (2017, table 7) also find a moderate passthrough of idiosyncratic marginal-cost changes into prices: between 0.2 and 0.4.

**Comparison with the literature.** In our model, price rigidity arises from a nonconstant price elasticity of demand, which creates variations in markups after shocks. In that respect, our model shares similarities to other models in which a variable price elasticity leads to price rigidity. In international economics, these models have long been used to explain the behavior of exchange rates and prices (for example, Dornbusch 1985; Bergin and Feenstra 2001; Atkeson and Burstein 2008). In macroeconomics, such models have been used to create real rigidities—in the sense of Ball and Romer (1990)—that amplify nominal rigidities (for example, Kimball 1995; Dotsey and
King 2005; Eichenbaum and Fisher 2007). Whereas many of these models make reduced-form assumptions (in the utility function or the demand curve) to generate a nonconstant price elasticity of demand, our model provides a microfoundation for this property.

**Additional comparative statics.** To obtain further results, we introduce a simple fairness function that satisfies all the requirements from definition 2:

\[
F(K^p) = 1 - \xi \times \left( K^p - \frac{\epsilon}{\epsilon - 1} \right),
\]

where \( \xi > 0 \) governs the intensity of fairness concerns. A higher \( \xi \) means that a consumer grows more upset when consuming an overpriced item and more content when consuming an underpriced item. The fairness function reaches 1 when the perceived markup equals \( \epsilon / (\epsilon - 1) \), the no-fairness markup; then fairness-adjusted consumption coincides with consumption. When the perceived markup exceeds \( \epsilon / (\epsilon - 1) \), the fairness function falls below one; and when the perceived markup lies below \( \epsilon / (\epsilon - 1) \), the fairness function surpasses one.

Furthermore, to compare different industries or economies, we focus on a situation in which customers have acclimated to prices by coming to judge firms’ equilibrium markups as acceptable: \( MC^b \) adjusts so \( K^p = \epsilon / (\epsilon - 1) \) and \( F = 1 \). Acclimation is likely to occur eventually within any industry or economy, once customers have faced the same prices for a long time.\(^6\) We then obtain:

**Corollary 1.** Assume that customers care about fairness according to the fairness function (10), infer subproportionally, and are acclimated. Then the monopoly’s markup is given by

\[
K = 1 + \frac{1}{(1 + \gamma \xi) \epsilon - 1}.
\]

The markup decreases with the competitiveness of the market (\( \epsilon \)), concern for fairness (\( \xi \)), and degree of underinference (\( \gamma \)). And the marginal-cost passthrough is given by

\[
\sigma = 1 \left\{ 1 + \frac{\gamma^2 \xi [(1 + \xi) \epsilon - 1]}{(\epsilon - 1)(1 + \gamma \xi)[(1 + \gamma \xi) \epsilon - 1]} \right\}.
\]

The passthrough increases with the competitiveness of the market, but decreases with the concern for fairness and degree of underinference.

The proof only involves algebra so it is relegated to appendix A. The corollary shows that

---

\(^6\)As noted by Kahneman, Knetsch, and Thaler (1986, p. 730), “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.”
the passthrough is higher in more-competitive markets.\textsuperscript{7} This property echoes the finding by Carlton (1986) that prices are less rigid in less-concentrated industries. It is also consistent with the finding by Amiti, Itskhoki, and Konings (2014) that firms with higher market power have a lower passthrough of marginal-cost shocks driven by exchange-rate fluctuations.

Another implication of the corollary is that stronger fairness concerns reduce passthroughs. This implies that prices are more rigid in fairness-oriented markets. This property could contribute to explain the finding by Kackmeister (2007) that retail prices were more rigid—they changed less frequently and by smaller amounts—in 1889–1891 than in 1997–1999. Kackmeister emphasizes that the relationship between retailers and customers is much less personal today.\textsuperscript{8} This weakened personal relationship suggests that the retail sector is less fairness-oriented today than in the 19th century, which helps to explain, according to our theory, greater price flexibility today. The property that prices are more rigid in fairness-oriented markets could also contribute to explain the finding by Nakamura and Steinsson (2008, tables 2 and 8) that prices change less frequently and by smaller amounts in the service sector than elsewhere. Indeed, in the service sector, relationships between buyers and sellers are more personal, making fairness concerns more salient.

\textbf{3.6. Disclosure of marginal cost}

We now explore behavior when the monopoly can credibly disclose its marginal cost at the same time as setting its price. We determine whether the firm optimally conceals or discloses, alongside calculating its optimal markup in each case. We denote all variables when the firm discloses costs with a subscript \textit{d}, and all variables when the firm conceals costs with a subscript \textit{c}.

\textbf{Observable marginal cost.} As a preliminary step, we explore pricing when the marginal cost is observable. In this case, customers correctly perceive marginal cost (\(MC^p = MC\)), so the perceived markup equals the true markup (\(K^p = K\)). From (3), we see that the price elasticity of demand is \(E = \epsilon + (\epsilon - 1)\phi(K) > \epsilon\). Using this expression, we obtain the following lemma:

\textbf{Lemma 5.} \textit{When customers care about fairness and observe marginal costs, the markup is}

\textsuperscript{7}Fairness operates by reducing the markup below its standard level \(\epsilon/(\epsilon - 1)\) and toward 1. Thus, as the market becomes perfectly competitive (\(\epsilon \rightarrow \infty\)), the markup necessarily approaches 1, and prices become flexible (as seen in (8) and (9) when \(\epsilon \rightarrow \infty\)).

\textsuperscript{8}Kackmeister (2007, p. 2008) notes that “In 1889–1891 retailing often occurred in small one- or two-person shops, retailers supplied credit to the customers, and retailers usually delivered the purchases to the customer’s home at no extra charge. Today retailing occurs in large stores, a third party supplies credit, and the customer takes his own items home. These changes decrease both the business and personal relationship between the retailer and the customer.”
implicitly defined by

\[(13) \quad K = 1 + \frac{1}{\varepsilon - 1} \cdot \frac{1}{1 + \phi(K)}, \]

implying that \( K \in (1, \varepsilon/(\varepsilon - 1)) \), and the marginal-cost passthrough is \( \sigma = 1 \). Hence, the markup is lower than without fairness concerns, but the passthrough is identical.

Without fairness concerns, the price affects demand solely through customers’ budget sets. With fairness concerns and observable marginal costs, the price also influences the perceived fairness of the transaction: when the price is high relative to marginal cost, customers deem the transaction to be less fair, which reduces the marginal utility from consuming the good and hence demand. Consequently, the monopoly’s demand is more price elastic than without fairness concerns, which forces the monopoly to charge a lower markup.

However, (13) shows that with fairness concerns and observable marginal costs, the markup does not depend on marginal cost, exactly as in the absence of fairness concerns. Since changes in marginal cost do not affect the markup, they are completely passed through into price: prices are flexible.

The lemma predicts that when customers care about fairness but observe costs, the passthrough of marginal costs into prices is one; in contrast, the passthrough is strictly below one when costs are not observed. Renner and Tyran (2004) provide evidence broadly consistent with this result: in a laboratory experiment, they find that price rigidity after a cost shock is much more pronounced when costs are observable than when they are not. Kachelmeier, Limberg, and Schadewald (1991a,b) also find in laboratory experiments that disclosing information on marginal-cost variations hastens the convergence of prices relative to the convergence observed in markets without disclosure.

**Disclosure with rational inference.** Now consider what would happen if the monopolist had the option to credibly disclose its marginal cost. We begin with the benchmark case in which customers infer rationally. Unlike in typical disclosure games, the monopoly has two distinct methods of revealing its marginal cost: directly through disclosure, or indirectly through price. This additional richness does not prevent the full-disclosure result of Milgrom (1981) from holding in our setting:

**Lemma 6.** Assume that customers care about fairness and infer rationally. In every PBE of the disclosure game, the monopoly discloses any marginal cost higher than the lowest possible value, and it sets a markup \( K_d \) given by (13). Hence, \( K_d \in (1, \varepsilon/(\varepsilon - 1)) \), and the marginal-cost passthrough is \( \sigma = 1 \).
The intuition for the proof, which is in appendix A, is as follows. If the monopoly were constrained to charge a fixed price, then all but the lowest-marginal-cost type would reveal by exactly the logic of Milgrom (1981): a firm with a high marginal cost wishes to avoid being confounded with lower-marginal-cost types, because that would increase perceived markup. Flexible prices add a layer of complication to the story, since the higher-marginal-cost type also can provide customers with information through price. However, equilibrium concealment of any marginal cost higher than the lowest possible one would induce lower-marginal-cost types to deviate from equilibrium by mimicking its behavior. Consequently, only the lowest-marginal-cost type can conceal in equilibrium.

**Disclosure with naive inference.** We now turn to the case of interest: customers fail to infer rationally. Here customers can draw inference both from the decision to disclose or not and from the price; it is therefore difficult to describe an inference somewhere in-between the rational inference—based on price and disclosure decision—and the naive inference. To simplify, we assume that customers are fully naive so they do not infer anything from concealment: $\gamma = 1$ in (4), implying that $MC^p = MC^b$. Customers do understand any marginal cost explicitly disclosed, however.

When the firm discloses its marginal cost, the perceived marginal cost $MC^p$ equals the true marginal cost $MC$, so by setting price $P$ the firm earns profits

$$V_d(MC, P) = (P - MC) Y^d(P) = (P - MC) P^e F\left(\frac{P}{MC}\right)^{\epsilon-1}. \tag{14}$$

When the firm conceals its marginal cost, the perceived marginal cost $MC^p$ equals the prior belief $MC^b$, so by setting price $P$ the firm earns profits

$$V_c(MC, P) = (P - MC) Y^d(P) = (P - MC) P^e F\left(\frac{P}{MC^b}\right)^{\epsilon-1}. \tag{15}$$

Since for any $MC$ and $P$, $V_d(MC, P) > V_c(MC, P)$ if and only if $MC > MC^b$, the firm optimally disclose whenever $MC > MC^b$, and conceals when $MC < MC^b$. The markups chosen following disclosure and concealment are given by (13) and (8) with $\gamma = 1$, respectively.

The following proposition states these results:

**Proposition 2.** Assume that customers care about fairness but infer nothing about marginal cost from concealment: $MC^p = MC^b$. The firm optimally conceals for $MC < MC^b$ and discloses for $MC > MC^b$. When concealing, the firm uses the markup $K_c$ given by (8) with $\gamma = 1$. When disclosing, the firm uses the markup $K_d$ given by (13).
The rationale for the proposition is simple. Fixing the firm’s price and marginal cost, its profits increase in its perceived marginal cost. When the firm conceals, its marginal cost is perceived as $MC^b$. A firm that has a marginal cost below this level wishes to conceal, whereas one with a higher marginal cost wishes to disclose.9

Proposition 2 can be interpreted as making a prediction about how a monopoly will respond to a cost shock. Suppose that $MC^b$ is the monopolist’s known marginal cost before it gets hit by a cost shock; the monopolist learns the realization of the shock, but customers do not. Proposition 2 implies that the firm will only disclose an increase in marginal cost, creating a stark asymmetry between cost increases and decreases:

**Corollary 2.** Assume that customers care about fairness but infer nothing about marginal cost from concealment: $MC^p = MC^b$. Suppose that the firm begins with marginal cost $MC^b$, which is known to customers, before being hit by a cost shock that is private information to the firm. Then prices are rigid downward but flexible upward. After a cost decrease, the firm conceals, so the passthrough is given by (9) with $γ = 1$, which is positive but strictly less than 1. After a cost increase, the firm discloses, so the passthrough is exactly 1.

There is evidence consistent corollary 2: while we have never observed a firm advertise a decrease in production costs, we frequently observe firms advertising cost increases. 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 1, panel A, presents examples of firms disclosing their costs in response to a substantial increase in labor costs. The pictures were taken in restaurants in California after the large increases in minimum wage enacted there in 2015–2017. Many businesses responded to the minimum-wage increase by raising prices; many also felt compelled to explain why. Figure 1, panel B, shows that firms go to great lengths to document large increases in the costs of raw material. In one picture, a bakery explains that an increase in wheat price translated into an increase in the price of flour, a key ingredient for bagels. To be more credible, the bakery also displayed next to the sign pictured here a graph from the *New York Times* plotting the prices of wheat over time.

Corollary 2 could also contribute to explain the finding by Peltzman (2000) that prices rise more after cost increases than they fall after cost decreases. Indeed, using US data on 77 consumer goods and 165 producer goods, Peltzman finds that on average, the price response to a cost increase is at least twice the price response to a cost decrease, and the difference lasts at least

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9Eyster and Rabin (2005) apply their game-theoretic equilibrium concept of “cursed equilibrium”, in which each player in a Bayesian game underappreciates the relationship between other players’ actions and those other players’ private information, to a persuasion game. Based upon a similar logic, they identify a cursed equilibrium taking a similar threshold form: “bad types” conceal their types and “good types” reveal.
A. Large increases in minimum wage in California

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

Due to the high demand and inclement weather in the south, the price of avocados has risen dramatically. With the sudden spike in cost we are forced to raise the price of the following, till prices come down.

- Sides of Guacamole
- Chips and Guacamole
- Chips, Guacamole, & Salsa

Thank you from the Tallulah’s Team for understanding and your continued patronage.

B. Large increases in commodity prices

Figure 1. Examples of firms revealing large cost increases

Panel A: pictures taken by Pascal Michailat at restaurants across California between 2015 and 2017: Gregoire Restaurant in Berkeley, CA; Prepkitchen in Del Mar, CA; Juhu Beach Club in Oakland, CA; Temple Coffee in Davis, CA. Panel B: left-side picture taken by Daniel Benjamin at Collegetown Bagels, Ithaca, NY, in 2008; right-side picture taken by Pascal Michailat at Tallulah’s Taqueria, Providence, RI in 2017.
two quarters. The mechanism could also contribute to explain the asymmetric tax passthrough documented by Benzarti et al. (2017). Studying all changes to value-added taxes in Europe between 1996 and 2015, they find that the average price response to a tax increase is at least three times the response to a tax decrease; furthermore, the difference persists for several years.\footnote{From a monopoly’s perspective, a change in value-added tax is equivalent to a change in marginal cost. With a value-added tax \(\tau\), there is a wedge between the post-tax price \(\hat{P}\) and the pretax price \(P = \hat{P}/(1 + \tau)\). The monopoly’s profits are \(Y^d(P)(\hat{P} - MC) = Y^d(P)[P - (1 + \tau)MC]/(1 + \tau)\). Maximizing profits implies maximizing \(Y^d(P)[P - (1 + \tau)MC]\). Hence, with a value-added tax, the monopoly behaves as if there was no tax but the marginal cost was \((1 + \tau)MC\). An change in tax is therefore tantamount to a change in marginal cost.}

4. New Keynesian model

Theories of price rigidity are central to modern macroeconomic models. To explore the macroeconomic implications of the pricing theory developed in section 3, we embed it into a New Keynesian model, thus replacing Calvo pricing. We find that when customers care about fairness and infer subproportionally, the markup charged by firms depends on the rate of inflation. As a result, monetary policy is nonneutral in the short run and in the long run.

4.1. Assumptions

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 save using 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 assume that each firm’s marginal cost is unobservable to households. When a household purchases good \(i\) at price \(P_i(t)\) in period \(t\), it infers that firm \(i\)’s marginal cost is \(MC_i^p(t)\). Unlike in the static model, the dynamic model provides a natural candidate for the anchor that households use to infer marginal costs: last period’s perception of marginal cost. Hence, instead of being given by (4) as in the static model, households’ current perception of firm \(i\)’s marginal cost evolves according to

\[
MC_i^p(t) = \left[MC_i^p(t - 1)\right]^\gamma \left[\frac{\epsilon - 1}{\epsilon} P_i(t)\right]^{1-\gamma},
\]

where \(MC_i^p(t - 1)\) is last period’s perception of the marginal cost.
Having inferred the marginal cost, the household deduces that the markup charged by firm i is $K_i^p(t) = P_i(t)/MC_i^p(t)$. This perceived markup determines the fairness of the transaction with firm i, measured by $F_i(K_i^p(t))$. The fairness function $F_i$, specific to good i, satisfies the conditions listed in definition 2. The elasticity of $F_i$ with respect to $K_i^p$ is $\phi_i = -d \ln(F_i)/d \ln(K_i^p)$.

An amount $Y_{ij}(t)$ of good i bought by household j at a unit price $P_i(t)$ yields a fairness-adjusted consumption $Z_{ij}(t) = F_i(K_i^p(P_i(t))) Y_{ij}(t)$. Household j’s fairness-adjusted consumption of the different goods aggregates into a consumption index

\[
Z_j(t) = \left[ \int_0^1 Z_{ij}(t)(t) \right]^\epsilon/(\epsilon-1),
\]

where $\epsilon > 1$ is the elasticity of substitution between different goods. The price of one unit of the consumption index at time t is given by the price index

\[
X(t) = \left\{ \int_0^1 \left[ \frac{P_i(t)}{F_i(K_i^p(P_i(t)))} \right]^{1-\epsilon} dt \right\}^{1/(1-\epsilon)}.
\]

**Households.** Household j derives utility from consuming goods and disutility from working. Its utility at time 0 is

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left[ \ln(Z_j(t)) - \frac{N_j(t)^{1+\eta}}{1+\eta} \right],
\]

where $E_0$ is expectation conditional on time-0 information, $N_j(t)$ is the amount of labor supplied, $\beta > 0$ is the time discount factor, and $\eta > 0$ is the inverse of the Frisch elasticity of labor supply.

Households also trade one-period bonds. Bonds purchased in period t have a price $Q(t)$, mature in period $t+1$, and pay one unit of money at maturity. In period t, household j holds $B_j(t)$ bonds.

Household j’s budget constraint in period t is

\[
\int_0^1 P_i(t) Y_{ij}(t) dt + Q(t) B_j(t) = W_j(t) N_j(t) + B_j(t-1) + V_j(t),
\]

where $W_j(t)$ is the wage of labor service j and $V_j(t)$ are dividends from ownership of firms. In addition, household j is subject to a solvency constraint preventing Ponzi schemes: for all t, $\lim_{T \to \infty} E_t[B_j(T)] \geq 0$.

Household j maximizes utility (19) by choosing sequences for the wage of labor service j, the
amount of labor service $j$ supplied, the amounts of goods consumed, and the amount of bonds held, $\{W_j(t), N_j(t), [Y_{ij}(t)]_{i=0}^{\infty}, B_j(t)\}_{t=0}^{\infty}$. The maximization is subject to the budget constraint (20), to the solvency condition, and to the constraint imposed by firms’ demand for labor service $j$. The household takes as given its endowment of bonds, $B_j(-1)$, and the sequences for fairness factors, prices, and dividends, $\{[F_i(t)]_{i=0}^{\infty}, Q(t), [P_i(t)]_{i=0}^{\infty}, V_j(t)\}_{t=0}^{\infty}$.

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

$$Y_i(t) = A_i(t)N_i(t)^\alpha,$$

where $Y_i(t)$ 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

$$N_i(t) = \left[\int_0^1 N_{ij}(t)^{(v-1)/v} \, dj\right]^{v/(v-1)}$$

is an employment index. In the employment index, $N_{ij}(t)$ is the quantity of labor service $j$ hired by firm $i$, and $v > 1$ is the elasticity of substitution between different labor services. The price of one unit of the employment index at time $t$ is given by the wage index

$$W(t) = \left[\int_0^1 W_j(t)^{1-v} \, dj\right]^{1/(1-v)}.$$

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, $\{P_i(t), Y_i(t), [N_{ij}(t)]_{j=0}^{\infty}\}_{t=0}^{\infty}$, to maximize the present-discounted value of profits

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

where $\Gamma(t) = \beta^t[X(0)Z(0)]/[X(t)Z(t)]$ is the stochastic discount factor for nominal payoffs in period $t$. The maximization is subject to the production constraint (21), to the demand for good $i$, and to the law of motion of the perceived marginal cost, given by (16). The firm takes as given the initial belief about its marginal cost, $MC^P_i(-1)$, and the sequences for wages and discount factor, $\{[W_j(t)]_{j=0}^{\infty}, \Gamma(t)\}_{t=0}^{\infty}$, and the firm’s profits are rebated to households as dividends.
Monetary policy. We define the inflation rate between $t$ and $t + 1$ as $\pi(t + 1) = \ln(P(t + 1)/P(t))$, the nominal interest between $t$ and $t + 1$ as $i(t) = -\ln(Q(t))$, and the real interest rate as $r(t) = i(t) - \pi(t)$. The nominal interest rate is determined by a simple monetary-policy rule:

\begin{equation}
\tag{25}
i(t) = i_0(t) + \mu \pi(t),
\end{equation}

where $i_0(t)$ is exogenous and possibly stochastic, and $\mu > 0$ determines how the interest rate responds to inflation.

4.2. Behavior of households and firms

We now describe the behavior of households and firms. The derivations are relegated to appendix B. Once this is done, we will characterize a symmetric equilibrium: all households receive the same endowment and dividends; all firms share a common technology and face the same fairness and belief functions. As a result, everybody behaves the same. Since all variables are the same for all households and all firms, we will drop the subscripts $i$ and $j$.

First, each household optimally allocates its consumption expenditure across all goods. Integrating over all households, we obtain the demand for good $i$:

\begin{equation}
\tag{26}
Y^d_i(t, P_i(t), MC_i^p(t - 1)) = Z(t) \left[ \frac{P_i(t)}{X(t)} \right]^{-\epsilon} F_i \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\gamma} \left[ \frac{P_i(t)}{MC_i^p(t - 1)} \right]^{\gamma} Z(t),
\end{equation}

where $Z(t) = \int_0^1 Z_j(t) \, dj$ describes the level of aggregate demand. The equation can be written as $Z_i^d = F_i \times Y_i^d = Z \times [(P_i/F_i)/X]^{-\epsilon}$. As the price of one unit of $Z_i$ is $P_i/F_i$ and the price of one unit of $Z$ is $X$, the relative price of $Z_i$ is $(P_i/F_i)/X$. 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 $-\epsilon$. This is the standard expression for demand curves in this type of models.

Similarly, each firm optimally allocates its wage bill across all labor services. Integrating over all firms, we obtain the usual demand for labor service $j$:

\begin{equation}
\tag{27}
N^d_j(t, W_j(t)) = N(t) \left[ \frac{W_j(t)}{W(t)} \right]^{-\nu},
\end{equation}

where $N(t) = \int_0^1 N_i(t) \, di$ is aggregate employment.

Then, given labor demand (27), household $j$ optimally sets its wage. In a symmetric equilibrium,
the optimal wage is given by

\begin{equation}
W(t) = \frac{v}{v - 1} P(t) N(t) Y(t).
\end{equation}

As usual, the household sets its real wage at a markup of \(v/(v - 1) > 1\) over its marginal rate of substitution between leisure and consumption.

Further, household \(j\) optimally smooths fairness-adjusted consumption over time. In a symmetric equilibrium, the household’s consumption evolves according to the usual consumption Euler equation:

\begin{equation}
Q(t) = \beta \mathbb{E}_t \left[ \frac{P(t) Y(t)}{P(t + 1) Y(t + 1)} \right].
\end{equation}

Next, firm \(i\) optimally sets its price. The price elasticity of the demand for good \(i\), given by (26), is

\begin{equation}
E_i(t) = -\frac{\partial \ln(Y^d_i)}{\partial \ln(P_i)} = \epsilon + (\epsilon - 1)\gamma \phi_i(K^p_i(t)).
\end{equation}

This expression is the same as in the static model. Unlike in the static model, however, the profit-maximizing markup is not necessarily given by \(E_i(t)/(E_i(t) - 1)\) because \(E_i(t)\) does not capture the effect of \(P_i(t)\) on future perceived marginal costs and thus future demand. Instead, the markup charged by firm \(i\) is determined a quasi elasticity \(D_i(t) > 1\):

\begin{equation}
K_i(t) = \frac{D_i(t)}{D_i(t) - 1}.
\end{equation}

The gap between \(D_i(t)\) and \(E_i(t)\) indicates how much the price today affects perceived marginal costs and thus demand in the future. We find that in a symmetric equilibrium, firms set prices such that

\begin{equation}
\beta E_t \left[ \frac{E(t + 1) - (1 - \gamma)\epsilon}{D(t + 1)} \right] + (1 - \gamma \beta) = \frac{E(t)}{D(t)}.
\end{equation}

This forward-looking equation gives the quasi elasticity \(D(t)\) when prices are optimal, and thus the markup charged by firms.

Finally, in a symmetric equilibrium, all real variables are determined by the markup. First, the nominal marginal cost is the nominal wage divided by the marginal product of labor:
$MC(t) = W(t)/(\alpha A(t)N(t)^{\alpha-1})$. Using (21) and (28), we obtain the real marginal cost:

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

The real marginal cost is increasing in employment because the real wage increases with employment and the marginal product of labor falls with employment. Moreover the markup is the inverse of the real marginal cost: $K(t) = P(t)/MC(t)$. Thus, employment is decreasing in the markup:

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

Then, employment determines output and real wage through (21) and (28).

### 4.3. Equilibrium

We now present the dynamical system describing a symmetric equilibrium (derivations in appendix B). We denote the log of any variable $C(t)$ by $c(t) \equiv \ln(C(t))$, and the steady-state values of $C(t)$ and $c(t)$ by $\bar{C}$ and $\bar{c}$. For any variable $C(t)$ except the interest and inflation rates, we denote the log-deviation from steady state by $\hat{c}(t) = c(t) - \bar{c}$. For the interest and inflation rates, we denote the deviation (not log-deviation) from steady state by $\hat{\pi}(t) = \pi(t) - \bar{\pi}$, $\hat{i}_0(t) = i_0(t) - \bar{i}_0$, and $\hat{r}(t) = r(t) - \bar{r}$.

The first condition is the usual IS equation, obtained by combining the Euler equation (29) with the monetary-policy rule (25):

$$(34) \quad \alpha \hat{n}(t) + \mu \hat{\pi}(t) = \alpha E_t[\hat{n}(t + 1)] + E_t[\hat{\pi}(t + 1)] - \hat{i}_0(t) - \hat{a}(t) + E_t[\hat{a}(t + 1)].$$  

The second equilibrium condition is the law of motion of the perceived markup, which derives from the inference mechanism (16):

$$(35) \quad \hat{k}(t) = \gamma \left[ \hat{\pi}(t) + \hat{k}(t - 1) \right].$$  

This equation shows that the perceived markup today tends to be high if inflation is high or if the past perceived markup was high. Past beliefs matter because people use them as a basis for their current beliefs. Inflation matters because people do not fully appreciate the effect of inflation on nominal marginal costs.
The third condition is the short-run Phillips curve, obtained from pricing equation (32):

\[(36) \quad (1 - \beta \gamma) \hat{k}^p(t) - \lambda_1 \hat{n}(t) = \beta \gamma \mathbb{E}_t[\hat{\pi}(t + 1)] - \lambda_2 \mathbb{E}_t[\hat{n}(t + 1)],\]

where

\[
\lambda_1 \equiv (1 + \eta) \epsilon + (\epsilon - 1) \phi \frac{1}{\phi' \chi} \left[ 1 + \frac{(1 - \beta) \phi}{1 - \beta \phi} \right]
\]

\[
\lambda_2 \equiv (1 + \eta) \beta \epsilon + (\epsilon - 1) \phi \frac{1}{\phi' \chi} \left[ 1 + \frac{(1 - \beta) \phi}{1 - \beta \phi} \right].
\]

Using (35), we can write \(\hat{k}^p(t)\) as a function of past inflation rates:

\[(37) \quad \hat{k}^p(t) = \sum_{i=0}^{\infty} \gamma^{i+1} \hat{\pi}(t - i).\]

Combining this expression with the short-run Phillips curve offers an alternative formulation of the Phillips curve that highlights the presence of past inflation rates:

\[(1 - \beta \gamma) \sum_{i=0}^{\infty} \gamma^{i+1} \hat{\pi}(t - i) - \lambda_1 \hat{n}(t) = \beta \gamma \mathbb{E}_t[\hat{\pi}(t + 1)] - \lambda_2 \mathbb{E}_t[\hat{n}(t + 1)].\]

The short-run Phillips curve relates inflation to employment. Beside current inflation and employment, the Phillips curve incorporates expectations of future inflation and employment, a typical feature of New Keynesian models (Gali 2008, p. 49). In addition, the Phillips curve includes past inflation rates. The lagged inflation terms appear in our Phillips curve because current perceived marginal costs, given by (16), depend on last period’s perception of marginal costs. It follows that the current perception of the markup depends not only on current inflation but also on last period’s perception of the markup; using the autoregressive structure of the perceived markup, we can express the perceived markup as a discounted sum of lagged inflation terms (equation (37)). These lagged terms are the ones in our Phillips curve.

The textbook New Keynesian Phillips curve is purely forward-looking. This is problematic because both lagged inflation and expected future inflation enter significantly in estimated New Keynesian Phillips curve (Mavroeidis, Plagborg-Moller, and Stock 2014, table 2). Our hybrid Phillips curve, involving both backward-looking and forward-looking elements, is therefore more realistic. Of course there exist other variations of the textbook model that append backward-looking components to the Phillips curve; for example, when the firms unable to reset their prices
in a given period index their prices to past inflation (Christiano, Eichenbaum, and Evans 2005).\footnote{Introducing fairness concerns into the New Keynesian model improves the realism of the Phillips curve but leaves the IS equation unchanged. The IS equation is also problematic, however. It is notably the source of the many New Keynesian anomalies at the zero lower bound. To improve the IS equation, other behavioral elements have been introduced into the New Keynesian model (for example, Gabaix 2016; Michaillat and Saez 2019).}

Combining (35), (34), and (36), we obtain the system of difference equations governing the equilibrium:

\begin{equation}
\begin{pmatrix}
\hat{\kappa}(t) \\
\mathbb{E}_t[\hat{\pi}(t + 1)] \\
\mathbb{E}_t[\hat{n}(t + 1)]
\end{pmatrix} = A \begin{pmatrix}
\hat{\kappa}(t - 1) \\
\hat{\pi}(t) \\
\hat{n}(t)
\end{pmatrix} + B \cdot \epsilon(t)
\end{equation}

where

\[
A = \begin{bmatrix}
\gamma & \gamma & 0 \\
(1-\beta\gamma)\alpha & \lambda_2 + \alpha\beta\gamma & (\lambda_2 - \lambda_1)\alpha \\
\lambda_2 + \alpha\beta\gamma & (\beta(\mu+\gamma)-1)\gamma & \lambda_1 + \alpha\beta\gamma \\
\lambda_2 + \alpha\beta\gamma & \lambda_2 + \alpha\beta\gamma & \lambda_2 + \alpha\beta\gamma
\end{bmatrix}, \quad B = \begin{bmatrix}
0 \\
\lambda_2 \\
\beta\gamma
\end{bmatrix},
\]

and \(\epsilon(t) \equiv \hat{i}_0(t) + \hat{a}(t) + \mathbb{E}_t[\hat{a}(t + 1)]\) is an exogenous shock realized at time \(t\). This dynamical system determines employment \(\hat{n}(t)\), inflation \(\hat{\pi}(t)\), and perceived markup \(\hat{\kappa}(t)\). We then obtain all the other variables from these three variables.

### 4.4. Calibration

We calibrate our model. For parameters related to fairness, we use new evidence on markups and marginal-cost passthrough. For other parameters, we use usual empirical evidence. The calibrated values of the parameters are summarized in table 4.

**Fairness function.** We set the shape of the fairness function to (10). This simple functional form has two advantages. First, it introduces only one new parameter: \(\xi\), which governs the concern for fairness. Second, it is such that in a zero-inflation steady state (the case considered here), the fairness factor is just one. As shown by (16), in a zero-inflation steady state the perceived markup is \(\bar{K}p = \epsilon / (\epsilon - 1)\), so \(\bar{F} = 1\). In steady state, customers are therefore acclimated: they are neither angry nor happy about markups. This seems like a desirable steady-state property.

**Fairness-related parameters.** We then calibrate the three parameters central to our theory: the fairness parameter \(\xi\), the inference parameter \(\gamma\), and the elasticity of substitution across goods \(\epsilon\). These parameters jointly determine the average markup and markup dynamics in response
to shocks—which determine the dynamics of the marginal-cost passthrough. Hence, for the
calibration, we match empirical evidence on markups and passthrough dynamics. We target the
following three empirical moments: average markup, short-run marginal-cost passthrough, and
long-run marginal-cost passthrough.

First, using firm-level data, De Loecker and Eeckhout (2017) estimate markups in the United
States between 1950 and 2014. They find that the average markup hovers between 1.2 and 1.3 in
the 1950–1980 period and rises from 1.2 to 1.7 in the 1980–2014 period. The average markup since
2000 is about 1.5; we use this value as a target.\footnote{The average markup computed by De Loecker and Eeckhout is commensurate to the markups estimated for
specific industries or goods in the United States. In the automobile industry, Berry, Levinsohn, and Pakes (1995, p. 882)
estimate that on average \((P − MC)/P = 0.239\), which translates into a markup of \(K = P/MC = 1/(1 − 0.239) = 1.3\). In
the ready-to-eat cereal industry, Nevo (2001, table 8) finds that a median estimate of \((P − MC)/P\) is 0.372, which
translate into a markup of \(K = P/MC = 1/(1 − 0.372) = 1.6\). In the coffee industry, Nakamura and Zerom (2010,
table 6) also estimate a markup of 1.6. For most national-brand items retailed in supermarkets, Barsky et al. (2003,
p. 166) discover that markups range between 1.4 and 2.1. Finally, earlier work surveyed by Rotemberg and Woodford
(1995, pp. 261–266) also estimates similar markups: in marketing, the markup for a typical good is usually below 2;
in industrial organization, markups are between 1.2 and 1.7.}

Second, when discussing proposition 1, we reported that the short-run marginal-cost
passthrough is estimated between 0.2 and 0.4. To be conservative, we target a short-run
passthrough of 0.4.

Third, we turn to the long-run marginal-cost passthrough. We have not found long-run
estimates for the marginal-cost passthrough, but Burstein and Gopinath (2014, table 7.4) provide
long-run estimates of the exchange-rate passthrough for the United States and seven other
countries. This passthrough measures the response of import prices to exchange-rate shocks. Its
level may not reflect the level of the marginal-cost passthrough because marginal costs may not
vary one-for-one with exchange rates (Amiti, Itskhoki, and Konings 2014), but there is no reason
for the two passthroughs to have different dynamics. The immediate exchange-rate passthrough is
estimated around 0.4 and the two-year passthrough around 0.7. Using these dynamics, we target
a two-year marginal-cost passthrough of 0.7.

We then take the perspective of a firm in our model, and we simulate passthrough dynamics
in response to an exogenous increase in the firm’s marginal costs (appendix B). We find that
the fairness parameter \(\xi\) primarily affects the passthrough level, while the inference parameter
\(\gamma\) primarily affects the passthrough dynamics. Based on the simulation, we set \(\epsilon = 2.2\), \(\xi = 9\),
and \(\gamma = 0.8\). With this calibration, we obtain a steady-state markup of 1.5, an instantaneous
passthrough of 0.4, and a two-year passthrough of 0.7.

\textbf{Other parameters.} We set the labor-supply parameter to \(\eta = 1.1\), which gives a Frisch
elasticity of labor supply of \(1/1.1 = 0.9\). This value is the median microestimate of the Frisch
Table 4. Parameter values in simulations

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Source or target</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\beta = 0.99)</td>
<td>Quarterly discount factor</td>
<td>Annual rate of return = 4%</td>
</tr>
<tr>
<td>(\alpha = 1)</td>
<td>Marginal returns to labor</td>
<td>Labor share = 2/3</td>
</tr>
<tr>
<td>(\eta = 1.1)</td>
<td>Inverse of Frisch elasticity of labor supply</td>
<td>Chetty et al. (2013, table 2)</td>
</tr>
<tr>
<td>(\mu = 1.5)</td>
<td>Response of interest rate to inflation</td>
<td>Gali (2008, p. 52)</td>
</tr>
</tbody>
</table>

A. Common parameters

B. Parameters of the New Keynesian model with fairness

| \(\epsilon = 2.2\) | Elasticity of substitution across goods | Steady-state markup = 1.5           |
| \(\xi = 9\)        | Fairness concern                       | Instantaneous passthrough = 0.4     |
| \(\gamma = 0.8\)   | Underinference                         | Two-year passthrough = 0.7          |

C. Parameters of the textbook New Keynesian model

| \(\epsilon = 3\) | Elasticity of substitution across goods | Steady-state markup = 1.5           |
| \(\theta = 2/3\)  | Share of firms keeping price unchanged | Average price duration = 3 quarters |

elasticity for aggregate hours (Chetty et al. 2013, table 2). We then set the quarterly discount factor to \(\beta = 0.99\), giving an annual rate of return on bonds of 4%. We set the production-function parameter to \(\alpha = 1\). This calibration guarantees that the labor share, which equals \(\alpha / K\) in steady state, takes its conventional value of 2/3. Last, we calibrate the monetary-policy parameter to \(\mu = 1.5\), which is consistent with observed variations in the federal funds rate (Gali 2008, p. 52).

Parameters of the textbook New Keynesian model. We also calibrate a textbook New Keynesian model (described in appendix B), which will be used as a benchmark. For the parameters common to the two models, we use the same values—except for \(\epsilon\). In the textbook model, the steady-state markup is \(\epsilon / (\epsilon - 1)\), so we set \(\epsilon = 3\) to obtain a markup of 1.5.

We also need to calibrate one parameter specific to the textbook model. The textbook model uses Calvo pricing, and the parameter \(\theta\) indicates the share of firms that cannot update their prices each period. As usual, we calibrate \(\theta\) from microevidence on the frequency of price adjustments. If a share \(\theta\) of firms keep their price fixed each period, the average duration of a price spell is \(1 / (1 - \theta)\) (Gali 2008, p. 43). In the microdata underlying the US Consumer Price Index, the mean duration of price spells is about 3 quarters (Nakamura and Steinsson 2013, table 1). Hence, we set \(1 / (1 - \theta) = 3\), which implies \(\theta = 2/3\).
4.5. **Simulations**

We simulate our model’s response to an unexpected, transitory shock to monetary policy. We focus on dynamics around the zero-inflation steady state.\(^{13}\)

**Setup.** We assume that the exogenous component of the monetary-policy rule (25) follows an AR(1) process:

\[
\hat{i}_0(t) = \zeta \hat{i}_0(t - 1) + \epsilon^i(t)
\]

where the disturbance \(\epsilon^i(t)\) follows a white noise process with mean zero, and \(\zeta \in (0, 1)\) governs the persistence of shocks. We set \(\zeta = 3/4\), which corresponds to moderate persistence (Gali 2008, p. 52; Gali 2011, p. 26). We simulate the response of the model to an initial disturbance of \(\epsilon^i(0) = 0.25\%\). Such a positive realization of \(\epsilon^i(t)\) is a contractionary monetary-policy shock, leading to a rise in the real interest rate. Without any response of inflation, this shock would lead to an increase of the annualized nominal interest rate by one percentage point.

**Results.** Figure 2 displays the dynamic response to the contractionary monetary-policy shock. In the figure, the responses of the real interest rate and inflation are expressed in annual terms (by multiplying by 4 the responses of the variables \(\hat{\pi}(t)\) and \(\hat{r}(t)\)). The responses of the other variables are expressed as percentage deviations from their steady-state values.

The tightening of monetary policy generates an increase in the real interest rate, and a decrease in inflation. Inflation is negative for about two quarters and close to zero after that. The deflation leads to a decrease in perceived markups, as customers underinfer the decrease in marginal costs from lower prices. Firms take advantage of lower perceived markups by raising their actual markups. The markup rises by more than 1%, and thus output and employment fall, by about 0.7%. (The responses of output and employment are the same since the production function is calibrated to be linear.)

**Comparison with empirical evidence.** As a monetary-policy shock influences output and employment, monetary policy is nonneutral. The nonneutrality of monetary policy is well documented; much of the evidence is summarized by Christiano, Eichenbaum, and Evans (1999) and Ramey (2016, sec. 3). Of course, many models of monetary nonneutrality have been developed (Blanchard 1990; Mankiw and Reis 2010), but with the exception of Rotemberg (2005) none invoking fairness.

\(^{13}\)In our model it is simple to study dynamics around steady states with positive or negative inflation. But in the textbook New Keynesian model, this is a complicated task (Coibion and Gorodnichenko 2011). To simplify the simulations of that model, we follow the literature and concentrate on the zero-inflation steady state.
This figure describes the response of the New Keynesian model with fairness (solid, blue lines) to an increase in the exogenous component of the monetary-policy rule (25) by one percentage point (annualized) at time 0. The real interest rate and inflation rate are deviations from steady state, measured in percentage points and annualized. The other variables are percentage deviations from steady state. The model is described in section 4 and calibrated in table 4. For comparison, the figure also displays the response of the textbook New Keynesian model (dashed, orange lines). The textbook model is described in appendix B and calibrated in table 4.
In fact the response of output to a monetary-policy shock is broadly the same in the model as in US data. First, the shape of the response is similar, as output is estimated to respond to monetary-policy shocks in a hump-shaped fashion (Ramey 2016, figs. 1–4). Second, the amplitude of the response is comparable. Ramey (2016, table 1) summarizes the literature: for a one-percentage-point increase of the nominal interest rate, output is estimated to drop between 0.6% and 5%, with a median value of 1.6%. Ramey (2016, table 2) also conducts her own analysis using a range of methods and samples: output is estimated to drop between 0.2% and 2.2%, with a median value of 0.8%. In our simulation, output falls by 0.7% when the exogenous component of monetary policy increases by one percentage point—quite close to Ramey’s estimates.

Moreover, the dynamics of the perceived markup allow us to make sense of the survey responses collected by Shiller (1997) and the Bank of Japan (table 1). When our consumers observe deflation, they mistakenly believe that markups are lower and transactions are more fair, which raises their consumption utility and triggers a feeling of happiness. Conversely, upon observing inflation, they would believe that markups are higher and transactions less fair, which would reduce their consumption utility and trigger a feeling of displeasure. Hence, our model naturally explains why Japanese customers have a positive opinion of deflation and a negative opinion of inflation. By the same token, it explains Shiller’s finding that people are angered by inflation, which they attribute to the greed of businesses.

Last, after monetary-policy shocks, markup and output move in opposite directions. Therefore, if business cycles are generated by aggregate-demand shocks, our model predicts that markups are countercyclical. There is indeed evidence of countercyclical markups (Rotemberg and Woodford 1999); but measuring aggregate markups is challenging, so the evidence is not definitive (Nekarda and Ramey 2013).

The main discrepancy between our model and US evidence concerns inflation. In our model, the response of inflation to a monetary shock is immediate. (The same is true in the textbook model.) In contrast, the response of US inflation to monetary shocks is delayed and very gradual (Ramey 2016, figs. 1–4). It is not clear yet how this issue can be addressed.

**Comparison with the textbook model.** In our model as in the textbook model, the markup rises when monetary policy tightens, so employment and output fall—matching what we see in the data. Beyond this similarity, the impulse responses of the two models differ on several counts.

First, the response of the perceived markup differs. In the fairness model, households misinfer that markups are lower and transactions more fair when they observe deflation. In the textbook model, on the other hand, households correctly infer that markups are higher when they see deflation; symmetrically, they understand that markups are lower when they see inflation. With
the textbook model it would therefore be difficult to understand why Japanese customers have a positive opinion of deflation; it would also be difficult to make sense of the Shiller finding that customers accuse businesses of greed in periods of inflation.

Second, the response of output and employment is hump-shaped in the fairness model but not in the textbook model. The hump shape appears in the fairness model because the dynamical system describing the equilibrium includes a backward-looking element, which is absent from the textbook model: the perceived markup \( \bar{k}^p(t) \), which enters the Phillips curve (36). The role of backward-looking elements in generating hump-shaped impulse responses is well-understood. Indeed, a typical way of obtaining hump-shaped responses in New Keynesian models is to assume that consumers form habits (Fuhrer 2000; Christiano, Eichenbaum, and Evans 2005). Under this assumption, consumers’ behavior depends on their past consumption, so past consumption enters the dynamical equilibrium system—which generates hump-shaped responses to shocks.

Third, the response of employment and output is about three times larger in the fairness model than in the textbook model. Thus, monetary shocks are more amplified in the fairness model—although both models are calibrated using microevidence on price dynamics.

4.6. Monetary policy in the long run

We study the long-run effects of monetary policy by comparing steady-state equilibria parameterized by different monetary-policy rules. In steady state, all real variables are constant and all nominal variables grow at a rate \( \bar{\pi} \).

In steady state, the Euler equation (29) implies \( \bar{i} = \rho + \bar{\pi} \), where \( \rho = -\ln(\beta) \) is the time discount rate. Combining this equation with the monetary-policy rule (25) implies

\[
\bar{\pi} = \frac{\rho - \bar{i}_0}{\mu - 1}.
\]

Hence, in the long run, monetary policy perfectly controls inflation: for instance, to obtain zero inflation, the exogenous component of the monetary-policy rule, \( \bar{i}_0 \), must be set to \( \rho \); and, to obtain higher inflation, it suffices to reduce \( \bar{i}_0 \).

In turn, inflation determines the perceived and actual markups:

**Proposition 3.** In steady state, the perceived markup is an increasing function of inflation:

\[
\bar{k}^p = \ln \left( \frac{\epsilon}{\epsilon - 1} \right) + \frac{Y}{1 - Y} \bar{\pi}.
\]
Thus the actual markup is a decreasing function of inflation:

\[
\bar{K} = 1 + \frac{1}{\varepsilon - 1} \cdot \frac{1}{1 + \frac{(1-\beta)_\gamma}{1-\beta} \phi(k\bar{p}(\bar{\pi}))}.
\]

The proof is only algebra, so it is relegated to appendix A. Equation (40) is the counterpart to equation (6) in the monopoly model. It shows that households perceive higher markups when inflation is higher. Households understand that marginal costs grow at the inflation rate (since perceived markups are constant in steady state), but because of subproportional inference, they misjudge the level of marginal costs.

Equation (41) is the counterpart to equation (8) in the monopoly model. The two equations have the same structure, so the two models operate similarly. After an increase in inflation, households underappreciate the increase in nominal marginal costs, so they partly attribute the higher prices to higher markups, which they find unfair. Since perceived markups are higher, the price elasticity of demand increases, leading firms to reduce their markups.

Finally, combining (33) with proposition 3, we link inflation to employment:

**Corollary 3.** Steady-state employment is an increasing function of steady-state inflation:

\[
\bar{n} = \frac{1}{1 + \eta} \left[ \ln(\alpha) - \ln\left( \frac{v}{\nu - 1} \right) - k\bar{p}(\bar{\pi}) \right].
\]

Thus, the long-run Phillips curve is not vertical (fixed \(\bar{n}\)) but upward sloping (\(\bar{n}\) increasing in \(\bar{\pi}\)).

As the long-run Phillips curve is upward sloping, monetary policy is nonneutral in the long run. The reason is that in the long run, higher inflation leads to a lower markup, and the markup determines employment. The markup is the inverse of the real marginal cost, which is the ratio of the real wage and the marginal product of labor. The real wage is proportional to the marginal rate of substitution between leisure and consumption, which is increasing in employment because the utility function is concave and because more employment means more consumption but less leisure. The marginal product of labor is decreasing in employment because of diminishing returns. Overall, in general equilibrium, the real marginal cost is increasing in employment. Since a lower markup implies a higher real marginal cost, it also implies higher employment.

The property that higher steady-state inflation leads to higher steady-state employment is consistent with evidence that higher average inflation leads to lower average unemployment (King and Watson 1994, 1997). There is also evidence that the mechanism behind the long-run Phillips curve—inflation lowers markups—operates. Benabou (1992) uncovers that in the US retail sector between 1948 and 1990, higher average inflation leads to lower average markup. Using aggregate US data for 1953–2000, Banerjee and Russell (2005) reach the same conclusion.
Our mechanism complements the traditional mechanism for an upward-sloping long-run Phillips curve: that because of downward nominal wage rigidity, steady-state inflation erodes real wages and thus reduces unemployment (Tobin 1972; Akerlof, Dickens, and Perry 1996; Benigno and Ricci 2011). While our mechanism operates on the goods market instead of the labor market, the psychological origins of the two mechanisms could be similar, since one possible source of wage rigidity is workers’ fairness concerns.

To illustrate the long-run nonneutrality, we compute the long-run Phillips curve in our calibrated model. Figure 3 displays two versions of the long-run Phillips curve: one describes the relationship (41) between steady-state inflation and steady-state markup, and the other the relationship (42) between steady-state inflation and steady-state employment. When inflation raises from 0% to 1%, the markup falls from 1.5 to 1.3, and employment increases by 8%. On the other hand, if inflation falls from 0% to −1%, the markup rises from 1.5 to 1.6, and employment falls by 3%. This link between inflation and markup could explain part of the variation in markups measured by De Loecker and Eeckhout (2017) in the United States between 1980 and 2014. They find that the average markup increased from 1.2 to 1.7 over that period. At the same time, average inflation fell from above 5% to around 1.5%. Through our mechanism, the drop in inflation could explain part of the observed increase in markups.
5. Conclusion

This paper develops a theory of pricing to fairness-minded customers. The theory revolves around two assumptions. First, customers derive more utility from a good priced at a low markup—perceived as fairly priced—than one priced at a high markup—perceived as unfairly priced. Second, customers attempting to work out markups infer hidden marginal costs from observed prices in a subproportional way: they infer too little, and to the extent that they do infer, they misperceive marginal costs as proportional to prices. These assumptions conform to common sense and copious evidence collected from customers and firms.

The main implication of the theory is price rigidity: the passthrough of marginal costs into prices is strictly less than one. When the theory is embedded into a New Keynesian model, price rigidity leads to the nonneutrality of monetary policy, both in the short run and in the long run. Furthermore, we are able to calibrate our two psychological parameters—concern for fairness and degree of underinference—from microevidence, just as any other parameter of the New Keynesian model. When we simulate our calibrated New Keynesian model, we obtain realistic impulse responses of output and employment to monetary-policy shocks: the responses are hump-shaped and have the appropriate amplitude.

The paper also clarifies the contexts in which fairness is likely to matter. First, hidden information and underinference seem important for fairness to operate. When costs are observable, or when costs are hidden but customers infer them rationally from prices, our model with fairness is isomorphic to a model without fairness. Only when costs are hidden and customers infer subproportionally does fairness affect the qualitative properties of equilibrium, such as by creating price rigidity. Second, the model proposes a channel through which fairness concerns may matter in large markets, which is not the case for many common approaches to fairness (Dufwenberg et al. 2011; Sobel 2007). Indeed, because fairness modifies the price elasticity of demand in our theory, fairness continues to matter in large markets—for instance, in a New Keynesian model.

One potentially fruitful application of our theory is the study of optimal monetary policy. Most models currently used to study optimal monetary policy rely on the assumption of staggered pricing from Calvo (1983). Yet Calvo pricing does not explain why firms change prices only infrequently—possibly missing important effects of inflation on welfare. Other theories that provide rationales for price rigidity have been less popular than Calvo pricing because they lack its tractability. By contrast, our pricing theory is about as simple as Calvo pricing, and its microfoundations capture well the motivations of real-world customers and firms. With better microfoundations, our theory may provide a more accurate welfare function, which could deliver new policy insights.
One aspect of our welfare function that differs from the Calvo welfare function is the direct effect of inflation on welfare. Under Calvo pricing, the direct effect is hump-shaped, with a maximum at zero: everything else equal, the desirable level of inflation is zero, and both inflation and deflation reduce welfare. The reason is that both inflation and deflation cause price dispersion, which distorts households’ consumption baskets. In our model, the direct effect of inflation on welfare is always decreasing: everything else equal, deflation always yields higher welfare than inflation. This is because inflation induces a misperception that markups are higher, thus lowering perceived fairness and welfare, whereas deflation induces a misperception that markups are lower, thus raising perceived fairness and welfare. This difference in the shape of the welfare function could produce new insights for optimal monetary policy.

Before drawing policy conclusions, however, we would need to add to our model other channels through which inflation may also affect welfare. First, moderate inflation could erode real wages if nominal wages are somewhat rigid, which would lead to lower unemployment (Akerlof, Dickens, and Perry 1996). Since unemployed workers suffer low well-being (Landais, Michaillat, and Saez 2018, pp. 193–195), higher inflation could improve welfare through this channel. Second, people seem to fear that rising prices always outpace wages, and that inflation impoverishes them (Shiller 1997). Through this channel, higher inflation could impose an additional psychological cost on consumers.

References


Fuhrer, Jeffrey C. 2000. “Habit Formation in Consumption and Its Implications for Monetary-Policy


Appendix A. Proofs

Proof of proposition 1

Markup. Since customers care about fairness and infer subproportionally, the price elasticity of demand, \( E(K^p) \), is given by (7). Then (2) indicates that the monopoly’s optimal markup is given by

\[
K = \frac{E(K^p)}{E(K^p) - 1}.
\]

By combining (7) with (A1), we obtain the expression (8) for the markup.

Toward showing that (8) admits a unique solution, we introduce

\[
P^b = \frac{\epsilon}{\epsilon - 1}(K^b)^{1/\gamma}MC^b \quad \text{and} \quad K^b = \frac{P^b}{MC}.
\]

The price \( P^b \) is defined such that if the firm sets a price \( P^b \), the perceived markup reaches the upper bound of the domain of the fairness function: \( K^p(P^b) = K^h \). Since \( MC^b \) satisfies (5), we have \( P^b > MC \) and \( K^b > 1 \).

Next, since \( P = K \times MC \), \( P \) strictly increases from 0 to \( P^b \) when \( K \) increases from 0 to \( K^b \). Next, (6) implies that \( K^p(P) \) strictly increases from 0 to \( K^h \) when \( P \) increases from 0 to \( P^b \). Last, lemma 3 indicates that \( \phi(K^p) \) strictly increases from 0 to \( \infty \) when \( K^p \) increases from 0 to \( K^h \). As \( \gamma > 0 \), we conclude that when \( K \) increases from 0 to \( K^b > 1 \), the right-hand side of (8) strictly decreases from \( \epsilon/(-1) \) to 1. Hence, (8) has a unique solution \( K \in [0, K^h] \), implying that the markup exists and unique. Given the range of values taken by the right-hand side of (8), we also infer that \( K \in (1, \epsilon/(-1)) \).

Passthrough. We now compute the marginal-cost passthrough, \( \sigma \). The equilibrium price is given by \( P = K(K^p(P)) \times MC \), where the monopoly’s markup, \( K(K^p) \), is given by (A1), and the perceived markup, \( K^p(P) \), is given by (6). Using this price equation, we obtain

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

Since \( d \ln(K^p)/d \ln(P) = \gamma \) and \( d \ln(P)/d \ln(MC) = \sigma \), the above equation yields

\[
\sigma = \frac{1}{1 - \gamma \frac{d \ln(K)}{d \ln(K^p)}}.
\]
Then using (A1), we express the elasticity of $K(K^p)$ as a function of the elasticity of $E(K^p)$:

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

Using (7), we express the elasticity of $E(K^p)$ as a function of the superelasticity of the fairness function, $\chi$:

$$\frac{d \ln(E)}{d \ln(K^p)} = \frac{E - \epsilon}{E} \cdot \frac{d \ln(\phi)}{d \ln(K^p)} = \frac{(E - \epsilon)\chi}{E}.$$ 

Combining the last two equations, and using the expression for $E(K^p)$ given by (7), we obtain

$$-\frac{d \ln(K)}{d \ln(K^p)} = \frac{(E - \epsilon)\chi}{(E - 1)E} = \frac{\gamma \phi \chi}{(1 + \gamma \phi)(\epsilon + (\epsilon - 1)\gamma \phi)}.$$ 

Combining this equation with (A2), we obtain (9). From (9), we infer that $\sigma \in (0, 1)$ because $\gamma > 0$ (definition 3), $\phi > 0$ (lemma 3), and $\chi > 0$ (also lemma 3).

**Proof of corollary 1**

The elasticity of the fairness function (10) satisfies

$$\phi(K^p) = -\frac{K^p}{F(K^p)} \cdot F'(K^p) = \frac{K^p}{F(K^p)} \cdot \xi.$$ 

Accordingly, the superelasticity of the fairness function (10) satisfies

$$\chi(K^p) = \frac{d \ln(\phi)}{d \ln(K^p)} = 1 - \frac{d \ln(F)}{d \ln(K^p)} = 1 + \phi(K^p).$$ 

Once customers are acclimated, $K^p = \epsilon/(\epsilon - 1)$ and $F(K^p) = 1$, so the elasticity and superelasticity of the fairness function simplify to

(A3) $\phi = \frac{\epsilon \xi}{\epsilon - 1}$

(A4) $\chi = 1 + \frac{\epsilon \xi}{\epsilon - 1}.$

**Markup.** Combining (8) with (A3), we obtain the following expression for the markup:

$$K = 1 + \frac{1}{\epsilon - 1} \cdot \frac{\frac{1}{1 + \gamma \epsilon \xi/(\epsilon - 1)}}{1 + \frac{1}{\epsilon - 1 + \gamma \epsilon \xi}} = 1 + \frac{1}{\epsilon - 1 + \gamma \epsilon \xi} = 1 + \frac{1}{\epsilon((1 + \gamma \xi) - 1)}.$$ 

This expression is just (11). It shows that $K$ is lower when $\epsilon$, $\gamma$, or $\xi$ are higher.
**Passthrough.** Combining (9) with (A3) and (A4), we obtain the following result about the passthrough $\sigma$:

$$\frac{1}{\sigma} = 1 + \frac{\gamma^2 \epsilon \xi [(\epsilon - 1) + \epsilon \xi]}{(\epsilon - 1) [(\epsilon - 1) + \gamma \epsilon \xi] (\epsilon + \gamma \epsilon \xi)} = 1 + \frac{\gamma^2 \xi [(1 + \xi) \epsilon - 1]}{(\epsilon - 1) [(1 + \gamma \xi) \epsilon - 1] (1 + \gamma \xi)},$$

which then gives (12).

Next consider the function

$$\Lambda(\gamma, \xi, \epsilon) = \frac{\gamma^2 \xi [(1 + \xi) \epsilon - 1]}{(\epsilon - 1) [(1 + \gamma \xi) \epsilon - 1] (1 + \gamma \xi)},$$

where $\gamma > 0$, $\xi > 0$, and $\epsilon > 1$. Dividing numerator and denominator by $\gamma^2$, we rewrite the function as

$$\Lambda(\gamma, \xi, \epsilon) = \frac{\xi [(1 + \xi) \epsilon - 1]}{(\epsilon - 1) [(\xi \epsilon + (\epsilon - 1) / \gamma) (\xi + 1 / \gamma)].$$

The denominator is decreasing in $\gamma$, so $\Lambda$ is increasing in $\gamma$. Since $\sigma = 1/(1 + \Lambda)$, we conclude that $\sigma$ is decreasing in $\gamma$.

Similarly, we divide numerator and denominator of (A5) by $(\epsilon - 1)$ and obtain

$$\Lambda(\gamma, \xi, \epsilon) = \frac{\gamma^2 [1 + \xi \epsilon / (\epsilon - 1)]}{[(1 + \gamma \xi) \epsilon - 1] (1 + \gamma \xi)},$$

Since $\epsilon / (\epsilon - 1)$ is decreasing in $\epsilon > 1$ and $(1 + \gamma \xi) \epsilon - 1$ is increasing in $\epsilon$, $\Lambda$ is decreasing in $\epsilon > 1$. As $\sigma = 1/(1 + \Lambda)$, we conclude that $\sigma$ is increasing in $\epsilon$.

Last, we divide numerator and denominator of (A5) by $\xi (\epsilon \xi + \epsilon - 1)$ and get

$$\Lambda(\gamma, \xi, \epsilon) = \frac{\gamma^2}{(\epsilon - 1) (\gamma + 1 / \xi) \frac{\gamma \epsilon \xi + \epsilon - 1}{\epsilon \xi + \epsilon - 1}},$$

First, $\gamma + 1 / \xi$ is decreasing in $\xi > 0$. Second, $(\gamma \epsilon \xi + \epsilon - 1) / (\epsilon \xi + \epsilon - 1)$ is decreasing in $\xi > 0$ because $\gamma \leq 1$. Hence, $\Lambda$ is increasing in $\xi > 0$. Since $\sigma = 1/(1 + \Lambda)$, we conclude that $\sigma$ is decreasing in $\xi$.

**Proof of lemma 6**

**Elements of a PBE.** Fix a PBE of the disclosure game. A PBE comprises three elements: a strategy for the monopolist, a belief mapping for customers, and a strategy for customers.

A strategy for the monopolist has three elements: one disclosure probability, which is a mapping $\sigma : [0, MC^b] \rightarrow [0, 1]$ that gives the probability that a firm discloses its marginal cost for every
possible value of marginal cost; and two price strategies, which are mappings $P_d : [0, MC^h] \to \mathbb{R}_+$ and $P_c : [0, MC^h] \to \mathbb{R}_+$ that select a price for every possible value of marginal cost when the firm discloses and conceals, respectively. We denote by $C = \{MC \in [0, MC^h] : \sigma(MC) > 0\}$ the set of types that conceal with positive probability.

The belief mapping for customers associates to every possible strategy by the monopolist a belief over possible marginal costs. If the monopolist discloses, irrespective of the price it sets, customers obviously know the marginal cost: $MC^p = MC$. If the monopolist conceals and sets a price $P$, customers form beliefs about the marginal cost of the firm; we denote by $B_P : [0, MC^h] \to [0, 1]$ the cumulative distribution function of customers’ beliefs about the marginal cost of a firm who conceals and chooses a price $P$.

Finally, a strategy for customers consists of a mapping $Y_d^d : \mathbb{R}_+ \to \mathbb{R}_+$ that selects a quantity purchased for every possible price when the firm discloses, and a mapping $Y_c^d : \mathbb{R}_+ \to \mathbb{R}_+$ that selects a quantity purchased for every possible price when the firm conceals.

**Strategy of customers.** We first derive the strategy of customers. If the monopoly discloses its marginal cost $MC$, customers know the cost. Using (1), we infer that customers’ demand is

$$Y^d(MC, P) = P^{-\varepsilon} F \left( \frac{P}{MC} \right)^{\varepsilon - 1}.$$

This is the same demand as when the monopoly’s cost is observable. If the monopoly conceals and prices $P$, customers are uncertain about its marginal cost, so their expected utility is

$$\mathbb{E}_{B_P} \left[ F \left( \frac{P}{MC^p} \right)^{(\varepsilon - 1)/\varepsilon} \right] + M,$$

which simplifies to

$$\mathbb{E}_{B_P} \left[ F \left( \frac{P}{MC^p} \right)^{(\varepsilon - 1)/\varepsilon} \right] Y^{(\varepsilon - 1)/\varepsilon} + M.$$  

Hence, at $P$, consumer demand is given by

$$Y^d(P) = P^{-\varepsilon} \mathbb{E}_{B_P} \left[ F \left( \frac{P}{MC^p} \right)^{(\varepsilon - 1)/\varepsilon} \right]^{\varepsilon}.$$
**Strategy of disclosing firms.** The profits of type $MC$ when disclosing and setting a markup $K$ and price $P = K \times MC$ are

\[ V_d(MC, K) = (P - MC) Y_d^d(MC, P) = MC^{1-\epsilon} K - 1 \frac{1}{K^\epsilon} F(K)^{\epsilon-1}. \]

When disclosing, the firm face the same problem as when marginal cost is observable, so it uses the markup $K_d$ given by (13) and sets a price $P_d(MC) = K_d \times MC$. The markup $K_d$ satisfies $K_d = \arg\max_K V_d(MC, K)$.

**No pooling equilibrium.** We show that there cannot be a pooling equilibrium when firms conceal; that is, firms in $C$ with distinct marginal costs charge distinct prices. Suppose instead that a subset $P_0 \subset C$ of firms with distinct marginal costs charge the same price $P_0$. Now, because customers’ priors are non-atomistic, the beliefs $B_{P_0}$ are either non-atomistic over $P_0$ or put atoms everywhere over $P_0$. In either case, there must be at least one marginal cost $MC_0 \in P_0$ which produces a value of $F$ such that

\[ Y_d^d(MC_0, P_0) = P_0^{-\epsilon} \left[ F\left( \frac{P_0}{MC_0} \right)^{(\epsilon-1)/\epsilon} \right] ^\epsilon > P_0^{-\epsilon} \mathbb{E}_{B_{P_0}} \left[ F\left( \frac{P_0}{MC_0} \right)^{(\epsilon-1)/\epsilon} \right] ^\epsilon = Y_d^d(P_0). \]

This means that type $MC_0$ would earn higher profits by disclosing its marginal cost without changing its price, a contradiction. Hence, no two types who conceal can charge the same price. This implies that the function $P_c$ separates types on $C$, and thus that rational customers learn the marginal cost of any firm in $C$.

**Strategy of concealing firms.** We then establish that when firms conceal, it is optimal for them to set the same price as when they disclose. Because the equilibrium is separating when firms conceal, customers are nevertheless able to infer firms’ marginal costs in equilibrium. Hence, the equilibrium profits of a firm with marginal cost $MC$ when it conceals and sets a markup $K$ are $V_c(MC, K) = V_d(MC, K)$. These equilibrium profits are uniquely maximized at the markup $K_d$, and the maximized equilibrium profits are $V_d(MC, K_d)$, which are also the profits earned by the firm when it discloses. Hence, the only way for a firm to earn at least as much when it conceals as when it discloses is to set a markup $K_c = K_d$, which can be done by charging a price $P_c = K_d \times MC$. Since equilibrium profits when a firm conceals must be at least as high as when it discloses—otherwise it would not be optimal to conceal—we infer that the price set by concealing firms is $P_c(MC) = K_d \times MC = P_d(MC)$. To conclude, firms set the same price whether they conceal or disclose.
**Only the lowest type conceals.** Finally, we establish that only the lowest type can conceal. Suppose instead that some interior type \(MC_0\) conceals and charges \(P_0\). We claim that for some \(\Delta > 0\), any type \(MC \in [MC_0 - \Delta, MC_0]\) would conceal and charge the same price \(P_0\). The profits of a type \(MC < MC_0\) when disclosing are \(V_d(MC, K_d)\), where \(V_d\) is given by (A6) and \(K_d\) by (13). Note that \(K_d < \epsilon/(\epsilon - 1)\) and \(K_d\) is independent of the firm’s type. When type \(MC < MC_0\) conceals and charges \(P_0\), customers believe that they are facing type \(MC_0\), so the firm’s profits are

\[
V_c = (P_0 - MC) Y_d^c(MC_0, P_0) = MC^{1-\epsilon} \frac{K_c - 1}{(K_c)^\epsilon} F(K_c)^{\epsilon-1},
\]

where \(K_c = P_0/MC\) is the markup charged by the concealing firm, and \(K_d = P_0/MC_0\) is the markup charged by type \(MC_0\), and also is the markup charged by disclosing firms. Since \(MC < MC_0\), we have \(K_c > K_d\). We saw previously that \(K_d < \epsilon/(\epsilon - 1)\), so for \(\Delta\) small enough, \(MC \in [MC_0 - \Delta, MC_0]\) is close enough to \(MC_0\), such that \(K_c\) is close enough to \(K_d\), which implies \(K_c \leq \epsilon/(\epsilon - 1)\).

Now, for any \(MC \in [MC_0 - \Delta, MC_0]\) with \(\Delta\) small enough, we have \(1 < K_d < K_c \leq \epsilon/(\epsilon - 1)\). Moreover, the function \(K \mapsto (K - 1)/K^\epsilon\) is strictly increasing in \(K\) for \(K \in [1, \epsilon/(\epsilon - 1)]\). Hence,

\[
\frac{K_c - 1}{(K_c)^\epsilon} > \frac{K_d - 1}{(K_d)^\epsilon},
\]

and thus that \(V_c > V_d(MC, K_d)\). We conclude that for any type \(MC \in [MC_0 - \Delta, MC_0]\), it is a profitable deviation to conceal and charge \(P_0\) so as to mimic \(MC_0\). Here we reach a contradiction since we have previously seen that in equilibrium, concealing firms with distinct marginal costs charge distinct prices. We infer that only the lowest type can conceal in equilibrium.

**Proof of proposition 3**

**Perceived markup.** The perceived markup is defined by \(K^p(t) = P(t)/MC^p(t)\), which in log gives \(k^p(t) = p(t) - mc^p(t)\). In steady state, \(k^p(t-1) = k^p(t) = \bar{k}^p\), so that \(mc^p(t-1) = p(t-1) - \bar{k}^p\) and \(mc^p(t) = p(t) - \bar{k}^p\). At the same time, we learn from (16) that

\[
mc^p(t) = \gamma mc^p(t-1) + (1 - \gamma)p(t) + (1 - \gamma) \ln \left( \frac{\epsilon - 1}{\epsilon} \right).
\]

Combining these two insights, we get

\[
p(t) - \bar{k}^p = \gamma p(t-1) - \gamma \bar{k}^p + (1 - \gamma)p(t) + (1 - \gamma) \ln \left( \frac{\epsilon - 1}{\epsilon} \right).
\]
Reshuffling the terms, we then obtain

$$(1 - \gamma)k^p = \gamma [p(t) - p(t - 1)] + (1 - \gamma) \ln \left( \frac{\epsilon}{\epsilon - 1} \right).$$

Noting that in steady state $p(t) - p(t - 1) = \pi$, we finally obtain (40).

**Markup.** Equation (30) shows that in steady state the price elasticity of demand is

$$\overline{E} = \epsilon + (\epsilon - 1)\gamma \phi(k^p).$$

Then (32) implies that in steady state the price elasticity $\overline{E}$ and the quasi elasticity $\overline{D}$ are related by

$$\overline{E} = \beta \left[ \overline{E} - (1 - \gamma)\epsilon \right] + (1 - \gamma \beta)\overline{D},$$

so that

$$\overline{D} = \frac{(1 - \beta)\overline{E} + \beta(1 - \gamma)\epsilon}{1 - \gamma \beta}.$$

Using the above expression for $\overline{E}$, we find

$$\overline{D} = \epsilon + (\epsilon - 1) \frac{(1 - \beta)\gamma}{1 - \beta \gamma} \phi(k^p).$$

Using this expression for $\overline{D}$ and (31), which implies that $K = 1 + 1/(\overline{D} - 1)$, we obtain (41).

Finally, since $k^p$ is increasing in $\pi$ (equation (40)) and $\phi$ is an increasing function (lemma 3), equation (41) implies that the markup $K$ is decreasing in inflation $\pi$.

**Appendix B. New Keynesian model**

Section 4 summarizes the properties of a New Keynesian model in which Calvo pricing is replaced by pricing under fairness concerns. Here, we derive these properties and present additional details. We also present the textbook New Keynesian model used as a benchmark in figure 2.

**Behavior of households and firms**

**Household’s problem.** Household $j$ chooses

$$\left\{ W_j(t), N_j(t), [Y_{ij}(t)]_{i=0}^1, B_j(t) \right\}_{t=0}^\infty$$
to maximize utility (19) subject to the budget constraint (20), to the labor-demand constraint $N_j(t) = N^d_j(t, W_j(t))$, and to a solvency condition. Labor demand $N^d_j(t, W_j(t))$ 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 as given $B_j(-1)$, and

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

To solve household $j$’s problem, we set up the Lagrangian:

$$L_j = \mathbb{E}_0 \sum_{t=0}^\infty \beta^t \left\{ \ln(Z_j(t)) - \frac{N_j(t)^{1+\eta}}{1 + \eta} + \mathcal{A}_j(t) \left[ W_j(t)N_j(t) + B_j(t-1) + V_j(t) - Q(t)B_j(t) - \int_0^1 P_i(t)Y_{ij}(t) \, di \right] + \mathcal{B}_j(t) \left[ N^d_j(t, W_j(t)) - N_j(t) \right] \right\}$$

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

**First-order conditions with respect to consumption.** We first compute the first-order conditions with respect to $Y_{ij}(t)$: for all $i \in [0, 1]$, $\partial L_j/\partial Y_{ij}(t) = 0$. We know that

$$\frac{\partial Z_{ij}}{\partial Y_{ij}} = F_i$$

$$\frac{\partial Z_j}{\partial Z_{ij}} = \left( \frac{Z_{ij}}{Z_j} \right)^{-1/\varepsilon} \, di.$$

Hence, the first-order conditions imply that for all $i \in [0, 1]$,

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

(A7)

Manipulating and integrating the conditions (A7) over $i \in [0, 1]$, then using the definitions of $Z_j$ and $X$ given by (17) and (18), we obtain

$$(A8) \quad \mathcal{A}_j(t)X(t) = \frac{1}{Z_j(t)}.$$
Combining (A7) and (A8), we obtain the optimal consumption of good \( i \) for household \( j \):

\[
Y_{ij}(t) = \left[ \frac{P_i(t)}{F_i(t)} \right]^{-\epsilon} \frac{Z_j(t)}{F_i(t)} \frac{X(t)}{Z_j(t)}. \]

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

\[
Y_i(t) = Z(t) \left[ \frac{P_i(t)}{X(t)} \right]^{-\epsilon} \frac{P_i(t)}{MC_i^p(t)} \left[ \frac{\epsilon}{\epsilon - 1} \right]^{1-\gamma} \left[ \frac{P_i(t)}{MC_i^p(t-1)} \right]^\gamma \epsilon^{-1}. \]

Last, substituting \( MC_i^p(t) \) by (16), we obtain the demand for good \( i \):

\[
Y_i^d(t, P_i(t), MC_i^p(t-1)) = Z(t) \left[ \frac{P_i(t)}{X(t)} \right]^{-\epsilon} \frac{P_i(t)}{MC_i^p(t-1)} \left[ \frac{\epsilon}{\epsilon - 1} \right]^{1-\gamma} \left[ \frac{P_i(t)}{MC_i^p(t-1)} \right]^\gamma \epsilon^{-1}. \]

For future reference, the derivatives of the function \( Y_i^d \) are

\[
(A9) \quad -\frac{\partial \ln(Y_i^d)}{\partial \ln(P_i)} = \epsilon + (\epsilon - 1)\gamma \phi(K_i^p(t)) \equiv E_i(t) \]

\[
(A10) \quad \frac{\partial \ln(Y_i^d)}{\partial \ln(MC_i^p)} = (\epsilon - 1)\gamma \phi(K_i^p(t)) = E_i(t) - \epsilon. \]

**First-order condition with respect to bond holdings.** The first-order condition with respect to \( B_j(t) \) is \( \partial \mathcal{L}_j / \partial B_j(t) = 0 \), which gives

\[
Q(t)A_j(t) = \beta E_t[A_j(t + 1)]. \]

Using (A8), we obtain

\[
Q(t) = \beta E_t \left[ \frac{X(t)Z_j(t)}{X(t + 1)Z_j(t + 1)} \right]. \]

**Firm’s problem.** 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

\[
\left\{ P_i(t), Y_i(t), [N_{ij}(t)]_{j=0}^\infty \right\}_{t=0}^\infty \]
to maximize profits (24) subject to the production constraint (21), to the demand constraint (26), and to the law of motion of beliefs (16). The firm takes as given

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

To solve firm i’s problem, we set up the Lagrangian:

\[
\mathcal{L}_i = \mathbb{E}_0 \sum_{t=0}^\infty \Gamma(t) \left\{ P_i(t)Y_i(t) - \int_0^1 W_j(t)N_{ij}(t) \, dj \right. \\
+ C_i(t) \left[ Y^{d_j}(t, P_i(t), MC^\delta_i(t-1)) - Y_i(t) \right] + \mathcal{D}_i(t) \left[ A_i(t)N_i(t)^{\alpha} - Y_i(t) \right] \\
+ \mathcal{E}_i(t) \left[ MC^\delta_i(t-1) \right]^\gamma \left[ \frac{\epsilon - 1}{\epsilon} P_i(t) \right]^{1-\gamma} - MC^\delta_i(t) \right\}
\]

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

**First-order conditions with respect to employment.** We compute the first-order conditions with respect to \( N_{ij}(t) \): for all \( j \in [0, 1] \), \( \partial \mathcal{L}_i / \partial N_{ij}(t) = 0 \). We know that

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

Hence, for all \( j \in [0, 1] \), the first-order conditions give

\[
(W) \quad W_j(t) = \alpha \mathcal{D}_i(t) A_i(t) N_i(t)^{\alpha-1} \left[ \frac{N_{ij}(t)}{N_i(t)} \right]^{-1/\nu}.
\]

Manipulating and integrating the conditions (W) over \( j \in [0, 1] \), then using the definitions of \( N_i \) and \( W \) given by (22) and (23), we obtain

\[
(A) \quad \mathcal{D}_i(t) = \frac{W(t)}{\alpha A_i(t) N_i(t)^{\alpha-1}}.
\]

Combining (W) and (A), 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 $j$:

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

**First-order conditions with respect to labor and wage.** 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 $\partial L_j / \partial N_j(t) = 0$ and $\partial L_j / \partial W_j(t) = 0$, which give

$$N_j(t)^\eta = A_j(t) W_j(t) - B_j(t)$$

$$A_j(t) N_j(t) = -B_j(t) \frac{dN_j^d}{dW_j}.$$

Since the elasticity of $N_j^d(t, W_j)$ with respect to $W_j$ is $-\nu$, we infer from these equations that

$$B_j(t) = \frac{N_j(t)^\eta}{\nu - 1}$$

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

Using (A8), we find that household $j$ sets its wage according to

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

**First-order condition with respect to output.** We then finish solving the problem of firm $i$. The first-order condition with respect to $Y_i(t)$ is $\partial L_i / \partial Y_i(t) = 0$, which gives $P_i(t) = C_i(t) + D_i(t)$. Using (A12), we obtain

$$C_i(t) = P_i(t) \left[ 1 - \frac{W(t)/P_i(t)}{A_i(t)\alpha N_i(t)^{\alpha-1}} \right].$$

Since firm $i$’s nominal marginal cost is

(A13) \[ MC_i(t) = \frac{W(t)}{A_i(t)\alpha N_i(t)^{\alpha-1}}, \]

the first-order condition can be written

$$C_i(t) = P_i(t) \left[ 1 - \frac{MC_i(t)}{P_i(t)} \right].$$
With the quasi elasticity \( D_i(t) = K_i(t)/(K_i(t) - 1) \), we rewrite the first-order condition as

\[
C_i(t) = \frac{P_i(t)}{D_i(t)}.
\]

**First-order condition with respect to price.** The first-order condition of the firm’s problem with respect to \( P_i(t) \) is \( \partial \mathcal{L}_i / \partial P_i(t) = 0 \), which yields

\[
0 = Y_i(t) + C_i(t) \frac{\partial Y_i^d}{\partial P_i} + (1 - \gamma) E_i(t) \frac{MC_i^p(t)}{P_i(t)}.
\]

The condition implies

\[
0 = 1 - \frac{C_i(t)}{P_i(t)} E_i(t) + (1 - \gamma) \frac{E_i(t)}{Y_i(t) K_i^p(t)}.
\]

Combining this equation with (A14) yields

\[
\frac{E_i(t)}{D_i(t)} - 1 = (1 - \gamma) \frac{E_i(t)}{Y_i(t) K_i^p(t)}.
\]

**First-order condition with respect to perceived marginal cost.** Finally, the first-order condition with respect to \( MC_i^p(t) \) is \( \partial \mathcal{L}_i / \partial MC_i^p(t) = 0 \), which gives

\[
0 = \mathbb{E}_t \left[ \frac{\Gamma(t + 1)}{\Gamma(t)} C_i(t + 1) \frac{\partial Y_i^d}{\partial MC_i^p} + \gamma \mathbb{E}_t \left[ \frac{\Gamma(t + 1)}{\Gamma(t)} E_i(t + 1) \frac{MC_i^p(t + 1)}{MC_i^p(t)} \right] - E_i(t) \right].
\]

Multiplying this equation by \( MC_i^p(t)/P_i(t) \), and using (A10), we get

\[
0 = \mathbb{E}_t \left[ \frac{\Gamma(t + 1)}{\Gamma(t)} C_i(t + 1) Y_i(t + 1)(E_i(t + 1) - \epsilon) + \gamma \frac{\Gamma(t + 1)}{\Gamma(t) P_i(t)} E_i(t + 1) MC_i^p(t + 1) \right] - E_i(t) \frac{MC_i^p(t)}{P_i(t)}.
\]

This equation is simplified in a symmetric equilibrium, where \( P_i(t) = P(t), Z(t) = F(t)Y(t), \) and \( X(t) = P(t)/F(t) \). Using \( \Gamma(t) = \beta X(0)Z(0)/[X(t)Z(t)] \), we find that in such equilibrium,

\[
\frac{\Gamma(t + 1)}{\Gamma(t) P_i(t)} = \beta \frac{X(t)}{X(t + 1) P(t)} \cdot \frac{Z(t)}{Z(t + 1)} = \frac{\beta}{P(t + 1)} \cdot \frac{Y(t)}{Y(t + 1)}.
\]

Hence, the equation simplifies to

\[
0 = \beta \mathbb{E}_t \left[ C(t + 1) \frac{Y(t)}{P(t + 1)}(E(t + 1) - \epsilon) + \gamma E(t + 1) \frac{Y(t)}{Y(t + 1)} \frac{MC^p(t + 1)}{P(t + 1)} \right] - E_i(t) \frac{MC_i^p(t)}{P(t)}.
\]
Using (A14) and \( K^p(t) = P(t)/MC^p(t) \), and dividing by \( Y(t) \), we now obtain
\[
0 = \beta \mathbb{E}_t \left[ \frac{E(t + 1) - \varepsilon}{D(t + 1)} + \gamma \frac{E(t + 1)}{Y(t + 1)K^p(t + 1)} \right] - \frac{E(t)}{Y(t)K^p(t)}.
\]

Finally, multiplying by \( 1 - \gamma \) and using (A15), we get
\[
0 = \beta \mathbb{E}_t \left[ (1 - \gamma) \frac{E(t + 1) - \varepsilon}{D(t + 1)} + \gamma \frac{E(t + 1)}{D(t + 1)} - \gamma \right] = \frac{E(t)}{D(t)} + 1.
\]

Rearranging the terms, we finally obtain
\[
\beta \mathbb{E}_t \left[ \frac{E(t + 1) - (1 - \gamma)\varepsilon}{D(t + 1)} \right] = \frac{E(t)}{D(t)} - (1 - \gamma \beta).
\]

This equation gives the quasi elasticity \( D(t) \) and thus the markup \( K(t) \).

**Equilibrium**

We derive the dynamical system describing a symmetric equilibrium. This system comprises three equation: law of motion for the perceived markup, IS equation, and Phillips curve.

**Law of motion for perceived markup.** We first rework the law of motion for the perceived marginal cost \( MC^p(t) \), given by (16), to obtain a law of motion for the perceived markup, \( K^p(t) = P(t)/MC^p(t) \):
\[
K^p(t) = \left( \frac{\varepsilon}{\varepsilon - 1} \right)^{1-\gamma} [K^p(t - 1)]^\gamma \left[ \frac{P(t)}{P(t - 1)} \right]^\gamma.
\]

Taking the log of this equation, and using \( \pi(t) = p(t) - p(t - 1) \), we find
\[
(A16) \quad k^p(t) = (1 - \gamma) \ln \left( \frac{\varepsilon}{\varepsilon - 1} \right) + \gamma \left[ \pi(t) + k^p(t - 1) \right].
\]

Subtracting the steady-state values of both sides yields
\[
(A17) \quad \tilde{k}^p(t) = \gamma \left[ \tilde{\pi}(t) + \tilde{k}^p(t - 1) \right].
\]
**IS equation.** We begin by computing a log-linear approximation of the Euler equation (29), as in Gali (2008, pp. 35–36):

\[
y(t) = E_t[y(t+1)] + E_t[\pi(t+1)] + \rho - i(t),
\]

where \(\rho = -\ln(\beta)\) is the time discount rate. Combining this equation with the monetary-policy rule (25) yields

\[
y(t) + \mu \pi(t) = E_t[y(t+1)] + E_t[\pi(t+1)] + \rho - i_0(t).
\]

Subtracting the steady-state values of both sides, we obtain

(A18) \(\hat{y}(t) + \mu \hat{\pi}(t) = E_t[\hat{y}(t+1)] + E_t[\hat{\pi}(t+1)] - \hat{i}_0(t)\).

Then, the log-linear version of the production function (21) is

(A19) \(\hat{y}(t) = \hat{a}(t) + \alpha \hat{n}(t)\).

Combining (A18) with (A19) yields the IS equation:

(A20) \(\alpha \hat{n}(t) + \mu \hat{\pi}(t) = \alpha E_t[\hat{n}(t+1)] + E_t[\hat{\pi}(t+1)] - \hat{i}_0(t) - \hat{a}(t) + E_t[\hat{a}(t+1)]\).

**Phillips curve.** As a first step toward computing the Phillips curve, we obtain a log-linear approximation of the price elasticity (30):

(A21) \(\hat{e}(t) = \Omega_0 \hat{k}p(t)\),

where

\[
\Omega_0 = \frac{\left(\frac{E - \epsilon}{E}\right) \bar{X}}{E} = \frac{(\epsilon - 1)\gamma \frac{\phi}{X}}{\epsilon + (\epsilon - 1)\gamma \phi}.
\]

We then compute a log-linear approximation of the quasi elasticity \(D = K/(K - 1)\):

\(\hat{d}(t) = -\Omega_1 \hat{k}(t)\),

where

\[
\Omega_1 = \frac{K}{K - 1} - 1 = \frac{1}{K - 1} = (\epsilon - 1) \left[ 1 + \frac{(1 - \beta)\gamma \frac{\phi}{X}}{1 - \beta \gamma} \right].
\]
(We have used (41) to get the value of $K$.) The log-linear version of (33) is
\[ \hat{k}(t) = -(1 + \eta) \hat{n}(t). \]
Hence, we obtain
\begin{equation}
\hat{d}(t) = (1 + \eta) \Omega_2 \hat{n}(t).
\end{equation}

The next step is to compute a log-linear approximation of the pricing equation (32):
\begin{equation}
\hat{e}(t) - \hat{d}(t) = \Omega_3 \mathbb{E}_t [\hat{e}(t + 1)] - \Omega_2 \mathbb{E}_t [\hat{d}(t + 1)],
\end{equation}
where
\begin{align*}
\Omega_3 &= \left[ \frac{\bar{E} - (1 - \gamma \beta) \bar{D}}{\bar{E}} \right] \left[ \frac{\bar{E}}{\bar{E} - (1 - \gamma) \epsilon} \right] = \beta \\
\Omega_2 &= \frac{\bar{E} - (1 - \gamma \beta) \bar{D}}{\bar{E}} = \beta \gamma \frac{\epsilon + (\epsilon - 1) \bar{\phi}}{\epsilon + (\epsilon - 1) \gamma \bar{\phi}}.
\end{align*}
To simplify $\Omega_3$ and $\Omega_2$, we combine $D = K/(K - 1)$, (41), and (30), which yields in turn
\begin{align*}
\bar{D} &= 1 + (\epsilon - 1) \left[ 1 + \frac{(1 - \beta) \bar{\gamma} \bar{\phi}}{1 - \beta \gamma \bar{\phi}} \right] \\
(1 - \gamma \beta) \bar{D} &= (1 - \gamma \beta) + (\epsilon - 1) \left[ (1 - \gamma \beta) + (1 - \beta) \bar{\gamma} \bar{\phi} \right] \\
(1 - \gamma \beta) \bar{D} &= (1 - \gamma \beta) \epsilon + (\epsilon - 1)(1 - \beta) \gamma \bar{\phi} \\
\bar{E} - (1 - \gamma \beta) \bar{D} &= \beta \gamma \left[ \epsilon + (\epsilon - 1) \bar{\phi} \right].
\end{align*}
We also use (30), which implies
\[ \bar{E} - (1 - \gamma) \epsilon = \gamma \left[ \epsilon + (\epsilon - 1) \bar{\phi} \right]. \]

Then, combining (A21), (A22), and (A23), we obtain
\begin{equation}
\Omega_0 \hat{k}(t) - (1 + \eta) \Omega_1 \hat{n}(t) = \beta \Omega_0 \mathbb{E}_t \left[ \hat{k}(t + 1) \right] - (1 + \eta) \Omega_1 \Omega_2 \mathbb{E}_t \left[ \hat{n}(t + 1) \right].
\end{equation}
We define

\[
\lambda_1 = (1 + \eta) \frac{\Omega_1}{\Omega_0} = (1 + \eta) \frac{\epsilon + (\epsilon - 1) \gamma \phi}{\gamma \phi X} \left[ 1 + \frac{(1 - \beta) \gamma \phi}{1 - \beta \gamma} \right] \\
\lambda_2 = (1 + \eta) \frac{\Omega_1 \Omega_2}{\Omega_0} = (1 + \eta) \beta \frac{\epsilon + (\epsilon - 1) \phi}{\phi X} \left[ 1 + \frac{(1 - \beta) \gamma \phi}{1 - \beta \gamma} \right].
\]

Dividing (A24) by \( \Omega_0 \) and using the definitions of \( \lambda_1 \) and \( \lambda_2 \) yields the Phillips curve:

(A25) \[ \lambda_1 \hat{n}(t) = (1 - \beta \gamma) \hat{k}(t) - \beta \gamma \mathbb{E}_t[\hat{\pi}(t + 1)] + \lambda_2 \mathbb{E}_t[\hat{n}(t + 1)]. \]

**Dynamical system.** Finally, we combine (A17), (A20), and (A25) to obtain the dynamical system describing the equilibrium:

\[
\begin{bmatrix} \gamma & \gamma & 0 \\ 0 & \mu & \alpha \\ 0 & 0 & \lambda_1 \end{bmatrix} \begin{bmatrix} \hat{k}(t) \\ \hat{\pi}(t) \\ \hat{n}(t) \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & \alpha \\ 1 - \beta \gamma & -\beta \gamma & \lambda_2 \end{bmatrix} \begin{bmatrix} \mathbb{E}_t[\hat{\pi}(t + 1)] \\ \mathbb{E}_t[\hat{n}(t + 1)] \end{bmatrix} - \begin{bmatrix} 0 \end{bmatrix} + \begin{bmatrix} \hat{\pi}(t - 1) \\ \hat{n}(t) \\ \hat{n}(t) \end{bmatrix} \cdot \begin{bmatrix} \epsilon(t) \end{bmatrix},
\]

where

\[ \epsilon(t) = \hat{i}_0(t) + \hat{a}(t) + \mathbb{E}_t[\hat{a}(t + 1)] \]

is an exogenous shock realized at time \( t \). The inverse of the matrix on the right-hand side is

\[
\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & \alpha \\ 1 - \beta \gamma & -\beta \gamma & \lambda_2 \end{bmatrix}^{-1} = \begin{bmatrix} 1 & 0 & 0 \\ \frac{(1 - \beta \gamma) \alpha}{\lambda_2 + \alpha \beta \gamma} & \frac{-\alpha}{\lambda_2 + \alpha \beta \gamma} & \frac{-\alpha}{\lambda_2 + \alpha \beta \gamma} \\ \frac{\beta \gamma - 1}{\lambda_2 + \alpha \beta \gamma} & \frac{\beta \gamma}{\lambda_2 + \alpha \beta \gamma} & \frac{1}{\lambda_2 + \alpha \beta \gamma} \end{bmatrix}.
\]

Premultiplying the dynamical system by the inverse matrix, we rewrite the system as follows:

\[
\begin{bmatrix} \hat{k}(t) \\ \mathbb{E}_t[\hat{\pi}(t + 1)] \\ \mathbb{E}_t[\hat{n}(t + 1)] \end{bmatrix} = A \begin{bmatrix} \hat{k}(t - 1) \\ \hat{\pi}(t) \\ \hat{n}(t) \end{bmatrix} + B \cdot \epsilon(t)
\]

where

\[
A = \begin{bmatrix} \gamma & \gamma & 0 \\ \frac{(1 - \beta \gamma) \alpha}{\lambda_2 + \alpha \beta \gamma} & \frac{\lambda_2 + \alpha \beta \gamma}{\lambda_2 + \alpha \beta \gamma} & \frac{(1 - \beta \gamma) \alpha}{\lambda_2 + \alpha \beta \gamma} \\ \frac{-\alpha (\lambda_2 - \lambda_1) \alpha}{\lambda_2 + \alpha \beta \gamma} & \frac{\lambda_2 - \lambda_1}{\lambda_2 + \alpha \beta \gamma} & \frac{\lambda_2 + \alpha \beta \gamma}{\lambda_2 + \alpha \beta \gamma} \end{bmatrix}
\]

and

\[
B = \begin{bmatrix} 0 \\ \frac{\lambda_2}{\lambda_2 + \alpha \beta \gamma} \\ \frac{\beta \gamma}{\lambda_2 + \alpha \beta \gamma} \end{bmatrix}.
\]
This dynamical system determines employment $\hat{n}(t)$, inflation $\hat{\pi}(t)$, and perceived markup $\hat{k}(t)$. Equations (21), (25), and (33) then give the other variables: output is given by $\hat{y}(t) = \hat{a}(t) + \alpha \hat{n}(t)$; the nominal and real interest rates by $\hat{i}(t) = \hat{i}_0(t) + \mu \hat{\pi}(t)$ and $\hat{r}(t) = \hat{i}_0(t) + (\mu - 1) \hat{\pi}(t)$; and the markup by $\hat{k}(t) = -(1 + \eta) \hat{n}(t)$.

**Calibration**

Using the derivations above, we study the behavior of a single firm $i$ that faces an exogenous demand curve and a stochastic marginal cost. This is a simplified version of the firm problem in the New Keynesian model, abstracting from hiring decisions. The objective is to calibrate three key parameters of the New Keynesian model—$\epsilon$, $\xi$, and $\gamma$—by matching the dynamics of the marginal-cost passthrough obtained in simulation to those estimated in the data.

**Firm’s problem.** Firm $i$ chooses $\{P_i(t), Y_i(t)\}_{t=0}^{\infty}$ to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [P_i(t) - MC_i(t)] Y_i(t),$$

subject to the demand constraint

$$(A26) \quad Y_d^i(P_i(t), MC_i^p(t-1)) = ZP_i(t)^{-\epsilon} \frac{\epsilon}{\epsilon - 1} \left( \frac{MC_i^p(t-1)}{P_i(t)} \right)^{\epsilon - 1}.$$

and to the law of motion of beliefs (16). The level of aggregate demand, $Z$, is exogenous and constant. The nominal marginal cost, $MC_i(t)$, is exogenous and stochastic. Since we assume that there is no underlying inflation, $MC_i(t)$ is constant in steady state.

To solve the firm’s problem, we set up the Lagrangian:

$$\mathcal{L}_i = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ [P_i(t) - MC_i(t)] Y_i(t) \right. \right.$$

$$\left. \left. + C_i(t) \left[ Y_d^i(P_i(t), MC_i^p(t-1)) - Y_i(t) \right] \right. \right.$$

$$\left. \left. + \mathcal{E}_i(t) \left[ MC_i^p(t-1) \right]^\gamma \left[ \frac{\epsilon - 1}{\epsilon} P_i(t) \right]^{1-\gamma} - MC_i^p(t) \right\} \right.$$

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

First-order condition with respect to output. The first-order condition with respect to \( Y_i(t) \) is \( \partial \mathcal{L}_i/\partial Y_i(t) = 0 \). It yields

\[
C_i(t) = P_i(t) \left[ 1 - \frac{MC_i(t)}{P_i(t)} \right].
\]

Using the markup \( K_i(t) = P_i(t)/MC_i(t) \) and the quasi elasticity \( D_i(t) = K_i(t)/(K_i(t) - 1) \), we rewrite the condition:

(A27) \[
C_i(t) = \frac{P_i(t)}{D_i(t)}.
\]

First-order condition with respect to price. The first-order condition with respect to \( P_i(t) \) is \( \partial \mathcal{L}_i/\partial P_i(t) = 0 \), which gives

\[
0 = Y_i(t) + C_i(t) \frac{\partial Y^d_i}{\partial P_i} + (1 - \gamma)E_i(t) \frac{MC^p_i(t)}{P_i(t)}.
\]

Using (A9), we infer

\[
0 = 1 - \frac{C_i(t)}{P_i(t)} E_i(t) + (1 - \gamma) \frac{E_i(t)}{Y_i(t)} \cdot \frac{MC^p_i(t)}{P_i(t)}.
\]

Combining this equation with (A27) leads to

(A28) \[
\frac{E_i(t)}{D_i(t)} - 1 = (1 - \gamma) \frac{E_i(t)}{Y_i(t)} \cdot \frac{MC^p_i(t)}{P_i(t)}.
\]

First-order condition with respect to perceived marginal cost. Finally, the first-order condition with respect to \( MC^p_i(t) \) is \( \partial \mathcal{L}_i/\partial MC^p_i(t) = 0 \), which yields

\[
0 = \beta E_i \left[ C_i(t + 1) \frac{\partial Y_i^d}{\partial MC^p_i} + \gamma E_i(t + 1) \frac{MC^p_i(t + 1)}{MC^p_i(t)} \right] - E_i(t).
\]

Multiplying the equation by \( (1 - \gamma)MC^p_i(t) \), and using (A10), we get

\[
(1 - \gamma)E_i(t)MC^p_i(t) = \beta E_i \left[ (1 - \gamma)C_i(t + 1)Y_i(t + 1) (E_i(t + 1) - \epsilon) + \gamma (1 - \gamma)E_i(t + 1)MC^p_i(t + 1) \right].
\]

Using both (A27) and (A28), the equation then becomes

\[
\frac{Y_i(t)P_i(t)}{D_i(t)} \left[ E_i(t) - D_i(t) \right] = \beta E_i \left[ \frac{Y_i(t + 1)P_i(t + 1)}{D_i(t + 1)} \left[ (1 - \gamma) (E_i(t) - \epsilon) + \gamma (E_i(t + 1) - D_i(t + 1)) \right] \right].
\]
The passthrough simulations are obtained from the pricing model in appendix B, under the calibration in table 4. The passthrough estimates are discussed in section 4.4.

We denote the profits of firm $i$ in period $t$ by $V_i(t) = [P_i(t) - MC_i(t)] Y_i(t)$. We have

$$V_i(t) = Y_i(t) P_i(t) \left[ 1 - \frac{MC_i(t)}{P_i(t)} \right] = Y_i(t) P_i(t) \left[ 1 - \frac{1}{K_i(t)} \right] = \frac{Y_i(t) P_i(t)}{D_i(t)}.$$  

Thus, the first-order condition simplifies to

$$V_i(t) [E_i(t) - D_i(t)] = \beta E_i(t) [V_i(t + 1) [E_i(t) - (1 - \gamma)\varepsilon - \gamma D_i(t + 1)]].$$  

**Equilibrium.** The eight equilibrium variables $P_i(t)$, $MC_i^p(t)$, $Y_i(t)$, $V_i(t)$, $K_i(t)$, $K_i^p(t)$, $E_i(t)$, and $D_i(t)$. The eight equilibrium conditions describing firm $i$'s pricing are (16), (A26), (A29), (A30), $D_i(t) = K_i(t)/(K_i(t) - 1)$, $E_i(t) = \epsilon + (\epsilon - 1)\gamma \phi(K_i^p(t))$, $K_i^p(t) = P_i(t)/MC_i^p(t)$, and $K_i(t) = P_i(t)/MC_i(t)$.

**Simulations.** We assume that the firm is in steady state for some marginal cost $MC_i$ and impose at time 0 an unexpected and permanent one-percent increase in $MC_i$. (The steady-state values of the variables are the same as in the New Keynesian model.) We compute the response of the variables to this shock by solving the nonlinear dynamical system of eight equations representing the equilibrium (using Dynare). Dynamics of the marginal-cost passthrough are then obtained by
computing the percentage change of firm $i$’s price over time:

$$\sigma_i(t) = \frac{P_i(t) - \bar{P}_i}{\bar{P}_i} \times 100.$$ 

**Calibration procedure.** Our goal is to calibrate three parameters of the model: the elasticity of substitution between goods, $\epsilon$, the concern for fairness, $\xi$, and the degree of underinference, $\gamma$. We aim to calibrate the model such that it produces a marginal-cost passthrough of 0.4 on impact and 0.7 after two years, and a steady-state markup of 1.5.

Our calibration procedure starts by initializing $\xi$ and $\gamma$ to some values. Then we compute $\epsilon$ using these values, (41), and $\bar{K} = 1.5$. Since we focus on a zero-inflation steady state, (40) implies that $\bar{K} = \epsilon / (\epsilon - 1)$ and $\bar{F} = 1$; therefore, we have $\phi(\bar{K}) = \xi \epsilon / (\epsilon - 1)$ in (41).

Using the values of $\xi$, $\gamma$, and $\epsilon$, we simulate passthrough dynamics. We repeat the simulation for different values of $\xi$ and $\gamma$ until we obtain a passthrough of 0.4 on impact and 0.7 after two years. We reach these targets with $\xi = 9$ and $\gamma = 0.8$; the corresponding value of $\epsilon$ is 2.2. The simulated passthrough dynamics under this calibration are displayed in figure A1.

**Textbook model**

We describe the textbook New Keynesian model used as benchmark in the simulations. The model is borrowed from Gali (2008, chap. 3).

Dynamics around the zero-inflation steady state are determined by two difference equations: the IS equation and the Phillips curve. The IS equation is given by (34), as in the model with fairness. This IS equation is equivalent to equation (12) in Gali (2008, chap. 3), but it also incorporates the production function (21) and monetary-policy rule (25), and it is simplified by assuming log consumption utility.

The Phillips curve is given by

$$\pi(t) = \beta \mathbb{E}_t[\pi(t + 1)] + \kappa \alpha \pi(t)$$

where

$$\kappa \equiv \frac{1 + \eta}{\alpha} \cdot \frac{(1 - \theta)(1 - \beta \theta)}{\theta} \cdot \frac{\alpha}{\alpha + (1 - \alpha) \epsilon},$$

and $\theta$ is the fraction of firms keeping their prices unchanged each period. The Phillips curve is not the same as in the model with fairness because pricing is different. The Phillips curve is obtained from equation (16) in Gali (2008, chap. 3), using log consumption utility. One of the
implications of log utility is that the output gap in (16) is equal to $\alpha \nabla(t)$.\footnote{The output gap is the gap between the actual and natural levels of output. The natural level of output is reached when prices are flexible, so when the markup is $\epsilon/(\epsilon - 1)$. But when the markup is $\epsilon/(\epsilon - 1)$, which is the steady-state markup, employment is at its steady-state level (equation (33)). Hence, using (21), we infer that log of natural output is $y^\nabla(t) = a(t) + \alpha \nabla$, while log of output is $y(t) = a(t) + \alpha n(t)$, so the output gap is $y(t) - y^\nabla(t) = \alpha \nabla$.}

The IS equation and Phillips curve jointly determine employment $\nabla(t)$ and inflation $\pi(t)$. The other variables directly follow. The real interest rate is given by the monetary-policy rule (25): $\hat{r}(t) = \hat{i}_0(t) + (\mu - 1)\pi(t)$. The markup is given by (33): $\hat{k}(t) = -(1 + \eta)\nabla(t)$. Since households observe both prices and costs in the textbook model, perceived and actual markups are equal: $\hat{k}^p(t) = \hat{k}(t)$. Last, output is given by the production function (21): $\hat{y}(t) = a(t) + \alpha \nabla(t)$.\footnote{The output gap is the gap between the actual and natural levels of output. The natural level of output is reached when prices are flexible, so when the markup is $\epsilon/(\epsilon - 1)$. But when the markup is $\epsilon/(\epsilon - 1)$, which is the steady-state markup, employment is at its steady-state level (equation (33)). Hence, using (21), we infer that log of natural output is $y^\nabla(t) = a(t) + \alpha \nabla$, while log of output is $y(t) = a(t) + \alpha n(t)$, so the output gap is $y(t) - y^\nabla(t) = \alpha \nabla$.}