Pricing under Fairness Concerns

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This paper proposes a theory of pricing based on two facts: customers care about the fairness of prices, and firms take these concerns into account when setting prices. The theory assumes that customers dislike unfair prices, namely those marked up steeply over cost. Since costs are unobservable, customers must extract them from prices. The theory assumes that customers infer less than rationally: when a price rises after a cost increase, customers partially misattribute the higher price to a higher markup—which they find unfair. Firms anticipate this response and trim their price increases, which drives the passthrough of costs into prices below one: prices are somewhat rigid. Embedded in a New Keynesian model as a replacement for the usual pricing frictions, our theory produces monetary-policy nonneutrality: when monetary policy loosens and inflation rises, customers misperceive markups as higher and feel unfairly treated; firms mitigate this perceived unfairness by reducing their markups; in general equilibrium, employment rises. The New Keynesian model also features a hybrid short-run Phillips curve, realistic impulse responses of output and employment to monetary and technology shocks, and an upward-sloping long-run Phillips curve.
1. Introduction

Prices are neither exactly fixed nor fully responsive to cost shocks (Carlsson and Skans 2012; De Loecker et al. 2016; Caselli, Chatterjee, and Woodland 2017; Ganapati, Shapiro, and Walker 2019). Such price rigidity is of first-order importance, as it determines the transmission of shocks and government policies to the economy.

Asked why they show such restraint when setting prices, firm managers explain that they avoid alienating customers, who balk at paying prices that they regard as unfair (Blinder et al. 1998). Yet theories of price rigidity almost never include fairness considerations (Blanchard 1990; Mankiw and Reis 2010).¹ The notable exception is Rotemberg (2005), which calls attention to the role of fairness in pricing. Due to its innovative nature, however, the theory itself is somewhat difficult to analyze or use in other frameworks (see section 2).

This paper therefore develops a pricing theory that incorporates the fairness concerns observed among firms and their customers and uses such concerns to generate the price rigidity observed in the data. The theory is designed to be easy to analyze, permitting closed-form expressions for price markups and passthroughs, as well as a set of comparative statics. It is also designed for easy transferal to other frameworks: here, we port it to a New Keynesian model to study its macroeconomic implications.

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 3). We formalize this assumption by weighting each unit of consumption in the utility function by a fairness factor that is a function of the markup that customers perceive firms to charge for the consumed good: the fairness factor 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’ costs but need them to assess markups, their fairness perceptions depend upon their cost estimates. The second element of our theory is that customers update their beliefs about marginal costs less than rationally. First, customers 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 customers do update their beliefs about marginal cost from price, they engage in a form of proportional thinking by estimating marginal costs that

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¹Fairness 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 fairness literature, see Fehr and Gachter (2000), Sobel (2005), and Fehr, Goette, and Zehnder (2009).
are proportional to price. We dub this pair of assumptions subproportional inference. They draw 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 (see also section 3).

We begin our analysis by embedding these psychological elements into a model of monopoly pricing (section 4). The monopolist's profit-maximizing price features a markup over marginal cost that decreases in the price elasticity of demand. We assume a standard utility function with the property that customers who did not care about fairness would exhibit constant price elasticity of demand. The monopolist best responds by using a constant markup that produces flexible prices, which move proportionally to marginal costs. If customers cared about fairness and rationally inverted price to uncover the hidden marginal cost, the same pricing rule would be an equilibrium. The reason is that when price increases by $x\%$, customers correctly 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 subproportional inference are combined, however, pricing changes. Demand decreases in price not only 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, which further decreases demand. This renders demand more elastic than it would be otherwise, leading the monopoly to lower its markup.

Second, fairness concerns and subproportional inference create price rigidity. After a price increase spurred by a cost increase, customers underappreciate the increase in marginal cost and partially misattribute the higher price 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 demand, which is more price elastic at higher perceived markups. Hence, after the cost increase, the monopoly reduces 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 empirical studies.

Theories of price rigidity are central to macroeconomic models. To illustrate how our theory can be embedded into such a model, and develop its implications, we substitute it for the usual pricing frictions in a New Keynesian model (section 5). Again we assume that customers infer less than they should about marginal cost from price. In the dynamic model, subproportional inference means that in each period $t$, customers average their period-$t-1$ beliefs about marginal
costs with beliefs that are proportional to current prices.

The macroeconomic model yields several realistic properties. First, monetary policy is non-neutral in the short run: 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 demands for goods rise; firms respond by reducing markups, thus stimulating the economy. Second, the New Keynesian Phillips curve is hybrid: it links current employment to not only current and expected future inflation but also past inflation. This property emerges because beliefs about marginal costs are backward-looking, forcing firms to account for both past and future inflation when setting prices. Third, the model yields reasonable impulse responses to monetary shocks and to technology shocks when the parameters governing fairness concerns and subproportional inference are calibrated to match the microevidence on passthrough. In particular, the impulse responses of employment are hump-shaped. Fourth, monetary policy is nonneutral in the long run: higher steady-state inflation leads to higher steady-state employment; that is, the long-run Phillips curve is nonvertical.

Our macroeconomic model is also consistent with survey evidence that inflation angers people—who attribute it to commercial greed—and that people appreciate deflation. In our model, because people partially misattribute higher prices to higher markups, inflation leads them to perceive transactions as less fair, generating disutility. Conversely, deflation leads people to misperceive markups as lower and deem transactions more fair, generating utility.

2. Related literature

Rotemberg (2005) developed the first theory of price rigidity based on fairness considerations. Customers in his model 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. Our continuous formulation seems more realistic and offers greater tractability. Its tractability allows us to obtain closed-form expressions for the markup and passthrough, and thus to perform a range of comparative-statics exercises. The tractability also allows us to embed our pricing

\footnote{Rotemberg (2011) explores other implications of fairness for pricing, such as price discrimination.}
theory into a standard New Keynesian model, to calibrate the theory’s parameters based on microevidence, and to perform standard simulations.

More broadly, our approach to fairness differs from the popular social-preferences approach, developed by Rabin (1993) and Fehr and Schmidt (1999), and used by Rotemberg. That approach models people as caring about one another’s payoffs, whether positively or negatively, leading a consumer who feels unfairly treated by a firm to withhold demand to hurt the firm’s profits. In our model, by contrast, because customers simply fail to savor unfairly priced goods, they withhold demand irrespective of whether it harms the firm. An advantage of our approach, which appears 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 others’ allocations, social preferences do not affect general-equilibrium prices or allocations (Dufwenberg et al. 2011; Sobel 2007).

3. Microevidence 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 erroneously infer marginal costs from prices and thus misperceive markups. Finally, we show that firms account for customers’ fairness concerns when they set prices.

3.1. Customers’ fairness concerns

Our theory assumes that customers deem a price to be unfair when it entails a high markup over marginal cost, and that they dislike such prices. 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

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) 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/GQ/two.lf/eight.lf-JMFC).

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 (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 (such as a hurricane or an epidemic). But by exempting price increases justified by higher costs, the legislation only outlaws price increases caused by higher markups (Rotemberg 2009, pp. 74–77).

**Fairness and willingness to pay.** We assume that customers who purchase a good at an unfair price derive less utility from consuming it; as a result, unfair pricing reduces 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 also suggests that customers 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.

3.2. Subproportional inference of costs

Customers do not observe firms’ marginal costs. Consequently, their perception of the fairness of firms’ prices depends upon their estimates of these costs. Since customers cannot easily learn about hidden costs, however, they are prone to develop mistaken beliefs. To describe such misperceptions, we assume subproportional inference. First, consumers underinfer marginal cost from price: they form beliefs that depend upon some anchor. Second, insofar as consumers do update their beliefs about cost from price, they engage in a form of proportional thinking by estimating marginal costs that are proportional to price. We now review evidence that supports this pair of assumptions.

Underinference in general. Numerous experimental studies establish that people underinfer other people’s information from those other people’s actions (Eyster 2019). In the context of bilateral bargaining with asymmetric information, Samuelson and Bazerman (1985), Holt and Sherman (1994), Carillo and Palfrey (2011), and others show 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 metastudy 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 encompasses such underinference.

Underinference from 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
Table 1. Opinions about price movements in Japan, 2001–2017

<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/.

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 from inflation and deflation. In our model, customers dislike inflation because it leads them to perceive higher markups; conversely, they enjoy deflation because it leads them to perceive lower markups. An opinion poll conducted by the Bank of Japan between 2001 and
### 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>

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 (Bushong, Rabin, and Schwartzstein 2017). In particular, 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 the absolute savings, people appear to care about the proportional savings. Someone who thinks about a price discount not in absolute terms but as a proportion of the purchase price may think about marginal cost not in absolute terms but rather as a percentage of price. If so, then the simplest assumption is that, insofar as the person infers marginal cost from price, she infers a marginal cost proportional to price.

### 3.3. Firms’ fairness concerns

In our model, in response to their customers’ fairness concerns, 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 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. We sampled bakeries in cities and villages around Grenoble, Aix-en-Provence, Paimpol, and Paris. 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.

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3In 2005, bakeries employed 148,000 workers, for a yearly turnover of 3.2 billion euros (Fraichard 2006). Since 1978, French bakers have been free to set their own prices, except during the inflationary period 1979–1987 when price ceilings and growth caps were imposed. For centuries, bread prices caused major social upheaval in France. Miller (1999, p. 35) explains that before the French Revolution, “affordable bread prices underlay any hopes for urban tranquility.” During the Flour War 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).
Survey respondents rated the relevance of several pricing theories to explain price rigidity at their own firm. The table ranks common theories 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 $999) 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 Kwapil, Bumgartner, and Schärler (2005); table 18 in Aucravenne and Druant (2005); table 6.1 in Loupias and Ricart (2004); table 8 in Lunneemann 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 Vignisdottr (2011).

### Table 3. Ranking of pricing theories in firm surveys

<table>
<thead>
<tr>
<th>Theory</th>
<th>Country of survey</th>
<th>Overall rank</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>US</td>
<td>GB</td>
<td>SE</td>
</tr>
<tr>
<td>Implicit contracts</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Nominal contracts</td>
<td>5</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Coordination failure</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Pricing points</td>
<td>8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Menu costs</td>
<td>6</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Information delays</td>
<td>11</td>
<td>–</td>
<td>13</td>
</tr>
</tbody>
</table>

Survey respondents rated the relevance of several pricing theories to explain price rigidity at their own firm. The table ranks common theories 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 $999) 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 Kwapil, Bumgartner, and Schärler (2005); table 18 in Aucravenne and Druant (2005); table 6.1 in Loupias and Ricart (2004); table 8 in Lunneemann 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 Vignisdottr (2011).
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 summer tourist season (again, when demand rises), or during the holiday absences of local competitors (when demand and market power rise), because it would be unfair—and hence anger and drive away customers.

4. Monopoly model

We extend a simple model of monopoly pricing to include fairness concerns and subproportional inference, along the lines described in section 3. 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.

4.1. Assumptions

A monopoly sells a good to a representative customer. The monopoly cannot price-discriminate, so each unit of 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 at price $P$ is given by a belief function $C^P(P)$. For simplicity, we restrict $C^P(P)$ to be deterministic. Having inferred the marginal cost, the customer deduces that the markup charged by the monopoly is

$$M^P(P) = \frac{P}{C^P(P)}.$$

The perceived markup determines the fairness of the transaction through a fairness function $F(M^P) > 0$. Both functions $C^P(P)$ and $F(M^P)$ are assumed to be twice differentiable.

A customer who buys a quantity $Y$ of the good at price $P$ experiences the fairness-adjusted consumption

$$Z = F(M^P(P)) \cdot Y.$$

The customer also faces a budget constraint:

$$P \cdot Y + B = W,$$

where $W > 0$ designates initial wealth, and $B$ designates remaining money balances. Fairness-
adjusted consumption and money balances enter a quasilinear utility function

\[ \frac{\epsilon}{\epsilon - 1} \cdot Z^{(\epsilon-1)/\epsilon} + B, \]

where the parameter \( \epsilon > 1 \) governs the concavity of the utility function. Given fairness factor \( F \) and price \( P \), the customer chooses purchases \( Y \) and money balances \( B \) to maximize utility subject to the budget constraint.

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

### 4.2. Demand and pricing

We begin by determining customers’ demand for the monopoly good. The customer chooses purchases \( Y \) to maximize utility

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

The customer’s utility function is strictly concave so the following first-order condition gives its global maximum:

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

This first-order condition yields the demand curve

\[ Y^d(P) = P^{-\epsilon} \cdot F(M^p(P))^{\epsilon^{-1}}. \]

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

We turn to the monopoly’s pricing. The monopoly chooses price \( P \) to maximize profits \((P - C) \cdot Y^d(P)\). The first-order condition is

\[ Y^d(P) + (P - C) \frac{dY^d}{dP} = 0. \]

We introduce the price elasticity of demand, normalized to be positive:

\[ E = \frac{d \ln(Y^d)}{d \ln(P)} = -\frac{P}{Y^d} \frac{dY^d}{dP}. \]
The first-order condition then yields the classical result that

\[ P = \frac{E}{E - 1} \cdot C; \]

that is, the monopoly optimally sets its price at a markup \( M = E/(E - 1) \) over marginal cost.4

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

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

where \( \phi = -d \ln(F)/d \ln(M^p) \) 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, \( (\epsilon - 1) \cdot \phi \cdot [1 - d \ln(C^p)/d \ln(P)] \), represents the fairness channel and splits into two subterms. The first subterm, \( (\epsilon - 1) \cdot \phi \), appears because a higher price mechanically raises the perceived markup and thus reduces fairness. The second subterm, \( -(\epsilon - 1) \cdot \phi \cdot [d \ln(C^p)/d \ln(P)] \), appears because a higher price conveys information about the marginal cost and thus influences perceived markup and fairness. We now use (2) to compute the markup in various situations.

### 4.3. 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 \( F(M^p) = 1 \).*

Without fairness concerns, the fairness function is constant, so its elasticity is \( \phi = 0 \). According to (2), the price elasticity of demand is therefore constant: \( E = \epsilon \). This implies that the optimal markup for the monopoly takes a standard value of \( \epsilon/(\epsilon - 1) \).

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

\[ \beta = \frac{d \ln(P)}{d \ln(C)}, \]

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

The following lemma summarizes the results:

4At this stage, we cannot guarantee that the first-order condition identifies the maximum of the monopoly’s profit function. But in appendix A.1, we use the assumptions introduced in the next sections to verify that in all cases the first-order condition indeed gives the maximum of the profit function.
Lemma 1. When customers do not care about fairness, the monopoly sets the markup to $M = \epsilon/(\epsilon - 1)$, and the cost passthrough is $\beta = 1$.

4.4. Fairness concerns and observable costs

We now introduce fairness concerns. As a preliminary step to the analysis with unobservable costs, we explore pricing when costs are observable.

To describe fairness concerns, we impose some structure on the fairness function.

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

The assumption that the fairness function strictly decreases in the perceived markup captures the pattern that customers find higher markups less fair and resent 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 could not find 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.

The assumptions about the fairness function lead to the following properties:

Lemma 2. When customers care about fairness, the elasticity of the fairness function

$$\phi(M^p) = -\frac{d\ln(F)}{d\ln(M^p)}$$

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

$$\sigma = \frac{d\ln(\phi)}{d\ln(M^p)}$$

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

Proof. By definition, $\phi(M^p) = -M^p \cdot F'(M^p)/F(M^p)$. Using the properties of the fairness function listed in Definition 2, $F(M^p) > 0$ and $F'(M^p) < 0$, so $\phi(M^p) > 0$. The properties also indicate that $F > 0$ is decreasing in $M^p$, and that $F' < 0$ is decreasing in $M^p$ (as $F$ is concave in $M^p$). Thus, both $1/F > 0$ and $-F' > 0$ are increasing in $M^p$, which implies that $\phi$ is strictly increasing in $M^p$. The properties also indicate that $F(0) > 0$ and $F'(0)$ is finite, so $\lim_{M^p \to 0} \phi(M^p) = 0$. Last, the properties indicate that $F(M^h) = 0$ while $M^h > 0$ and $F'(M^h) < 0$, so that $\lim_{M^p \to M^h} \phi(M^p) = +\infty$. The final result immediately follows, as $\sigma = M^p \cdot \phi'(M^p)/\phi(M^p)$, $\phi'(M^p) > 0$, and $\phi(M^p) > 0$. ■
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 follows from the assumptions in definition two because a positive, decreasing, and weakly concave function always has positive superelasticity. It will play a central role in the analysis.\footnote{The concavity of the fairness function is not a necessary condition for any of the results in the paper. The necessary conditions are that the fairness function is decreasing in the perceived markup, and that its elasticity is increasing in the perceived markup. The elasticity is increasing with weakly concave functions but also with other, not-too-convex functions. For example, the logistic function $F(M^p) = 1/[1 + (M^p)^\theta]$ with $\theta > 0$ is not concave but it is decreasing and has an increasing elasticity: $\phi(M^p) = -d \ln(F)/d \ln(M^p) = \theta/[1 + (M^p)^{-\theta}]$. All the results would carry over with such logistic fairness function. We limit ourselves to concave functions instead of allowing for any function with an increasing elasticity because we find such restriction more natural (it is a natural extension of a linear function) and easier to interpret.}

Since the marginal cost is assumed to be observable, customers correctly perceive marginal cost ($C^p = C$), so the perceived markup equals the true markup ($M^p = M$). From (2), we see that the price elasticity of demand is $E = \epsilon + (\epsilon - 1) \cdot \phi(M) > \epsilon$; therefore, the markup charged by the monopoly satisfies

$$M = 1 + \frac{1}{\epsilon - 1} \cdot \frac{1}{1 + \phi(M)}.$$\hspace{1cm}(3)

Since $\phi(M)$ is strictly increasing from 0 to $+\infty$ when $M$ increases from 0 to $M^h$ (lemma 2), the right-hand side of the equation is strictly decreasing from $\epsilon/(\epsilon - 1)$ to 1 when $M$ increases from 0 to $M^h > \epsilon/(\epsilon - 1) > 1$. We infer that the fixed-point equation (3) admits a unique solution, located between 1 and $\epsilon/(\epsilon - 1)$. Therefore, the markup $M$ is well-defined and $M \in (1, \epsilon/(\epsilon - 1))$.

The next lemma records the results:

**Lemma 3.** When customers care about fairness and observe costs, the monopoly’s markup $M$ is implicitly defined by (3). This implies that $M \in (1, \epsilon/(\epsilon - 1))$ and the cost passthrough is $\beta = 1$. 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, (3) shows that with fairness concerns and observable costs, the markup does not depend on costs, 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 remain flexible.
4.5. Fairness concerns and rational inference of costs

Next, we combine fairness concerns with unobservable marginal costs. We study a last preliminary case: we assume that customers 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 $[0, C^h] \subset \mathbb{R}_+$ be the set of all possible marginal costs for the monopoly. The monopoly knows its marginal cost $C \in [0, C^h]$, but customers do not; instead, customers have non-atomistic prior beliefs over $[0, C^h]$.

A pure-strategy perfect Bayesian equilibrium (PBE) of this game comprises three elements: a pure strategy for the monopolist, which is a mapping $P : [0, C^h] \rightarrow \mathbb{R}_+$ that selects a price for every possible value of marginal cost; a belief function for customers, which is a mapping $C^p : \mathbb{R}_+ \rightarrow [0, C^h]$ that determines a marginal cost for every possible price; and a pure strategy for customers, which is a mapping $Y^d : \mathbb{R}_+ \rightarrow \mathbb{R}_+$ that selects a quantity purchased for every possible price.

We look for a PBE that is fully separating: 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.

We now demonstrate the existence of a PBE in which the monopolist uses the strategy $P(C) = \epsilon \cdot C / (\epsilon - 1)$; customers believe $C^p(P) = (\epsilon - 1)P / \epsilon$ if $P \in \mathcal{P} \equiv [0, \epsilon C^h / (\epsilon - 1)]$, and $C^p(P) = 0$ otherwise; and customers demand $Y^d(P) = P^{-\epsilon} \cdot F(P / C^p(P))^{\epsilon - 1}$. In such a 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 shown 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 $d \ln(C^p)/dp \ln(P) = 1$. Then, according to (2) (which is implied by customers’ strategy), the price elasticity of demand for any price on $\mathcal{P}$ is $E = \epsilon$. Hence, it is optimal for the monopolist to charge a price $P = \epsilon C / (\epsilon - 1)$. It remains to show that the monopoly has no incentive to charge some price not belonging to $\mathcal{P}$. This is straightforward: if it does, customers infer that the markup is infinite, which brings fairness factor, demand, and thus profits to zero. Thus, the monopolist has no incentive to deviate from the equilibrium markup $\epsilon / (\epsilon - 1)$, regardless of its marginal cost.

\footnote{Strictly speaking, $C^p$ should allow the consumer to hold probabilistic beliefs about the firm’s marginal cost given price, but we sidestep this subtlety because it does not affect our analysis.}
The following lemma records the findings:

**Lemma 4.** When customers care about fairness and rationally infer costs, there is a PBE in which the monopoly uses the markup \( M = \epsilon / (\epsilon - 1) \), and customers learn marginal cost from price. In this PBE, the cost passthrough is \( \beta = 1 \). Hence, in this PBE, the markup and passthrough are the same as without fairness concerns.

The lemma shows that when customers care about fairness and rationally infer costs, there is a PBE in which fairness does not 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 \( \epsilon / (\epsilon - 1) \). The second channel closes, so the monopoly indeed sets the standard markup \( \epsilon / (\epsilon - 1) \). Since the markup does not depend on marginal cost, changes in marginal cost are fully passed through into prices—prices are flexible again.

Of course, there may exist other equilibria beside the one described in lemma 4. An example of a pooling PBE is one in which all types of the firm charge the same price \( P > C^h \), and consumers believe that a firm who prices otherwise has zero marginal cost. However, this and other non-fully-separating PBEs fail standard signaling refinements.\(^7\) Because the linear PBE in lemma 4 is so simple and robust, it is more plausible than any alternative, which suggests that fairness is unlikely to matter when customers rationally infer costs.

### 4.6. Fairness concerns and subproportional inference of costs

We turn to the case of interest: customers care about fairness and subproportionally infer costs from prices. In this case, the fairness function satisfies definition 2, and the belief function takes the following form:

**Definition 3.** Customers who update subproportionally use the belief-updating rule

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

\(^7\)Only a separating PBE satisfies the D\(_{1}\) Criterion from Cho and Kreps (1987). Intuitively, consumers ought to interpret a price \( P' > P \) as coming from type \( C = C^h \) rather than type \( C = 0 \), which undermines the pooling equilibrium. Indeed, if consumers demand no less at \( P' \) than in equilibrium, then all types of firm benefit from deviating; if consumers demand less at \( P' \) than in equilibrium, then the highest-cost firm strictly benefits whenever any other type of firm weakly benefits. On these grounds, the D\(_{1}\) Criterion suggests that consumers should interpret \( P' > P \) as coming from the highest marginal-cost firm.
where $C^b > (\epsilon - 1) \cdot (M^h)^{-1/\gamma} \cdot C / \epsilon$ 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 evidence 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 no inference with proportional inference, so it encompasses these two types of error.\(^8\)

First, customers underinfer marginal costs from price by clinging to their prior belief $C^b$. 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 $C^b$, 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.

Last, we impose a constraint on the parameter $C^b$ such that the perceived markup falls below $M^h$ when the firm prices at marginal cost; this is necessary for the equilibrium to exist.

Despite its apparent arbitrary nature, the assumption of subproportional inference has close ties to game-theoretic models of failure of contingent thinking. It is related to the concept of cursed equilibrium, developed by Eyster and Rabin (2005), and to the concept of analogy-based expectation equilibrium, developed by Jehiel (2005) and extended to Bayesian games by Jehiel and Koessler (2008). Both concepts propose mechanisms that can be used to explain why people might fail to account for the information that equilibrium prices reveal about marginal costs.\(^9\) Subproportional inference is also related to the cursed-expectation equilibrium developed by Eyster, Rabin, and Vayanos (2019) as an alternative to rational-expectations equilibrium in markets.\(^{10}\)

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\(^8\)We use a geometric average instead of an arithmetic average because it is much more tractable.

\(^9\)In fact, with $\gamma = 1$, the beliefs about marginal cost given by (4) resemble those in a fully cursed equilibrium and the coarsest analogy-based-expectation equilibrium, when recasting our model as a Bayesian game, as in section 4.5. In these equilibrium concepts, an unsophisticated household infers nothing about marginal cost from any economic variable. Consequently, a consumer with average prior beliefs about marginal cost equal to $C^b$ would continue to perceive marginal costs with mean $C^b$ given any price.

\(^{10}\)In a cursed-expectation equilibrium of a 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
Our assumption of subproportional inference is also related to several well-documented psychological biases. Customers in our model are 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 underinference 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 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 make inferences by drawing upon a limited set of scenarios that come to mind; higher prices suggest increased markups and greed, rather than higher marginal costs. Altogether, the updating rule (4) captures a well-known bias: people do not update their beliefs sufficiently from available information.

**Analytical results.** Plugging the belief-updating rule (4) into $M_p = P/C_p$, we obtain the following:

**Lemma 5.** When customers update subproportionally, they perceive the monopoly’s markup to be

$$M_p(P) = \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\gamma} \left( \frac{P}{C} \right)^{\gamma},$$

which is a strictly 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 $M_p(P)$ and $F(M_p)$ 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).

Combining (2) and (4), we then find that the price elasticity of demand satisfies

$$E = \epsilon + (\epsilon - 1) \cdot \gamma \cdot \phi(M_p).$$

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 two rules differ in that consumers in our model average naive beliefs with a particular form of incorrect beliefs (proportional inference); 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 results of the paper would go through if people averaged their prior beliefs with rational beliefs about cost.
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 is always greater than $\epsilon$. Moreover, since $\phi(M^p)$ is increasing in $M^p$ and $M^p(P)$ in $P$, the price elasticity of demand is increasing in $P$. These properties have implications for the markup charged by the monopoly, $M = E/(1 - E)$.

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

$$M = 1 + \frac{1}{\epsilon - 1} \cdot \frac{1}{1 + \gamma \phi(M^p(M \cdot C))},$$

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

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

which implies that $\beta \in (0,1)$. Hence, the markup is lower than without fairness concerns or with rational inference; and unlike without fairness concerns or with rational inference, the cost passthrough is incomplete.

The proof is relegated to appendix A.2, 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 microevidence.** The result that prices do not fully respond to marginal-cost shocks accords well with evidence on real firm behavior. First, using matched data on product prices and producers’ unit labor cost in Sweden, Carlsson and Skans (2012) find a limited
passthrough of idiosyncratic marginal-cost changes into prices of 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 reduction, 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 modest passthrough of idiosyncratic marginal-cost changes into prices: between 0.2 and 0.4. Last, combining production data for US manufacturing firms with data on energy prices and consumption, Ganapati, Shapiro, and Walker (2019, tables 5 and 6) find a moderate passthrough of marginal-cost changes caused by energy-price variations into prices: between 0.5 and 0.7. Taking the midpoint estimates from the four studies, we find an average passthrough of \(0.3 + (0.3 + 0.4)/2 + (0.2 + 0.4)/2 + (0.5 + 0.7)/2 = 0.4\). Hence, across studies, the cost passthrough is well below 1.

Additionally, our theory predicts that when customers care about fairness, the passthrough of marginal costs into prices is markedly different when costs are observable and when they are not. The passthrough is one when costs are observable (lemma 3) but is strictly below one when costs are not observable (proposition 1). Kachelmeier, Limberg, and Schadewald (1991a,b) and Renner and Tyran (2004) provide experimental evidence consistent with this result: they find that after a cost shock, prices adjust much more when costs are observable than when they are not.

**Comparison with the literature.** In our model, price rigidity arises from a nonconstant price elasticity of demand, which creates variations in markups after cost 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 (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 (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 analytical results.** To obtain further results, we introduce a simple fairness function that satisfies all the requirements from definition 2:

\[
F(M^p) = 1 - \theta \cdot \left( M^p - \frac{\epsilon}{\epsilon - 1} \right),
\]
where $\theta > 0$ governs the intensity of fairness concerns. A higher $\theta$ 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 $\epsilon/(\epsilon - 1)$; then fairness-adjusted consumption coincides with actual 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’ markups as acceptable: $C^b$ adjusts so $M^p = \epsilon/(\epsilon - 1)$ 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.\textsuperscript{11}

We then obtain the following corollary:

**Corollary 1.** Assume that customers care about fairness according to the fairness function (6), infer subproportionally, and are acclimated. Then the monopoly’s markup is given by

$$M = 1 + \frac{1}{(1 + \gamma \theta) \epsilon - 1}.$$  

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

$$\beta = 1 \left\{ 1 + \frac{\gamma^2 \theta [(1 + \theta) \epsilon - 1]}{(\epsilon - 1)(1 + \gamma \theta) [(1 + \gamma \theta) \epsilon - 1]} \right\}.$$  

The passthrough increases with the competitiveness of the market ($\epsilon$), but decreases with the concern for fairness ($\theta$) and degree of underinference ($\gamma$).

The proof is in appendix A.3; it involves applying proposition 1 to the fairness function (6), under acclimation.

**Comparison with additional microevidence.** Our theory predicts that the cost passthrough is higher in more-competitive markets.\textsuperscript{12} 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,

\textsuperscript{11}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 belief-updating rule (7) introduced in the New Keynesian model has the property that for any initial belief, people eventually become acclimated.

\textsuperscript{12}Fairness operates by reducing the markup below its standard level $\epsilon/(\epsilon - 1)$ and toward 1. As the market becomes perfectly competitive, the markup approaches 1, and prices become flexible (see proposition 1 when $\epsilon \to \infty$).
Itskhoki, and Konings (2014) that firms with higher market power have a lower passthrough of cost shocks driven by exchange-rate fluctuations.

Our theory also predicts that the passthrough is lower—so prices are more rigid—in markets that are more fairness-oriented. This property could contribute to explain the finding by Kackmeister (2007) that retail prices were more rigid in 1889–1891 than in 1997–1999. Kackmeister emphasizes that the relationship between retailers and customers was much more personal in the 19th century than today. This more personal relationship could have made the retail sector more fairness-oriented, which would help to explain, according to our theory, greater price rigidity in the past. The property that prices are more rigid in markets that are more fairness-oriented could also contribute to explain the finding by Nakamura and Steinsson (2008, table 8) that prices are more rigid in the service sector than elsewhere. Indeed, in the service sector, relationships between buyers and sellers are more personal, which could make fairness concerns more salient and thus prices more rigid.

5. New Keynesian model

We now explore the macroeconomic implications of the pricing theory developed in section 4. To that end, we embed it into a New Keynesian model as a substitute for usual pricing frictions (either Calvo pricing or Rotemberg pricing). We find that when customers care about fairness and infer subproportionally, the price markup depends on the rate of inflation; thus, monetary policy is nonneutral in both short and long run. (All derivations are relegated to appendix B.)

5.1. Assumptions

The economy is composed of a continuum of firms indexed by $j \in [0, 1]$ and a continuum of households indexed by $k \in [0, 1]$. Firms use labor services to produce goods. Households supply labor services, consume goods, and save using riskless nominal bonds. Since goods are imperfect substitutes for one another, and labor services 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. Households cannot observe firms’ marginal costs. When a household purchases good $j$ at price $P_j(t)$ in period $t$, it infers that firm $j$’s marginal cost is $C_j^p(t)$. The dynamic

---

Kackmeister notes: “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” (p. 2008).
model provides a natural candidate for the anchor that households use when inferring costs: last period’s perception of marginal cost. Hence, instead of being given by (4) as in the static model, households’ perception of firm j’s marginal cost at time t is given by

\[
C^p_j(t) = \left[C^p_j(t-1)\right]^\gamma \left[\frac{\epsilon - 1}{\epsilon} P_j(t)\right]^{1-\gamma},
\]

where \(C^p_j(t-1)\) is last period’s perception of marginal cost, and \(\gamma \in (0, 1)\) is the degree of underinference.

Having inferred the marginal cost, the household deduces that the markup charged by firm j is \(M^p_j(t) = P_j(t)/C^p_j(t)\). This perceived markup determines the fairness of the transaction with firm j, measured by \(F_j(M^p_j(t))\). The fairness function \(F_j\), specific to good j, satisfies the conditions listed in definition 2. The elasticity of \(F_j\) with respect to \(M^p_j\) is \(\phi_j = -d \ln(F_j)/d \ln(M^p_j)\).

An amount \(Y_{jk}(t)\) of good j bought by household k at a unit price \(P_j(t)\) yields a fairness-adjusted consumption

\[
Z_{jk}(t) = F_j(M^p_j(P_j(t))) \cdot Y_{jk}(t).
\]

Household k’s fairness-adjusted consumption of the different goods aggregates into a consumption index

\[
Z_k(t) = \left[\int_0^1 Z_{jk}(t)^{\epsilon/(\epsilon-1)} \,dj\right]^{\epsilon/(\epsilon-1)},
\]

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

\[
X(t) = \left\{ \int_0^1 \left[\frac{P_j(t)}{F_j(M^p_j(P_j(t)))}\right]^{1-\epsilon} \,dj \right\}^{1/(1-\epsilon)}.
\]

**Households.** Household k derives utility from consuming goods and disutility from working. Its expected lifetime utility takes the form of

\[
E_0 \sum_{t=0}^{\infty} \delta^t \ln(Z_k(t)) - \frac{N_k(t)^{1+\eta}}{1 + \eta},
\]

where \(E_t\) is the mathematical expectation conditional upon time-t information, \(N_k(t)\) is its labor supply, \(\delta \in (0, 1)\) is its time discount factor, and \(\eta > 0\) is the inverse of the Frisch elasticity of labor supply.

To smooth consumption over time, households trade one-period bonds. In period t, household k holds \(B_k(t)\) bonds. Bonds purchased in period t have a price \(Q(t)\), mature in period \(t + 1\),
and pay one unit of money at maturity.

Household $k$’s consumption-savings decisions in each period $t$ must obey the constraint

$$
\int_0^1 P_j(t)Y_{jk}(t) \, dj + Q(t)B_k(t) = W_k(t)N_k(t) + B_k(t-1) + V_k(t),
$$

where $W_k(t)$ is the wage rate for labor service $k$, and $V_k(t)$ are dividends from firm ownership. In addition, household $k$ satisfies a solvency constraint that prevents Ponzi schemes.

Finally, in each period $t$, household $k$ chooses purchases $Y_{jk}(t)$ for each $j \in [0, 1]$, labor supply $N_k(t)$, bond holdings $B_k(t)$, and wage rate $W_k(t)$. The household’s objective is to maximize its expected utility subject to the budget constraint, to the solvency constraint, and to firms’ demand for labor service $k$. The household takes as given its initial endowment of bonds $B_k(-1)$, all fairness factors $F_j(t)$, all prices $P_j(t)$ and $Q(t)$, and dividends $V_k(t)$.

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

$$
Y_j(t) = A_j(t)N_j(t)^\alpha,
$$

where $Y_j(t)$ is output of good $j$, $A_j(t) > 0$ is its technology level, $\alpha \in (0, 1]$ is the extent of diminishing marginal returns to labor, and

$$
N_j(t) = \left[ \int_0^1 N_{jk}(t)^{(\nu-1)/\nu} \, dk \right]^{\nu/(\nu-1)}
$$

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

Each period $t$, firm $j$ chooses output $Y_j(t)$, price $P_j(t)$, and employment levels $N_{jk}(t)$ for all $k \in [0, 1]$. The firm’s objective is to maximize the expected present-discounted value of profits

$$
\mathbb{E}_0 \sum_{t=0}^\infty \Gamma(t) \left[ P_j(t)Y_j(t) - \int_0^1 W_k(t)N_{jk}(t) \, dk \right],
$$

where $\Gamma(t) = \delta^t[X(0)Z(0)]/\delta[X(t)Z(t)]$ is the stochastic discount factor for period-$t$ nominal payoffs, subject to the production constraint (8), to the demand for good $j$, and to the law of motion of the perceived marginal cost (7). The firm takes as given the initial belief about its marginal cost $C_j^p(-1)$, all wage rates $W_k(t)$, and discount factors $\Gamma(t)$. 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:

\[
i(t) = i_0(t) + \psi \pi(t),
\]

where \( i_0(t) \) is stochastic, and \( \psi > 1 \) governs the response of interest rates to inflation.

**Symmetry.** We assume a symmetric economy: all households receive the same initial bond endowment and same dividends; and all firms share a common technology and face the same fairness and belief functions. Hence, all households behave identically, as do all firms.

**Notation.** Since the equilibrium is symmetric, we drop subscripts \( j \) and \( k \) to denote the equilibrium values taken by the variables. We also denote the steady-state value of any variable \( H(t) \) by \( \bar{H} \). And for any variable \( H(t) \) except the interest and inflation rates, we denote the logarithmic deviation from steady state by \( \hat{h}(t) \equiv \ln(H(t)) - \ln(\bar{H}) \). For the interest and inflation rates, we denote the deviation from steady state by \( \hat{\pi}(t) \equiv \pi(t) - \bar{\pi} \), \( \hat{i}_0(t) \equiv i_0(t) - \bar{i}_0 \), and \( \hat{r}(t) \equiv r(t) - \bar{r} \).

### 5.2. Demand for goods and pricing

Households and firms behave exactly as in the textbook model, except that fairness concerns modify consumers’ demand and, consequently, firms’ pricing.

The demand for good \( j \) from all households is

\[
Y^d_j(t, P_j(t), C^p_j(t - 1)) = Z(t) \left[ \frac{P_j(t)}{X(t)} \right]^{-\varepsilon \gamma} F_j \left( \left( \frac{\varepsilon}{\varepsilon - 1} \right)^{1-\gamma} \left[ \frac{P_j(t)}{C^p_j(t - 1)} \right]^{\varepsilon - 1} \right),
\]

where \( Z(t) = \int_0^1 Z_k(t) \, dk \) describes the level of aggregate demand.\(^{14}\) The price of good \( j \) appears twice in the demand curve: as part of the relative price \( P_j/X \), as in the textbook model; and as part of the fairness factor \( F_j(\cdot) \). This second element leads to unconventional pricing.

Once again, fairness affects pricing through the price elasticity of demand. As in the static

\(^{14}\)The equation can be rewritten in the standard form of this type of model: \( Z^d_j = F_j \cdot Y^d_j = Z \cdot [(P_j/F_j)/X]^{-\varepsilon} \). As the price of one unit of \( Z_j \) is \( P_j/F_j \) and the price of one unit of \( Z \) is \( X \), the relative price of \( Z_j \) is \( (P_j/F_j)/X \). Hence, the demand for \( Z_j \) equals aggregate demand \( Z \) times the relative price of \( Z_j \) to the power of \(-\varepsilon\).
model, this elasticity is a function of the perceived price markup:

\[ E_j(M^p_j(t)) = -\frac{\partial \ln(Y^d_j)}{\partial \ln(P_j)} = \epsilon + (\epsilon - 1)\gamma \phi_j(M^p_j(t)). \]

Unlike in the static model, however, the profit-maximizing markup does not equal \( E_j(t)/[E_j(t) - 1] \) because the price elasticity of demand does not capture the effect of the current price on future perceived marginal costs and thus future demands. Instead, in equilibrium, firms set their price markup \( M(t) \) such that

\[ \frac{M(t) - 1}{M(t)} E(M^p(t)) = 1 - \delta \gamma + \delta \mathbb{E}_t \left[ \frac{M(t + 1) - 1}{M(t + 1)} [E(M^p(t + 1)) - (1 - \gamma)\epsilon]\right]. \]

The gap between \( M(t) \) and \( E(t)/[E(t) - 1] \) reflects how much today's price affects future perceived marginal costs, demand, and profits. Conversely, if firms do not care about the future (\( \delta = 0 \), then the equation reduces to \( M(t) = E(t)/[E(t) - 1] \), as in the static model.

The price markup plays an important role because it directly determines employment:

\[ N(t) = \left[ \frac{(\nu - 1)\alpha}{\nu} \cdot \frac{1}{M(t)} \right]^{1/(1+\eta)}. \]

This equation shows that in equilibrium employment is strictly decreasing in the price markup. This is because in equilibrium the price markup is the inverse of the real marginal cost, which is itself increasing in employment. Since a lower price markup implies a higher real marginal cost, it also implies higher employment.

### 5.3. Calibration

Before simulating the model, we calibrate it to US data. To set values of the fairness-related parameters, we use new evidence on price markups and cost passthroughs. For the other parameters, we rely on standard evidence. The calibrated values of the parameters are summarized in table 4.

**Fairness function.** We set the shape of the fairness function \( F \) to (6). This simple functional form has two advantages. First, it introduces only one new parameter, \( \theta > 0 \), which governs the concern for fairness. Second, it produces a fairness factor equal to one at the zero-inflation

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15 The real marginal cost is the ratio of real wage to marginal product of labor. The marginal product of labor is decreasing in employment because of diminishing returns. Simultaneously, 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.
Fairness-related parameters. We then calibrate the three parameters central to our theory: the fairness parameter \( \theta \), the inference parameter \( \gamma \), and the elasticity of substitution across goods \( \epsilon \). These parameters jointly determine the average value of the price markup and its response to shocks—which determines the cost passthrough. Hence, for the calibration, we match evidence on price markups and cost passthroughs. We target three empirical moments: average price markup, short-run cost passthrough, and long-run cost passthrough.

First, using firm-level data, De Loecker and Eeckhout (2017) estimate price 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. Since the average markup since 2000 is about 1.5, we adopt this value as a target.\(^{16}\)

\(^{16}\) 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 \( (P - C)/P = 0.239 \), which translates into a markup of \( M = P/C = 1/(1 - 0.239) = 1.3 \). In the ready-to-eat cereal industry, Nevo (2001, table 8) finds that a median estimate of \( (P - C)/P \) is 0.372, which translate into a markup of \( M = P/C = 1/(1 - 0.372) = 1.6 \). 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. 260–267) estimates similar markups: the industrial-organization literature estimates markups to be between 1.2 and 1.7, and the marketing literature estimates a typical markup to be around 2.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Source or target</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta = 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>( \psi = 1.5 )</td>
<td>Response of nominal interest rate to inflation</td>
<td>Gali (2008, p. 52)</td>
</tr>
<tr>
<td>( \mu^i = 3/4 )</td>
<td>Persistence of interest-rate shock</td>
<td>Gali (2008, p. 52), Gali (2011, p. 26)</td>
</tr>
<tr>
<td>( \mu^a = 0.9 )</td>
<td>Persistence of technology shock</td>
<td>Gali (2008, p. 55)</td>
</tr>
</tbody>
</table>

### B. Parameters of the New Keynesian model with fairness

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Source or target</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \epsilon = 2.2 )</td>
<td>Elasticity of substitution across goods</td>
<td>Steady-state price markup = 1.5</td>
</tr>
<tr>
<td>( \theta = 9 )</td>
<td>Fairness concern</td>
<td>Instantaneous cost passthrough = 0.4</td>
</tr>
<tr>
<td>( \gamma = 0.8 )</td>
<td>Degree of underinference</td>
<td>Two-year cost passthrough = 0.7</td>
</tr>
</tbody>
</table>

### C. Parameters of the textbook New Keynesian model

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Source or target</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \epsilon = 3 )</td>
<td>Elasticity of substitution across goods</td>
<td>Steady-state price markup = 1.5</td>
</tr>
<tr>
<td>( \xi = 2/3 )</td>
<td>Share of firms keeping price unchanged</td>
<td>Average price duration = 3 quarters</td>
</tr>
</tbody>
</table>
Second, we reported in section 4.6 that in the United States, Sweden, India, and Mexico, the short-run cost passthrough is estimated between 0.2 and 0.7, with an average value of 0.4. Hence, we target a short-run cost passthrough of 0.4.

Third, although we have not found long-run estimates for the cost passthrough, 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 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. Based on these dynamics, and the fact that the immediate cost passthrough is also 0.4, we target a two-year cost passthrough of 0.7.

We then take the perspective of a firm in the model, and simulate price dynamics in response to an unexpected and permanent increase in the firm’s marginal cost (appendix B.5). We find that the fairness parameter $\theta$ primarily affects the level of the cost passthrough, while the inference parameter $\gamma$ primarily affects its persistence. Based on the simulations, we set $\epsilon = 2.2$, $\theta = 9$, and $\gamma = 0.8$. This calibration allows us to achieve a steady-state price markup of 1.5, an instantaneous cost passthrough of 0.4, and a two-year cost passthrough of 0.7.

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 elasticity for aggregate hours (Chetty et al. 2013, table 2). We then set the quarterly discount factor to $\delta = 0.99$, 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 $\alpha/M$ in steady state, takes its conventional value of $2/3$. Last, we calibrate the monetary-policy parameter to $\psi = 1.5$, 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 C), which we will use as a benchmark in simulations. For the parameters common to the two models, we use the same values—except for $\epsilon$. In the textbook model, the steady-state price markup is $\epsilon/(\epsilon - 1)$, so we set $\epsilon = 3$ to obtain a markup of 1.5.

We also need to calibrate a parameter specific to the textbook model, $\xi$, which governs price rigidity. To generate price rigidity, the New Keynesian literature uses either the staggered pricing of Calvo (1983) or the price-adjustment cost of Rotemberg (1982). Both pricing assumptions lead to the same linearized Phillips curve around the zero-inflation steady state, and therefore to the
same simulations (Roberts 1995). For calibration purposes, however, the Calvo interpretation of \( \xi \) is easier to map to the data, so we use it here. The parameter \( \xi \) indicates the share of firms that cannot update their prices each period; it can be calibrated from microevidence on the frequency of price adjustments. If a share \( \xi \) of firms keep their price fixed each period, the average duration of a price spell is \( 1/(1 - \xi) \) (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 \( 1/(1 - \xi) = 3 \), which implies \( \xi = 2/3 \).

5.4. Effects of monetary policy in the short run

Price rigidity is a central concept in macroeconomic theory because it is a source of monetary nonneutrality. Here we explore how our pricing theory produces monetary nonneutrality.

At this stage, we focus on the short-run effects of monetary policy. We trace how an unexpected and transitory shock to monetary policy permeates through the economy.

**Analytical results.** The dynamics of the textbook model around the steady state are governed by an IS equation, describing households’ consumption-savings decisions, and a short-run Phillips curve, describing firms’ pricing decisions. In the model with fairness, the same IS equation remains valid, but the Phillips curve is modified—because firms price differently.\(^{17}\)

The main difference is that the Phillips curve involves not only employment and inflation but also the perceived price markup, which itself obeys the following law of motion:

**Lemma 6.** In the New Keynesian model with fairness, the perceived price markup evolves according to

\[
\tilde{m}_p(t) = \gamma \left[ \tilde{\pi}(t) + \tilde{m}_p(t - 1) \right].
\]

Accordingly, the perceived price markup is a discounted sum of lagged inflation terms:

\[
\tilde{m}_p(t) = \sum_{s=0}^{\infty} \gamma^{s+1} \tilde{\pi}(t - s).
\]

\(^{17}\)Introducing fairness concerns into the New Keynesian model improves the realism of the Phillips curve but not that of the IS equation. Yet the IS equation is also problematic. It is notably the source of the many anomalies of the New Keynesian model at the zero lower bound on nominal interest rates. Other behavioral elements have been introduced into the New Keynesian model to improve the realism of the IS equation. For instance, Gabaix (2016) assumes that households are inattentive to unusual events. Alternatively, Michaillat and Saez (2019) assume that households derive utility not only from consumption and leisure but also from social status, which is measured by relative wealth.
The proof is in appendix B.4; it is obtained by reworking the inference rule (7).

Equation (12) shows that the perceived price 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. Because of its autoregressive structure, the perceived price markup is fully determined by past inflation.

As a result, the short-run Phillips curve involves not only forward-looking elements—expected future inflation and employment—but also backward-looking elements—past inflation.

**Proposition 2.** In the New Keynesian model with fairness, the short-run Phillips curve is

\[
(1 - \gamma) m^\theta(t) - \lambda_1 \hat{n}(t) = \delta \gamma \mathbb{E}_t(\pi(t + 1)) - \lambda_2 \mathbb{E}_t(\hat{n}(t + 1)),
\]

where

\[
\lambda_1 = (1 + \eta) (\epsilon + (\epsilon - 1)\phi) \left[ 1 + \frac{(1 - \delta)\gamma - \phi}{1 - \delta\gamma} \right],
\]

\[
\lambda_2 = (1 + \eta) \delta (\epsilon + (\epsilon - 1)\phi) \left[ 1 + \frac{(1 - \delta)\gamma - \phi}{1 - \delta\gamma} \right].
\]

Hence the short-run Phillips curve is hybrid, including both past and future inflation rates:

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

The proof appears in appendix B.4. It is obtained by log-linearizing firms’ pricing equation (10) around the steady state, and combining it with the log-linear version of (11)—to link the price markup to employment—and with (12)—to link the future perceived price markup to inflation.

**Simulation results.** Next we simulate the dynamical response of our calibrated model to an unexpected and transitory monetary shock. Following the literature, we simulate dynamics around the zero-inflation steady state. We assume that the exogenous component \(i_0(t)\) of the monetary-policy rule (9) follows an AR(1) process, such that

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

where the disturbance \(\zeta^i(t)\) follows a white-noise process with mean zero, and \(\mu^i \in (0, 1)\) governs the persistence of shocks. We set \(\mu^i = 3/4\), which corresponds to moderate persistence (Gali 2008,
A negative realization of $\zeta_i(t)$ is an expansionary monetary shock, leading to a fall in the real interest rate. Without any inflation response, this shock would lead to a decrease of the annualized interest rate by 1 percentage point.

Figure 1 depicts the dynamical response to the expansionary monetary shock. The real-interest and inflation rates are expressed as deviations from steady-state values, measured in percentage points and annualized (by multiplying by four the variables $\hat{r}(t)$ and $\hat{\pi}(t)$); all other variables are expressed as percentage deviations from steady-state values.

Loosening monetary policy generates a decrease in the real interest rate and an increase in inflation. Inflation is positive for two quarters and close to zero thereafter. Observing higher prices, customers underinfer the underlying increase in nominal marginal costs and thus perceive higher price markups. Firms respond to higher perceived markups by cutting their actual markups. The price markup falls by 1.4%, which raises output and employment by 0.7%. (Output and employment respond identically because the production function is calibrated to be linear.)

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

**Comparison with macroevidence.** Monetary policy is nonneutral in the model because monetary shocks influence output and employment. The nonneutrality of monetary policy is well documented; the evidence is summarized by Christiano, Eichenbaum, and Evans (1999) and Ramey (2016, sec. 3). Furthermore, the effect of monetary policy is mediated by a hybrid Phillips curve, which is realistic as both past inflation and expected future inflation enter significantly in estimated New Keynesian Phillips curve (Mavroeidis, Plagborg-Moller, and Stock 2014, table 2).

In fact the response of output to a monetary 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 shocks in a hump-shaped fashion (Ramey 2016, figs. 1–4). Second, the amplitude of the response is comparable. After a one-percentage-point decrease of the nominal interest rate, the literature
This figure describes the response of the New Keynesian model with fairness (solid, blue lines) to a decrease in the exogenous component of the monetary-policy rule (9) by 1 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. For comparison, the figure also displays the response of the textbook New Keynesian model (dashed, orange lines). The log-linearized equilibrium conditions used in the simulation of the model with fairness are described in appendix B.4; those used in the simulation of the textbook model are in appendix C. The calibration of the two models is described in table 4.
estimates that output increases between 0.6% and 5%, with a median value of 1.6% (Ramey 2016, table 1); and using a range of methods and samples, Ramey (2016, table 2) estimates that output increases between 0.2% and 2.2%, with a median value of 0.8%. In our simulation, output rises by 0.7% when the exogenous component of monetary policy increases by 1 percentage point—close to Ramey’s median estimate.

After a monetary shock, price markup and output move in opposite directions; the same would be true with other aggregate-demand shocks. At the same time, Gali (1999) and Basu, Fernald, and Kimball (2006) have shown that aggregate-demand shocks explain the majority of business-cycle fluctuations. Accordingly, our model predicts that price markups are countercyclical. And indeed, much of the evidence points to countercyclical price markups (Rotemberg and Woodford 1999; Bils, Klenow, and Malin 2018).

The main discrepancy between our model and US evidence concerns inflation. The response of US inflation to monetary shocks is delayed and gradual (Ramey 2016, figs. 1–4). In our model the response of inflation to monetary shocks occurs immediately, which also happens in the textbook model. It is not clear yet how this issue can be addressed.

Comparison with the textbook New Keynesian model. In both our model and the textbook model, looser monetary policy leads to higher inflation and lower markups, boosting employment and output. Beyond these similarities, the two models differ on several counts.

First, the textbook’s short-run Phillips curve is purely forward-looking, so it does not include the backward-looking elements found in US data and present in the fairness model. Of course, other variations of the textbook model append backward-looking components to the Phillips curve; for example, having firms index their prices to past inflation in periods when they cannot reset their prices (Christiano, Eichenbaum, and Evans 2005).

Second, the textbook model cannot produce the positive correlation between perceived price markup and inflation that occurs in the fairness model, and that rationalizes the survey findings by Shiller (1997) and the Bank of Japan. This is because households in the textbook model correctly infer that price markups are lower when they see higher inflation.

Third, the textbook model cannot produce the hump-shaped response of output observed in US data and predicted by the fairness model, since it does not include any backward-looking element. The fairness model, by contrast, includes a backward-looking element in the form of the perceived price markup $\hat{m}(t)$, which enters the Phillips curve (13) and depends on the past via (12). It is well understood that backward-looking elements generate hump-shaped impulse responses. Many authors have obtained such responses by assuming that consumers form habits (Fuhrer 2000; Christiano, Eichenbaum, and Evans 2005). Under this assumption, consumers’
behavior depends on their past consumption, which then enters the IS curve and generates hump-shaped responses.

Fourth, the response of output in the textbook model is about one third the size of that in the fairness model, and much smaller than in US data. Despite both models being calibrated through microevidence on price dynamics, monetary shocks are more amplified in the fairness model.

5.5. Effects of technology shocks

The price rigidity arising from fairness concerns allows the transmission of monetary policy to real variables, such as employment and output. The price rigidity also affects the transmission of nonpolicy shocks to the economy. Here we illustrate the effects of a technology shock—the most studied nonpolicy shock in modern macroeconomics—on the economy under fairness concerns.

Simulation results. We simulate the dynamical response of our calibrated model to an unexpected and transitory shock to technology. Once again, we simulate dynamics around the zero-inflation steady state. We assume that the logarithm of technology $A(t)$ in the production function (8) follows an AR(1) process, such that

$$\hat{a}(t) = \mu^a \cdot \hat{a}(t-1) + \zeta^a(t),$$

where the disturbance $\zeta^a(t)$ follows a white-noise process with mean zero, and $\mu^a \in (0, 1)$ governs the persistence of shocks. We set $\mu^a = 0.9$, which is typical (Gali 2008, p. 55), and we simulate the response to an initial disturbance of $\zeta^a(0) = 1\%$.

Figure 2 displays the response to the positive technology shock. The inflation rate is expressed as deviation from steady-state value, measured in percentage points and annualized (by multiplying by four the variable $\hat{\pi}(t)$), whereas all other variables are expressed as percentage deviations from steady-state values.

The increase in technology reduces marginal costs, which generates a drop in inflation: inflation is negative for about four quarters and virtually zero thereafter. Observing lower prices, customers underinfer the underlying decrease in marginal costs and thus perceive lower price markups and fairer transactions. The improvement in perceived fairness decreases the price elasticity of the demand for goods. Firms best respond by raising their markups. The price markup increases by 1.3% at the peak, which depresses employment by 0.7%. Despite the drop in employment, output initially increases by 0.5% because technology is higher.
This figure describes the response of the New Keynesian model with fairness (solid, blue lines) to a 1% increase in technology at time 0. The inflation rate is a deviation from steady state, measured in percentage points and annualized. The other variables are percentage deviations from steady state. For comparison, the figure also displays the response of the textbook New Keynesian model (dashed, orange lines). The log-linearized equilibrium conditions used in the simulation of the model with fairness are described in appendix B; those used in the simulation of the textbook model are in appendix C. The calibration of the two models is described in table 4.
Comparison with macroevidence. In our model, an increase in technology leads to higher output but lower employment. This prediction conforms to much of the evidence from US data (Gali and Rabanal 2005; Basu, Fernald, and Kimball 2006; Francis and Ramey 2009). Our model also predicts that inflation falls after the increase in technology, as documented by Basu, Fernald, and Kimball (2006, fig. 4). Finally, in the model, price markups and output are positively correlated under technology shocks. Nekarda and Ramey (2013) report evidence consistent with this prediction.

Comparison with the textbook New Keynesian model. The similarities and differences between the fairness model and textbook model identified under monetary shocks also apply under technology shocks. The main similarity is that in response to a technology shock, inflation, price markup, employment, and output move in the same directions in the two models. There are three main differences. First, the fairness model produces a hump-shaped response of employment to the technology shock, which the textbook model does not. Second, the fairness model produces a negative correlation between perceived and actual price markups, whereas the two coincide in the textbook model. Last, in response to a positive technology shock, employment falls much more in the fairness model than in the textbook model; as a corollary, output increases much less in the fairness model than in the textbook model.

5.6. Effects of monetary policy in the long run

Our pricing theory implies that monetary policy is nonneutral in the short run, so that a transitory monetary shock affects employment. Here we develop another implication of the theory: monetary policy is nonneutral in the long run, so that different rates of steady-state inflation lead to different levels of steady-state employment. In other words, the theory generates a nonvertical long-run Phillips curve.

We study the long-run effects of monetary policy by comparing the steady-state equilibria induced by different values of the exogenous component \( \bar{l}_0 \) in the monetary-policy rule (9). In steady state the real interest rate equals the time discount rate \( \rho \equiv -\ln(\delta) \); therefore, by choosing \( \bar{l}_0 \), monetary policy perfectly controls steady-state inflation:

\[
\bar{\pi} = \frac{\rho - \bar{l}_0}{\psi - 1}.
\]

To obtain zero inflation, it suffices to set \( \bar{l}_0 = \rho \); to obtain higher inflation, it suffices to reduce \( \bar{l}_0 \).

Acclimation. Kahneman, Knetsch, and Thaler (1986, p. 730) have hypothesized that “any stable state of affairs tends to become accepted eventually”. We adapt this idea to our model by assuming
that people become partially acclimated to the steady-state inflation rate. Formally, we generalize the fairness function (6) to

\[
F(M^p) = 1 - \theta \cdot (M^p - M^f),
\]

where \(M^f\) is the fair markup resulting from acclimation. We assume that the fair markup is the weighted average of the standard markup, \(\epsilon/(\epsilon - 1)\), and the steady-state perceived markup \(\overline{M^p}\):

\[
M^f = \chi \cdot \overline{M^p} + (1 - \chi) \cdot \frac{\epsilon}{\epsilon - 1}.
\]

The parameter \(\chi \in [0, 1]\) measures acclimation: when \(\chi = 0\), there is no acclimation, as in the previous version of the paper; when \(\chi = 1\), there is perfect acclimation, so people do not mind whatever is happening in steady state; when \(\chi \in (0, 1)\), people may be permanently satisfied or dissatisfied in steady state, but less than when \(\chi = 0\).\(^{18}\)

**Analytical results.** In steady state, the rate of inflation determines the perceived price markup, fairness factor, and elasticity of the fairness function:

**Lemma 7.** In the New Keynesian model with fairness, the steady-state perceived price markup is a strictly increasing function of steady-state inflation:

\[
\overline{M^p}(\pi) = \frac{\epsilon}{\epsilon - 1} \cdot \exp\left(\frac{\gamma}{1 - \gamma} \pi\right).
\]

Hence, the steady-state fairness factor is a weakly decreasing function of steady-state inflation:

\[
\overline{F}(\pi) = 1 - \theta \cdot (1 - \chi) \cdot \left[\overline{M^p}(\pi) - \frac{\epsilon}{\epsilon - 1}\right].
\]

Accordingly, the steady-state elasticity of the fairness function is a strictly increasing function of steady-state inflation:

\[
\overline{\phi}(\pi) = \frac{\theta \cdot \overline{M^p}(\pi)}{\overline{F}(\pi)}.
\]

The proof is relegated to appendix B.3; it requires to manipulate the inference mechanism (7) to obtain \(\overline{M^p}\), and to use (14) and (15) to obtain \(\overline{F}\) and \(\overline{\phi}\).

The lemma shows that in steady state households perceive higher price markups when inflation is higher. Households understand that in steady state nominal marginal costs grow at

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\(^{18}\)This specification does not change anything at the zero-inflation steady state. With zero inflation, \(\overline{M^p} = \epsilon/(\epsilon - 1)\), so \(M^f = \epsilon/(\epsilon - 1)\) for any \(\chi\). Therefore, for any \(\chi\), the fairness function (14) simplifies to the function (6).
the inflation rate, but because of subproportional inference, they misjudge the level of those costs and thus of price markups. Since perceived price markups are higher when inflation is higher, the fairness factor is lower—except when consumers are completely acclimated \((\chi = 1)\), in which case the fairness factor is always one. Finally, when inflation is higher, the elasticity of the fairness function is higher. This result holds even if consumers are completely acclimated.

From the lemma, we infer that the long-run Phillips curve is upward sloping:

**Proposition 3.** In the New Keynesian model with fairness, the steady-state price markup is a strictly decreasing function of steady-state inflation:

\[
\bar{M}(\pi) = 1 + \frac{1}{\epsilon - 1} \cdot \frac{1}{1 + \frac{(1-\delta)\gamma}{1-\delta^\gamma} \phi(\pi)}.
\]

Hence, steady-state employment is a strictly increasing function of steady-state inflation:

\[
\bar{N} = \left[ \frac{(\nu - 1)\alpha}{\nu} \cdot \frac{1}{\bar{M}(\pi)} \right]^{1/(1+\eta)}.
\]

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

The proof is in appendix B.3; the main step is reworking (10) in steady state to obtain \(\bar{M}\).

The proposition shows that the long-run Phillips curve slopes upward for any degree of acclimation. Hence, monetary policy is nonneutral in the long run. The reason is that in the long run, higher inflation leads to a lower price markup—and thus higher employment in general equilibrium. In fact, (16) has the same structure as (5) in the monopoly model, 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.

**Simulation results.** To quantify long-run monetary nonneutrality, we compute the long-run Phillips curve in our calibrated model. Figure 3 displays two versions of the curve: one describes the relationship between steady-state inflation and steady-state price markup, and the other the relationship between steady-state inflation and steady-state employment. In the absence of microevidence on acclimation, we compute the long-run Phillips curve for various degrees of acclimation, and show how acclimation affects the slope of the Phillips curve.

With full acclimation \((\chi = 1)\), the Phillips curve is almost vertical, so that steady-state inflation has very little effect on price markup and employment: a permanent increase in inflation by 1
The left-hand panel gives the relationship between steady-state inflation and steady-state price markup. The right-hand panel gives the relationship between steady-state inflation and steady-state employment (measured as percentage deviation from employment in the zero-inflation steady state). These long-run Phillips curve are constructed using the expressions in proposition 3 under the calibration in table 4, for various degrees of acclimation: $\chi = 0$ (no acclimation), $\chi = 1/2$, $\chi = 3/4$, and $\chi = 1$ (full acclimation).

Percentage point raises employment by 0.2%. With less-than-full acclimation, the Phillips curve becomes flatter. For instance, with an acclimation of $\chi = 3/4$, a permanent increase in inflation by 1 percentage point raises employment by 1.3%; and with a lower acclimation of $\chi = 1/2$, a permanent increase in inflation by 1 percentage point raises employment by 3%. Finally, with no acclimation ($\chi = 0$), the Phillips curve is quite flat, and steady-state inflation has a dramatic effect on price markup and inflation. For example, a permanent increase in inflation by 1 percentage point lowers the price markup from 1.5 to 1.25.

Lemma 7 explains why greater acclimation steepens the long-run Phillips curve. With more acclimation, the perceived fairness in steady state, $\overline{F}$, depends less on inflation, because consumers adapt to a larger degree to different inflation rates. As a result, the elasticity of the fairness function in steady state, $\overline{\varphi}$, depends less on inflation. Through formula (16), this means that the steady-state price markup responds less to steady-state inflation: the Phillips curve is steeper.

Comparison with macroevidence. 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, table 1) find in US data that a permanent increase in inflation by 1 percentage point reduces the unemployment rate between 0.2 and 1.3 percentage points, depending on the period and identification strategy. King and Watson (1997) confirm these findings, while highlighting the uncertainty surrounding the Phillips curve's slope.

Quantitatively, the findings by King and Watson are consistent with a good amount of accli-
mation. If we neglect the effect of monetary policy on labor force participation, these results imply that in the United States a permanent increase in inflation by 1 percentage point increases employment by 0.2% to 1.3%. This range corresponds to our model’s predictions for a degree of acclimation between $3/4$ and 1. Indeed, with an acclimation of $\chi = 3/4$, a permanent increase in inflation by 1 percentage point raises employment by 1.3%. With more acclimation, the Phillips curve becomes steeper, and employment rises less. With $\chi = 1$ (full acclimation), a permanent increase in inflation by 1 percentage point only raises employment by 0.2%.

The mechanism behind the long-run Phillips curve is that inflation lowers price markups. There is also direct evidence that this mechanism operates. Benabou (1992) uncovers that in the US retail sector, higher average inflation leads to lower average markup. Banerjee and Russell (2005) reach the same conclusion using aggregate US data.

Finally, the relationship between inflation and price 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 price markup increased from 1.2 to 1.7 over that period. At the same time, average inflation dropped from above 5% to about 2%. Through our mechanism, the drop in inflation could partly explain the increase in markups.

**Comparison with the literature.** The property that in steady state inflation has an effect on the price markup and employment also appears in the textbook New Keynesian model. With Rotemberg (1982) pricing, an increase in steady-state inflation leads to a lower price markup and higher output, as in our model (Ascari and Rossi 2012, fig. 1). With Calvo (1983) pricing, the opposite occurs: an increase in steady-state inflation leads to a higher price markup and lower output, which appears inconsistent with available evidence (Ascari and Rossi 2012, fig. 2).

Our mechanism complements the traditional mechanism for an upward-sloping long-run Phillips curve: that higher steady-state inflation reduces the likelihood that firms experiencing negative shocks are constrained by downward nominal wage rigidity to lay off workers (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 source of downward wage rigidity is workers’ fairness concerns (Bewley 2007).

### 6. 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—

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19 Although the New Keynesian models with Rotemberg and Calvo pricing are the same around the zero-inflation steady state, they differ when steady-state inflation is nonzero (Ascari and Rossi 2012).
perceived as fairly priced—than one priced at a high markup—perceived as unfairly priced. Second, customers who estimate markups infer firms' hidden marginal costs from firms' prices in a subproportional manner: they infer too little, and to the extent that they do infer, they misperceive marginal costs as proportional to prices. These assumptions conform to 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 simulating the calibrated model, we obtain realistic impulse responses of output and employment to monetary shocks: the responses are hump-shaped and have the appropriate amplitude. We also obtain realistic impulse responses to technology shocks: a transitory improvement in technology leads to higher output but lower employment.

The paper delineates a mechanism through which fairness affects a market economy. Hidden information and underinference play crucial roles. 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. Another key ingredient to our theory is that fairness modifies the price elasticity of demand, which allows fairness to sway large markets—a feature not shared by many common approaches to fairness (Dufwenberg et al. 2011; Sobel 2007).

Our model helps bridge a gap between the public's attitude toward inflation and the harm from inflation described by macroeconomic models. Romer (2002, p. 519) argues that “There is a wide gap between the popular view of inflation and the costs of inflation that economist can identify. Inflation is intensely disliked. In periods when inflation is moderately high in the United States, for example, it is often cited in opinion polls as the most important problem facing the country. It appears to have an important effect on the outcome of Presidential elections.” This assessment is consistent with the findings by Shiller (1997) and the results of the Bank of Japan's survey displayed in table 1, which confirm that inflation is indeed intensely disliked. “Yet,” Romer notes, “economists have difficulty in identifying substantial costs of inflation.” Our model contributes to explaining such intense dislike for inflation.

Finally, we hope that our theory might be fruitfully applied to the study of optimal monetary policy. Since its microfoundations match the motivations of real-world customers and firms, as well as their real-world reactions to inflation and deflation, our theory should underpin a more
accurate welfare function that would enhance the design of monetary policy.

References


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### Appendix A. Derivations for the monopoly model

We derive several of the monopoly results stated in section 4. In particular, we provide proofs for proposition 1 and corollary 1.

#### A.1. Properties of the profit function

We show that in all the cases treated in section 4, the monopoly’s profit function is single-peaked (strictly increasing to a peak, then strictly decreasing), so its maximum can be determined by first-order condition.

The monopoly chooses a price $P > C$ to maximize profits

$$ V(P) = (P - C) \cdot Y^d(P). $$

The derivative of the profit function is

$$ V'(P) = Y^d + (P - C) \frac{dY^d}{dP} = Y^d - (P - C) \frac{Y^d}{P} E(P), $$

where $E(P) \equiv -d \ln(Y^d)/d \ln(P) = -(P/Y^d)(dY^d/dP)$ is the price elasticity of demand. Hence the derivative of the profit function satisfies

$$ (A1) \quad V'(P) = Y^d(P) \left[1 - \frac{P - C}{P} E(P)\right]. $$

We now study the properties of the derivative (A1) in the various cases considered in section 4.
No fairness concerns. Without fairness concerns, the price elasticity of demand is \( E = \epsilon \) (section 4.3). Hence the derivative (A1) becomes

\[
V'(P) = Y^d(P) \left[ 1 - \frac{(P - C)}{P} \right].
\]

The function \( P \mapsto (P - C)/P \) is strictly increasing from 0 to 1 as \( P \) increases from \( C \) to \( +\infty \), so the term in square brackets is strictly decreasing from 1 to \( 1 - \epsilon < 0 \) as \( P \) increases from \( C \) to \( +\infty \). Hence, the term in square brackets has a unique root \( P^* \) on \( (C, +\infty) \) is positive for \( P < P^* \), and is negative for \( P > P^* \). Since \( Y^d(P) > 0 \), these properties transfer to the derivative of the profit function: \( V'(P) > 0 \) for \( P \in (C, P^*) \), \( V'(P) = 0 \) at \( P = P^* \), and \( V'(P) < 0 \) for \( P \in (P^*, +\infty) \). We conclude that the profit function is single-peaked, and its maximum \( P^* \) is the unique solution to the first-order condition \( V'(P) = 0 \).

Fairness concerns and observable costs. With fairness concerns and observable costs, the price elasticity of demand is \( E = \epsilon + (\epsilon - 1)\phi(P/C) \) (section 4.4). The profit function is now defined for \( P \in (C, M^h \cdot C) \). The derivative (A1) becomes

\[
V'(P) = Y^d(P) \left[ 1 - \frac{(P - C)}{P} \cdot \left\{ \epsilon + (\epsilon - 1)\phi(P/C) \right\} \right].
\]

Again, the function \( P \mapsto (P - C)/P \) is strictly increasing from 0 to 1 as \( P \) increases from \( C \) to \( +\infty \). The elasticity of the fairness function \( \phi(P/C) \) is strictly increasing from \( \phi(1) > 0 \) to \( +\infty \) as \( P \) increases from \( C \) to \( M^h \cdot C \) (lemma 2). Hence the term in square brackets is strictly decreasing from 1 to \( -\infty \) as \( P \) increases from \( C \) to \( M^h \cdot C \). This implies that the term in square brackets has a unique root \( P^* \) on \( (C, M^h \cdot C) \), is positive for \( P < P^* \), and is negative for \( P > P^* \). Following the same argument as in the previous case, we conclude that the profit function is single-peaked, and its maximum \( P^* \) is the unique solution to the first-order condition \( V'(P) = 0 \).

Fairness concerns and rational inference of costs. With fairness concerns rational inference of marginal costs, the price elasticity of demand is again \( E = \epsilon \) (section 4.5). Hence, as in the case of no fairness concerns, the profit function is single-peaked so its maximum is the unique solution to the first-order condition \( V'(P) = 0 \).

Fairness concerns and subproportional inference of costs. With fairness concerns and subproportional inference of costs, the price elasticity of demand is \( E = \epsilon + (\epsilon - 1)\gamma \phi(M^p(P)) \) (section 4.6).
The profit function is now defined for \( P \in (C, P^b) \), where the upper bound is defined by

\[
(A2) \quad P^b = \frac{\epsilon}{\epsilon - 1} (M^h)^{1/\gamma} C^b.
\]

The price \( P^b \) is such that at \( P^b \), the perceived markup reaches the upper bound of the domain of the fairness function: \( M^p(P^b) = M^h \). The derivative \((A1)\) becomes

\[
V'(P) = Y^d(P) \left[ 1 - \frac{P - C}{P} \cdot \left\{ \epsilon + (\epsilon - 1)\gamma \phi(M^p(P)) \right\} \right].
\]

Again, the function \( P \mapsto (P - C)/P \) is strictly increasing from 0 to 1 as \( P \) increases from \( C \) to \( +\infty \). The perceived markup \( M^p(P) \) is strictly increasing from \( M^p(C) > 0 \) to \( M^h \) as \( P \) increases from \( C \) to \( P^b \) (lemma 5). Hence, the elasticity of the fairness function \( \phi(M^p(P)) \) is strictly increasing from \( \phi(M^p(C)) > 0 \) to \( +\infty \) as \( P \) increases from \( C \) to \( P^b \) (lemma 2). Since \( \gamma > 0 \), we infer that the term in square brackets is strictly decreasing from 1 to \( -\infty \) as \( P \) increases from \( C \) to \( P^b \). Thus the term in square brackets has a unique root \( P^* \) on \((C, P^b)\), is positive for \( P < P^* \), and is negative for \( P > P^* \). Following the same argument as in the previous cases, we conclude that the profit function is single-peaked, and its maximum \( P^* \) is the unique solution to the first-order condition \( V'(P) = 0 \).

### A.2. Proof of proposition 1

**Markup.** Since customers care about fairness and infer subproportionally, the price elasticity of demand is \( E = \epsilon + (\epsilon - 1)\gamma \phi(M^p(P)) \). Moreover, the monopoly’s optimal markup is \( M = E/(E - 1) = 1 + 1/(E - 1) \). Combining these equations yields the markup

\[
(A3) \quad M = 1 + \frac{1}{\epsilon - 1} \cdot \frac{1}{1 + \gamma \phi(M^p(M \cdot C))}.
\]

In \((A3)\) we have used the fact that the price is related to the markup by \( P = M \cdot C \).

Toward showing that \((A3)\) admits a unique solution, we introduce the price \( P^b \) defined by \((A2)\) and the markup \( M^b = P^b/C > 1 \). Since \( P = M \cdot C \), \( P \) strictly increases from 0 to \( P^b \) when \( M \) increases from 0 to \( M^b \). Next, lemma 5 shows that \( M^p(P) \) strictly increases from 0 to \( M^h \) when \( P \) increases from 0 to \( P^b \). Last, lemma 2 indicates that \( \phi(M^p) \) strictly increases from 0 to \( \infty \) when \( M^p \) increases from 0 to \( M^h \). As \( \gamma > 0 \), we conclude that when \( M \) increases from 0 to \( M^b > 1 \), the right-hand side of \((A3)\) strictly decreases from \( \epsilon/(\epsilon - 1) \) to 1. Hence, \((A3)\) has a unique solution \( M \in [0, M^b] \), implying that the markup exists and unique. Given the range of values taken by the right-hand side of \((A3)\), we also infer that \( M \in (1, \epsilon/(\epsilon - 1)) \).

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Footnote: We know that \( P^b > C \) because \( C^b \) satisfies \( C^b > (\epsilon - 1) \cdot (M^h)^{-1/\gamma} \cdot C/\epsilon \) (definition 3).
**Passthrough.** We now compute the cost passthrough, $\beta = d \ln(P)/d \ln(C)$. The equilibrium price is $P = M(M^p(P)) \cdot C$, where the markup $M(M^p)$ is given by (A3). Using this price equation, we obtain

$$\beta = \frac{d \ln(M)}{d \ln(M^p)} \cdot \frac{d \ln(M^p)}{d \ln(P)} \cdot \frac{d \ln(P)}{d \ln(C)} + 1.$$  

Since $d \ln(M^p)/d \ln(P) = \gamma$ (Lemma 5) and $d \ln(P)/d \ln(C) = \beta$ (by definition), we get

$$(A4) \quad \beta = \frac{1}{1 - \gamma \frac{d \ln(M)}{d \ln(M^p)}}.$$

Our next step is to compute the elasticity of $M(M^p)$ with respect to $M^p$ from (A3):

$$-\frac{d \ln(M)}{d \ln(M^p)} = -\frac{1}{M} \cdot \frac{d M}{d \ln(M^p)} = \frac{1}{M} \cdot \frac{1}{\epsilon - 1} \cdot \frac{1}{1 + \gamma \phi} \cdot \frac{1}{1 + \gamma \phi} \cdot \gamma \cdot \frac{d \phi}{d \ln(M^p)}.$$

Using (A3), we find that

$$(\epsilon - 1)(1 + \gamma \phi)M = \epsilon + (\epsilon - 1)\gamma \phi.$$  

Moreover, by definition, the superelasticity $\sigma$ of the fairness function satisfies $\phi \sigma = d \phi/d \ln(M^p)$. Combining these three results, we obtain

$$(A5) \quad -\frac{d \ln(M)}{d \ln(M^p)} = \frac{\gamma \phi \sigma}{[\epsilon + (\epsilon - 1)\gamma \phi](1 + \gamma \phi)}.$$

Finally, combining (A4) with (A5) yields the cost passthrough

$$(A6) \quad \beta = \frac{1}{1 + \left(\frac{\gamma^2 \phi \sigma}{(1 + \gamma \phi)[\epsilon + (\epsilon - 1)\gamma \phi]}\right)}.$$

Since $\gamma > 0$ (Definition 3), $\phi > 0$ (Lemma 2), and $\sigma > 0$ (also Lemma 2), we infer that $\beta \in (0, 1)$.

**A.3. Proof of corollary 1**

We apply the results of proposition 1 to a specific fairness function:

$$(A7) \quad F(M^p) = 1 - \theta \cdot \left(M^p - \frac{\epsilon}{\epsilon - 1}\right).$$

We also assume that customers are acclimated, so $M^p = \epsilon / (\epsilon - 1)$ and $F = 1$.  

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**Preliminary results.** The elasticity of the fairness function (A7) is

\[ \phi = -\frac{M_p}{F} \cdot \frac{dF}{dM_p} = \frac{M_p}{F} \cdot \theta. \]

Accordingly, the superelasticity of the fairness function (A7) satisfies

\[ \sigma = \frac{d\ln(\phi)}{d\ln(M_p)} = 1 - \frac{d\ln(F)}{d\ln(M_p)} = 1 + \phi. \]

When \( M_p = \frac{\epsilon}{(\epsilon - 1)} \) and \( F = 1 \), the elasticity and superelasticity simplify to

(A8) \[ \phi = \frac{\epsilon \theta}{\epsilon - 1} \]

(A9) \[ \sigma = 1 + \frac{\epsilon \theta}{\epsilon - 1}. \]

**Markup.** Combining (A3) with (A8), we obtain the following markup:

\[ M = 1 + \frac{1}{\epsilon - 1} \cdot \frac{1}{1 + \gamma \epsilon \theta / (\epsilon - 1)} = 1 + \frac{1}{(1 + \gamma \theta)\epsilon - 1}. \]

This expression shows that \( M \) is lower when \( \epsilon, \gamma, \) or \( \theta \) are higher.

**Passthrough.** Combining (A6) with (A8) and (A9), we find that the cost passthrough \( \beta \) satisfies

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

Next we introduce the auxiliary function

(A10) \[ \Delta(\gamma, \theta, \epsilon) = \frac{\gamma^2 \epsilon \theta \left[ (1 + \theta)\epsilon - 1 \right]}{(\epsilon - 1) \left[ (1 + \gamma \theta)\epsilon - 1 \right] (1 + \gamma \theta)}, \]

where \( \gamma > 0, \theta > 0, \) and \( \epsilon > 1 \). Dividing numerator and denominator of \( \Delta \) by \( \gamma^2 \), we get

\[ \Delta(\gamma, \theta, \epsilon) = \frac{\theta \left[ (1 + \theta)\epsilon - 1 \right]}{(\epsilon - 1) \left[ \theta \epsilon + (\epsilon - 1)/\gamma \right] (\theta + 1/\gamma)}. \]

The denominator is decreasing in \( \gamma \), so \( \Delta \) is increasing in \( \gamma \). Since \( \beta = 1/(1 + \Delta) \), we conclude that \( \beta \) is decreasing in \( \gamma \).
Next, we divide numerator and denominator of $\Delta$ in (A10) by $(\epsilon - 1)$:

$$\Delta(\gamma, \theta, \epsilon) = \frac{\gamma^2 \theta [1 + \theta \epsilon / (\epsilon - 1)]}{(1 + \gamma \theta) \epsilon - 1}.$$ 

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

Last, we divide numerator and denominator of $\Delta$ in (A10) by $\theta$ $(\epsilon \theta + \epsilon - 1)$:

$$\Delta(\gamma, \theta, \epsilon) = \frac{\gamma^2}{(\epsilon - 1)(\gamma + 1/\theta)\frac{\gamma \epsilon \theta + \epsilon - 1}{\epsilon \theta + \epsilon - 1}}.$$ 

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

### Appendix B. Derivations for the New Keynesian model

We derive the properties of the New Keynesian model with fairness presented in section 5. In particular, we prove lemmas 6 and 7, as well as propositions 2 and 3.

#### B.1. Household and firm problems

We begin by solving the problems of households and firms.

**Household $k$’s problem.** To solve household $k$’s problem, we set up the Lagrangian:

$$\mathcal{L}_k = \mathbb{E}_0 \sum_{t=0}^{\infty} \delta^t \left\{ \ln(Z_k(t)) - \frac{N_k(t)^{1+\eta}}{1 + \eta} \right. \right. $$

$$+ \mathcal{A}_k(t) \left[ W_k(t)N_k(t) + B_k(t-1) + V_k(t) - Q(t)B_k(t) - \int_0^1 P_j(t)Y_{jk}(t) \, dj \right]$$

$$+ \mathcal{B}_k(t) \left[ N_{k}^{\theta}(t, W_k(t)) - N_k(t) \right].$$

In the Lagrangian, $\mathcal{A}_k(t)$ is the Lagrange multiplier on the budget constraint in period $t$; $\mathcal{B}_k(t)$ is the Lagrange multiplier on the labor-demand constraint in period $t$; and $Z_k(t)$ is the fairness-
Adjusted consumption index:

\[(A11) \quad Z_k(t) = \left[ \int_0^t Z_{jk}(t)^{(e-1)/\epsilon} \, dj \right]^{\epsilon/(\epsilon-1)}. \]

In the consumption index, \(Z_{jk}(t)\) is the fairness-adjusted consumption of good \(j\):

\[(A12) \quad Z_{jk}(t) = F_j(t) \cdot Y_{jk}(t). \]

**First-order conditions with respect to consumption.** We first compute the first-order conditions with respect to \(Y_{jk}(t)\) for all goods \(j \in [0, 1]\): \(\partial \mathcal{L}_k / \partial Y_{jk}(t) = 0\). From the definitions of \(Z_k(t)\) and \(Z_{jk}(t)\) given by (A11) and (A12), we find

\[
\frac{\partial Z_{jk}(t)}{\partial Y_{jk}(t)} = F_j(t) \quad \text{and} \quad \frac{\partial Z_k(t)}{\partial Z_{jk}(t)} = \left[ \frac{Z_{jk}(t)}{Z_k(t)} \right]^{-1/\epsilon} \, dj.
\]

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

\[(A13) \quad \left[ \frac{Z_{jk}(t)}{Z_k(t)} \right]^{-1/\epsilon} \frac{F_j(t)}{Z_k(t)} = \mathcal{A}_k(t) P_j(t).
\]

Taking (A13) to the power of \(1 - \epsilon\) and reshuffling terms, we then obtain

\[
\frac{1}{Z_k(t)^{1-\epsilon}} \cdot \frac{1}{Z_k(t)^{(e-1)/\epsilon}} \cdot Z_{jk}(t)^{(e-1)/\epsilon} = \mathcal{A}_k(t)^{1-\epsilon} \left[ \frac{P_j(t)}{F_j(t)} \right]^{1-\epsilon}
\]

We integrate this equation over \(j \in [0, 1]\), use the definition of \(Z_k(t)\) given by (A11), and introduce the price index

\[(A14) \quad X(t) = \left\{ \int_0^1 \left[ \frac{P_j(t)}{F_j(t)} \right]^{1-\epsilon} \, dj \right\}^{1/(1-\epsilon)}. \]

We obtain the following:

\[
\frac{1}{Z_k(t)^{1-\epsilon}} \cdot \frac{Z_k(t)^{(e-1)/\epsilon}}{Z_k(t)^{(e-1)/\epsilon}} = \mathcal{A}_k(t)^{1-\epsilon} X(t)^{1-\epsilon}.
\]

From this equation we infer

\[(A15) \quad \mathcal{A}_k(t) = \frac{1}{X(t)Z_k(t)}. \]
Last, combining (A/13) and (A/15), we find that the optimal fairness-adjusted consumption of good \( j \) by household \( k \) satisfies

\[
Z_{jk}(t) = Z_k(t) \left[ \frac{P_j(t)}{X(t)} \right]^{-\epsilon} F_j(t)^{\epsilon}.
\]

As consumption and fairness-adjusted consumption of good \( j \) are related by \( Y_{jk}(t) = Z_{jk}(t)/F_j(t) \), the optimal consumption of good \( j \) by household \( k \) satisfies

(A/16)

\[
Y_{jk}(t) = Z_k(t) \left[ \frac{P_j(t)}{X(t)} \right]^{-\epsilon} F_j(t)^{\epsilon - 1}.
\]

Integrating (A/16) over all households \( k \in [0, 1] \) yields the output of good \( j \):

\[
Y_j(t) = Z(t) \left[ \frac{P_j(t)}{X(t)} \right]^{-\epsilon} F_j(t)^{\epsilon - 1}.
\]

We note that the fairness factor \( F_j(t) \) is a function of the perceived price markup, \( F_j(t) = F_j(P_j(t)/C^p_j(t)) \), and that the perceived marginal cost \( C^p_j(t) \) follows the law of motion (7). These observations allow us to obtain the demand for good \( j \):

\[
Y^d_j(t, P_j(t), C^p_j(t - 1)) = Z(t) \left[ \frac{P_j(t)}{X(t)} \right]^{-\epsilon} F_j \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\gamma} \left[ \frac{P_j(t)}{C^p_j(t - 1)} \right]^{\gamma} F_j^{\gamma - 1}.
\]

For future reference, the elasticities of the function \( Y^d_j(t, P_j(t), C^p_j(t - 1)) \) are

(A/17)

\[
- \frac{\partial \ln(Y^d_j)}{\partial \ln(P_j)} = \epsilon + (\epsilon - 1)\gamma \phi_j(M^p_j(t)) \equiv E_j(M^p_j(t))
\]

(A/18)

\[
- \frac{\partial \ln(Y^d_j)}{\partial \ln(C^p_j)} = (\epsilon - 1)\gamma \phi_j(M^p_j(t)) = E_j(M^p_j(t)) - \epsilon.
\]

The function \( E_j(M^p_j) \) gives the price elasticity of the demand for good \( j \), normalized to be positive.

Moreover, using (A/16) and the definition of the price index \( X \) given by (A/14), we find that

\[
\int_0^1 P_j Y_{jk} \, dj = X^\epsilon Z_k \int_0^1 \left( \frac{P_j}{F_j} \right)^{1-\epsilon} \, dj = XZ_k.
\]

This means that when households optimally allocate their consumption expenditures across goods, the price of one unit of fairness-adjusted consumption index is \( X \).
First-order condition with respect to bonds. The first-order condition with respect to $B_k(t)$ is $\partial \mathcal{L}_k / \partial B_k(t) = 0$, which gives

$$Q(t)\mathcal{A}_k(t) = \delta \mathbb{E}_t(\mathcal{A}_k(t + 1)).$$

Using (A15), we obtain household $k$’s consumption Euler equation:

$$(A19) \quad Q(t) = \delta \mathbb{E}_t \left( \frac{X(t)Z_k(t)}{X(t + 1)Z_k(t + 1)} \right).$$

This equation governs how the household smooths fairness-adjusted consumption over time.

Firm $j$’s problem. Since the wages set by households depend on firms’ labor demands, we turn to the firms’ problems before finishing the households’ problems. To solve firm $j$’s problem, we set up the Lagrangian:

$$\mathcal{L}_j = \mathbb{E}_0 \sum_{t=0}^{\infty} \Gamma(t) \left\{ P_j(t)Y_j(t) - \int_0^1 W_k(t)N_{jk}(t) \, dk \right. \right.$$

$$+ \mathcal{H}_j(t) \left[ Y_j(t), P_j(t), C_j^p(t - 1) - Y_j(t) \right] + \mathcal{J}_j(t) \left[ A_j(t)N_j(t)^\alpha - Y_j(t) \right]

$$+ \mathcal{K}_j(t) \left[ C_j^p(t - 1)^\gamma \left[ \frac{\epsilon - 1}{\epsilon} P_j(t) \right]^{1-\gamma} - C_j^p(t) \right].$$

In the Lagrangian, $\mathcal{H}_j(t)$ is the Lagrange multiplier on the demand constraint in period $t$; $\mathcal{J}_j(t)$ is the Lagrange multiplier on the production constraint in period $t$; $\mathcal{K}_j(t)$ is the Lagrange multiplier on the law of motion of the perceived marginal cost in period $t$; and $N_j(t)$ is the employment index:

$$(A20) \quad N_j(t) = \left[ \int_0^1 N_{jk}(t)^{(\nu - 1)/\nu} \, dk \right]^{\nu/(\nu - 1)}.$$

First-order conditions with respect to employment. We compute the first-order conditions with respect to $N_{jk}(t)$ for all labor services $k \in [0, 1]$: $\partial \mathcal{L}_j / \partial N_{jk}(t) = 0$. From the definition of $N_j(t)$ given by (A20), we know that

$$\frac{\partial N_j(t)}{\partial N_{jk}(t)} = \left[ \frac{N_{jk}(t)}{N_j(t)} \right]^{-1/\nu} dk.$$
Hence the first-order conditions imply that for all $k \in [0, 1]$,

\[(A21) \quad W_k(t) = \alpha \mathcal{F}_j(t)A_j(t)N_j(t)^{\alpha - 1} \left[ \frac{N_{jk}(t)}{N_j(t)} \right]^{-1/\nu}.\]

Toward deriving firm $j$'s labor demand, we introduce the wage index

\[(A22) \quad W(t) = \left[ \int_0^1 W_k(t)^{1-\nu} \, dk \right]^{1/(1-\nu)}.\]

Taking $(A21)$ to the power of $1 - \nu$, we obtain

\[W_k(t)^{1-\nu} = \left[ \alpha \mathcal{F}_j(t)A_j(t)N_j(t)^{\alpha - 1} \right]^{1-\nu} \frac{1}{N_j(t)^{(\nu-1)/\nu}} N_{jk}(t)^{(\nu-1)/\nu}.\]

Integrating this condition over $k \in [0, 1]$ and using the definitions of $N_j$ and $W$ given by $(A20)$ and $(A22)$, we find

\[W(t)^{1-\nu} = \left[ \alpha \mathcal{F}_j(t)A_j(t)N_j(t)^{\alpha - 1} \right]^{1-\nu} \frac{N_j(t)^{(\nu-1)/\nu}}{N_j(t)^{(\nu-1)/\nu}}.\]

From this equation we infer

\[(A23) \quad W(t) = \alpha \mathcal{F}_j(t)A_j(t)N_j(t)^{\alpha - 1}.\]

Last, we combine $(A21)$ and $(A23)$ to determine the quantity of labor that firm $j$ hires from household $k$:

\[(A24) \quad N_{jk}(t) = N_j(t) \left[ \frac{W_k(t)}{W(t)} \right]^{-\nu}.\]

Integrating $(A24)$ over all firms $j \in [0, 1]$ yields the demand for labor service $k$:

\[(A25) \quad N_k^d(t, W_k(t)) = N(t) \left[ \frac{W_k(t)}{W(t)} \right]^{-\nu},\]

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

Moreover, $(A22)$ and $(A24)$ imply that

\[\int_0^1 W_k N_{jk} \, dk = W^\nu N_j \int_0^1 W_k^{1-\nu} \, dk = WN_j.\]

This means that when firms optimally allocate their wage bill across labor services, the cost of
one unit of labor index is $W$.

**First-order conditions with respect to labor and wage.** We now finish solving household $k$’s problem using labor demand (A25). The first-order conditions with respect to $N_k(t)$ and $W_k(t)$ are $\partial \mathcal{L}_k / \partial N_k(t) = 0$ and $\partial \mathcal{L}_k / \partial W_k(t) = 0$; they yield

\begin{align*}
(A26) & \quad \quad N_k(t) = \mathcal{A}_k(t)W_k(t) - \mathcal{B}_k(t) \\
(A27) & \quad \quad \mathcal{A}_k(t)N_k(t) = -\mathcal{B}_k(t) \frac{dN_k^d}{dW_k}.
\end{align*}

Since the elasticity of $N_k^d$ with respect to $W_k$ is $-\nu$, we infer from (A27) that

\begin{equation}
(A28) \quad \mathcal{A}_k(t)W_k(t) = \mathcal{B}_k(t)\nu.
\end{equation}

Plugging this result into (A26), we obtain

\begin{equation}
\mathcal{B}_k(t) = \frac{N_k(t)\nu}{\nu - 1}.
\end{equation}

Combining this result with (A28) then yields

\begin{equation}
W_k(t) = \frac{\nu}{\nu - 1} \cdot \frac{N_k(t)\nu}{\mathcal{A}_k(t)}.
\end{equation}

Finally, by merging this equation with (A15), we find that household $k$ sets its wage rate at

\begin{equation}
(A29) \quad \frac{W_k(t)}{X(t)} = \frac{\nu}{\nu - 1}N_k(t)\nu Z_k(t).
\end{equation}

This equation shows that households set their real wage at a markup of $\nu/(\nu - 1) > 1$ over the marginal rate of substitution between leisure and consumption.

**First-order condition with respect to output.** We then finish solving firm $j$’s problem. The first-order condition with respect to $Y_j(t)$ is $\partial \mathcal{L}_j / \partial Y_j(t) = 0$, which gives

\begin{equation}
P_j(t) = \mathcal{H}_j(t) + \mathcal{I}_j(t).
\end{equation}

Using the value of $\mathcal{I}_j(t)$ given by (A23), we then obtain

\begin{equation}
(A30) \quad \mathcal{H}_j(t) = P_j(t) \left[1 - \frac{W(t)/P_j(t)}{A_j(t)N_j(t)^{\alpha-1}}\right].
\end{equation}
Note that firm $j$'s nominal marginal cost is the nominal wage divided by the marginal product of labor:

$$C_j(t) = \frac{W(t)}{\alpha A_j(t) N_j(t)^{\alpha-1}}. \tag{A31}$$

Hence the first-order condition (A30) can be written

$$\mathcal{H}_j(t) = P_j(t) \left[ 1 - \frac{C_j(t)}{P_j(t)} \right]. \tag{A32}$$

Given that firm $j$'s markup is $M_j(t) = P_j(t)/C_j(t)$, we rewrite this equation as

$$\frac{\mathcal{H}_j(t)}{P_j(t)} = \frac{M_j(t) - 1}{M_j(t)}. \tag{A33}$$

**First-order condition with respect to price.** The first-order condition of firm $j$'s problem with respect to $P_j(t)$ is $\partial L_j/\partial P_j(t) = 0$. It yields

$$0 = Y_j(t) + \mathcal{H}_j(t) \frac{\partial Y^d_j}{\partial P_j} + (1 - \gamma) \mathcal{K}_j(t) \frac{C^\phi_j(t)}{P_j(t)}. \tag{A34}$$

We divide this condition by $Y_j(t)$, and we insert the price elasticity of the demand for good $j$, $E_j(M^\phi_j(t)) = -\partial \ln(Y^d_j)/\partial \ln(P_j)$, as well as the perceived price markup for good $j$, $M^\phi_j(t) = P_j(t)/C^\phi_j(t)$. We obtain

$$0 = 1 - \frac{\mathcal{H}_j(t) E_j(M^\phi_j(t))}{P_j(t)} + (1 - \gamma) \frac{\mathcal{K}_j(t)}{Y_j(t) M^\phi_j(t)}. \tag{A35}$$

Using the value of $\mathcal{H}_j(t)$ given by (A33), we finally obtain

$$(1 - \gamma) \frac{\mathcal{K}_j(t)}{Y_j(t) M^\phi_j(t)} = \frac{M_j(t) - 1}{M_j(t)} E_j(M^\phi_j(t)) - 1. \tag{A36}$$

**First-order condition with respect to perceived marginal cost.** Finally, the first-order condition of firm $j$'s problem with respect to $C^\phi_j(t)$ is $\partial L_j/\partial C^\phi_j(t) = 0$. It gives

$$0 = \mathbb{E}_t \left( \frac{\Gamma(t+1)}{\Gamma(t)} \mathcal{H}_j(t+1) \frac{\partial Y^d_j}{\partial C^\phi_j} \right) + \gamma \mathbb{E}_t \left( \frac{\Gamma(t+1)}{\Gamma(t)} \mathcal{K}_j(t+1) \frac{C^\phi_j(t+1)}{C^\phi_j(t)} \right) - \mathcal{K}_j(t).$$
And using the elasticity given by (A18), we find

$$\mathcal{K}_j(t) = \mathbb{E}_t \left( \frac{\Gamma(t + 1)}{\Gamma(t)} \left\{ \mathcal{H}_j(t + 1) \frac{Y_j(t + 1)}{C_j(t)} \left[ E_j(M_j^p(t + 1)) - \epsilon \right] + \gamma \mathcal{K}_j(t + 1) \frac{C_j(t + 1)}{C_j(t)} \right\} \right).$$

We modify this equation in two steps: first, we multiply it by $C_j^p(t)/[Y_j(t)P_j(t)]$; second, we insert the perceived price markups $M_j^p(t) = P_j(t)/C_j^p(t)$ and $M_j^p(t + 1) = P_j(t + 1)/C_j^p(t + 1)$. We get

$$\frac{\mathcal{K}_j(t)M_j^p(t)}{Y_j(t)} = \mathbb{E}_t \left( \frac{\Gamma(t + 1)Y_j(t + 1)P_j(t + 1)}{\Gamma(t)Y_j(t)P_j(t)} \left\{ \frac{\mathcal{H}_j(t + 1)}{P_j(t + 1)} \left[ E_j(M_j^p(t + 1)) - \epsilon \right] + \gamma \frac{\mathcal{K}_j(t + 1)M_j^p(t + 1)}{Y_j(t + 1)} \right\} \right).$$

Last, we multiply the equation by $(1 - \gamma)$; and we eliminate $\mathcal{H}_j(t + 1)$ using (A33) and $\mathcal{K}_j(t)$ and $\mathcal{K}_j(t + 1)$ using (A35). We obtain firm $j$'s pricing equation, which links its markup to its perceived markup:

$$(A36) \quad \frac{M_j(t) - 1}{M_j(t)}E_j(M_j^p(t)) =$$

$$1 + \mathbb{E}_t \left( \frac{\Gamma(t + 1)Y_j(t + 1)P_j(t + 1)}{\Gamma(t)Y_j(t)P_j(t)} \left\{ \frac{M_j(t + 1) - 1}{M_j(t + 1)} \left[ E_j(M_j^p(t + 1)) - (1 - \gamma)\epsilon \right] \right\} \right).$$

**B.2. Equilibrium**

We present the equilibrium of the model. Because all households and firms face the same conditions, they all behave the same in equilibrium, so we drop the subscripts $j$ and $k$ on all variables.

The equilibrium can be described by seven variables: output $Y(t)$, employment $N(t)$, the price level $P(t)$, the wage $W(t)$, the bond price $Q(t)$, the price markup $M(t)$, and the perceived price markup $M^p(t)$. These seven variables are determined by seven equations.

The first equation is the monetary-policy rule, given by (9). The second equation is the production function, which is directly obtained from (8):

$$(A37) \quad Y(t) = A(t)N(t)^\alpha.$$  

The third equation is the usual consumption Euler equation, which is obtained by simplifying (A19). By symmetry $X(t) = P(t)/F(t)$ and $Z_k(t) = F(t)Y(t)$, so (A19) simplifies to

$$(A38) \quad Q(t) = \delta \mathbb{E}_t \left( \frac{P(t)Y(t)}{P(t + 1)Y(t + 1)} \right).$$

The fourth equation is the usual expression for the real wage, which is obtained by simplifying
(A29). Once again, by symmetry \( X(t) = P(t)/F(t) \) and \( Z_k(t) = F(t)Y(t) \), so (A29) yields

\[
\frac{W(t)}{P(t)} = \frac{\nu}{\nu - 1} N(t)^\eta Y(t).
\]

Combining this equation with (A37), we express the real wage as a function of employment:

\[
(A39) \quad \frac{W(t)}{P(t)} = \frac{\nu}{\nu - 1} A(t)N(t)^{\eta + \alpha}.
\]

The fifth equation is the standard link between price markup and employment, which is obtained from the definition of the price markup. In a symmetric economy the price markup is just the inverse of the real marginal cost: \( M(t) = P(t)/C(t) \). Combining the expression of the nominal marginal cost given by (A31) with the value of the real wage given by (A39), we infer the real marginal cost:

\[
\frac{C(t)}{P(t)} = \frac{\nu}{(\nu - 1)\alpha} N(t)^{1 + \eta}.
\]

Since the price markup is the inverse of the real marginal cost, we find

\[
(A40) \quad N(t) = \left[ \frac{(\nu - 1)\alpha}{\nu} \cdot \frac{1}{M(t)} \right]^{1/(1 + \eta)}.
\]

The sixth equation is a pricing equation, which is obtained by simplifying (A36). Recall that \( \Gamma(t) = \delta^t X(0)Z(0)/[X(t)Z(t)] \). Since by symmetry \( Z(t) = F(t)Y(t) \) and \( X(t) = P(t)/F(t) \), we have

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

Hence, (A36) simplifies to

\[
(A41) \quad \frac{M(t) - 1}{M(t)} E(M^P(t)) = 1 - \delta Y + \delta E_t \left( \frac{M(t + 1) - 1}{M(t + 1)} \left[ E(M^P(t + 1)) - (1 - \gamma)\epsilon \right] \right).
\]

This pricing equation shows the dynamic relationship between actual and perceived price markups. Unlike the other equilibrium conditions—which are the same as in the textbook model—the pricing equation is unique to the model with fairness.

The seventh and last equation is the law of motion of the perceived price markup. It derives from the law of motion of the perceived marginal cost, given by (7). Since \( M^P(t) = P(t)/C^P(t) \), (7) implies

\[
M^P(t) = \left[ \frac{P(t)}{(\epsilon - 1)P(t)/\epsilon} \right]^{1 - \gamma} \left[ \frac{P(t)}{C^P(t - 1)} \right]^\gamma = \left( \frac{\epsilon}{\epsilon - 1} \right)^{1 - \gamma} \left[ \frac{P(t)}{P(t - 1)} \right]^\gamma \left[ \frac{P(t - 1)}{C^P(t - 1)} \right].
\]
Hence the perceived price markup satisfies

\[(A42) \quad M^p(t) = \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\gamma} \left[ \frac{P(t)}{P(t-1)} \right]^\gamma \left[ M^p(t-1) \right]^\gamma.\]

### B.3. Steady-state equilibrium

We now apply the equilibrium conditions to a steady-state environment, in which all real variables are constant and all nominal variables grow at the inflation rate, $\pi$. We then use these steady-state conditions to prove lemma 7 and proposition 3.

We describe the steady-state equilibrium by six variables: output $\overline{Y}$, employment $\overline{N}$, inflation $\overline{\pi}$, real interest rate $\overline{r}$, price markup $\overline{M}$, and perceived price markup $\overline{M^p}$. These six variables are governed by six equations.

**Steady-state equilibrium conditions.** First, in steady state the consumption Euler equation (A38) gives

\[\overline{Q} = \delta \cdot \frac{P(t)}{P(t+1)}.\]

Taking the logarithm of this equation yields $-\overline{i} = -\rho - \overline{\pi}$, where $\rho \equiv -\ln(\delta)$ is the time discount rate. Hence the steady-state real interest rate $\overline{r} = \overline{i} - \overline{\pi}$ satisfies

\[\overline{r} = \rho.\]

Second, in steady state the monetary-policy rule (9) implies that $\overline{r} = \overline{r_0} + (\psi - 1)\overline{\pi}$. Since $\overline{r} = \rho$, the steady-state inflation rate is

\[\overline{\pi} = \frac{\rho - \overline{r_0}}{\psi - 1}.\]

Third, in steady state the law of motion of the perceived price markup (A42) implies that

\[\left( \overline{M^p} \right)^{1-\gamma} = \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\gamma} \left[ \frac{P(t)}{P(t-1)} \right]^\gamma.\]

Taking this expression to the power of $1/(1-\gamma)$, and noting that in steady state $P(t)/P(t-1) = \exp(\overline{\pi})$, we find that the steady-state perceived price markup is

\[(A43) \quad \overline{M^p} = \frac{\epsilon}{\epsilon - 1} \exp\left( \frac{\gamma}{1-\gamma} \overline{\pi} \right).\]
Fourth, in steady state the pricing equation \((A/4.1)\) implies that
\[
0 = 1 - \delta \gamma - \frac{\bar{M} - 1}{\bar{M}} E(\bar{M}^p) + \frac{\delta (\bar{M} - 1)}{\bar{M}} \left[ E(\bar{M}^p) - (1 - \gamma) \epsilon \right].
\]

Reshuffling this expression, we obtain the following:
\[
0 = (1 - \delta \gamma)\bar{M} - (\bar{M} - 1)E(\bar{M}^p) + \frac{\delta (\bar{M} - 1)}{\bar{M}} \left[ E(\bar{M}^p) - (1 - \gamma) \epsilon \right]
\]
\[
0 = \left[ 1 - \delta \gamma - (1 - \delta)E(\bar{M}^p) - \delta (1 - \gamma) \epsilon \right] \bar{M} + (1 - \delta)E(\bar{M}^p) + \delta (1 - \gamma) \epsilon
\]
\[
\bar{M} = \frac{(1 - \delta)E(\bar{M}^p) + \delta (1 - \gamma) \epsilon}{(1 - \delta)E(\bar{M}^p) + \delta (1 - \gamma) \epsilon - (1 - \delta \gamma)}.
\]

In addition, \((A/1.7)\) shows that in steady state the price elasticity of demand is
\[E(\bar{M}^p) = \epsilon + (\epsilon - 1) \gamma \psi(\bar{M}^p)\].

Using this expression, we rewrite the denominator of the fraction in \((A/45)\) as
\[
(1 - \delta)\epsilon + (1 - \delta)(\epsilon - 1) \gamma \psi(\bar{M}^p) + (\delta - \delta \gamma) \epsilon - (1 - \delta \gamma) = (\epsilon - 1) \left[ (1 - \delta \gamma) + (1 - \delta) \gamma \psi(\bar{M}^p) \right].
\]

Plugging this result back into \((A/45)\), we obtain the steady-state price markup:
\[
\bar{M} = 1 + \frac{1}{\epsilon - 1} \cdot \frac{1}{1 + \frac{(1 - \delta) \gamma}{1 - \delta \gamma} \psi(\bar{M}^p)}.
\]

Fifth, we apply the markup-employment relation \((A/4.0)\) to the steady state. We obtain steady-state employment:
\[
\bar{N} = \left[ \frac{(\nu - 1) \alpha}{\nu} \cdot \frac{1}{\bar{M}} \right]^{1/(1+\eta)}.
\]

Sixth, we apply the production function \((A/3.7)\) to the steady state. We obtain steady-state output:
\[
\bar{Y} = \bar{A} \cdot \bar{N}^\alpha.
\]

**Proof of lemma 7.** The expression for the steady-state perceived price markup \(\bar{M}^p\) in lemma 7 comes from \((A/43)\). The expression for the steady-state fairness factor \(\bar{F} = F(\bar{M}^p)\) is obtained by combining (14) with (15). Last, the expression for the steady-state elasticity of the fairness function \(\bar{\phi} = \phi(\bar{M}^p) = -F'(\bar{M}^p) \cdot \bar{M}^p / F(\bar{M}^p)\) is obtained by noting that with the fairness function
(14), \( F'(M^p) = \theta \). The properties that \( M^p \) and \( \hat{\phi} \) are strictly increasing in \( \pi \), and that \( \bar{F} \) is weakly decreasing in \( \pi \), follow from the assumptions that \( \epsilon > 1, \gamma \in (0, 1), \theta > 0, \) and \( 1 - \chi \geq 0 \).

**Proof of proposition 3.** The expression for the steady-state price markup \( \bar{M} \) in proposition 3 comes from (A46). The expression for steady-state employment \( \bar{N} \) comes from (A47). Since \( \delta < 1, \gamma \in (0, 1) \), and \( \hat{\phi} > 0 \) is strictly increasing in \( \pi \) (lemma 7), it follows that \( \bar{M} \) is strictly decreasing in \( \pi \). And since \( \alpha > 0, \nu > 1, \eta > 0, \) and \( \bar{M} > 0 \) is strictly decreasing in \( \pi \), it follows that \( \bar{N} \) is strictly increasing in \( \pi \).

**B.4. Log-linearized equilibrium**

We log-linearize the equilibrium conditions around a steady state. We then use these log-linearized conditions to prove lemma 6 and proposition 2. We also use these conditions to compute the impulse responses to monetary and technology shocks that are presented in figures 1 and 2.

We describe the log-linearized equilibrium by six variables. The first four variables are the log-deviations from steady state of output, employment, price markup, and perceived price markup: \( \hat{y}(t), \hat{n}(t), \hat{m}(t), \) and \( \hat{m}^p(t) \). The last two variables are the deviations from steady state of the real-interest and inflation rates: \( \hat{r}(t) \) and \( \hat{\pi}(t) \). These six variables are governed by six linear equations.

**Log-linear equilibrium conditions.** Several of the original equilibrium conditions take a log-linear form, so they can immediately be log-linearized. The first is the monetary-policy rule (9), which implies

\[
(A48) \quad \hat{r}(t) = \hat{\rho}(t) + (\psi - 1)\hat{\pi}(t).
\]

The second is the production function (A37), which gives

\[
(A49) \quad \hat{y}(t) = \hat{a}(t) + \alpha\hat{n}(t).
\]

The third is markup-employment relation (A40), which yields

\[
(A50) \quad \hat{m}(t) = -(1 + \eta)\hat{n}(t).
\]

The fourth is the law of motion for the perceived price markup (A42), which gives

\[
(A51) \quad \hat{m}^p(t) = \gamma \left[ \hat{\pi}(t) + \hat{m}^p(t - 1) \right].
\]
**IS equation.** The fifth equation is the IS equation, which is based on the consumption Euler equation (A38). We start by computing a log-linear approximation of (A38), as in Gali (2008, pp. 35–36):

\[
\ln(Y(t)) = \mathbb{E}_t(\ln(Y(t + 1))) + \mathbb{E}_t(\pi(t + 1)) + \rho - i(t),
\]

where \(\rho = -\ln(\delta)\) is the time discount rate. Subtracting the steady-state values of both sides yields

\[
\hat{y}(t) = \mathbb{E}_t(\hat{y}(t + 1)) + \mathbb{E}_t(\hat{\pi}(t + 1)) - \hat{i}(t).
\]

Finally, we introduce the values of \(\hat{y}(t)\) and \(\hat{y}(t + 1)\) given by (A49), an the value of \(\hat{i}(t)\) given by the monetary-policy rule (9). We obtain the IS equation:

\[
(A52) \quad \alpha\hat{n}(t) + \psi\hat{\pi}(t) = \alpha\mathbb{E}_t(\hat{n}(t + 1)) + \mathbb{E}_t(\hat{\pi}(t + 1)) - \hat{i}_0(t) - \hat{\alpha}(t) + \mathbb{E}_t(\hat{\alpha}(t + 1)).
\]

**Short-run Phillips curve.** The sixth and final equation is the short-run Phillips curve. It is based on the pricing equation (A41).

As a first step toward computing the Phillips curve, we compute the elasticity of the price elasticity of demand, \(E(M^p) = \epsilon + (\epsilon - 1)\gamma\phi(M^p)\). Given that the elasticity of \(\phi(M^p)\) is \(\sigma\) (lemma 2), the elasticity of \(E(M^p)\) at the steady state is

\[
(A53) \quad \frac{d\ln(E)}{d\ln(M^p)} = \frac{(\epsilon - 1)\gamma\phi}{\epsilon + (\epsilon - 1)\gamma\phi} \cdot \sigma \equiv \Omega_0.
\]

Second, we introduce the auxiliary function

\[
\Lambda_1(M) = \frac{M - 1}{M}.
\]

Its elasticity at the steady state is

\[
\frac{d\ln(\Lambda_1)}{d\ln(M)} = \frac{M}{M - 1} - 1 = \frac{1}{M - 1} \equiv \Omega_1.
\]

Using the value of \(\bar{M}\) in (A46), we find that \(\Omega_1\) satisfies

\[
(A54) \quad \Omega_1 = (\epsilon - 1) \left[ 1 + \frac{(1 - \delta)\gamma\phi}{1 - \delta\gamma\phi} \right].
\]

The left-hand side of (A41) can be written \(LHS = \Lambda_1(M(t)) \cdot E(M^p(t))\). Accordingly, around the
steady state the log-linear approximation of $LHS$ is

\[(A55) \quad \ln(LHS) - \ln(LHS) = \Omega_1 \hat{m}(t) + \Omega_0 \hat{m}^P(t).\]

Next, we introduce another auxiliary function:

$$\Lambda_2(M^P) = E(M^P) - (1 - \gamma)\epsilon = \gamma \left[ \epsilon + (\epsilon - 1)\phi(M^P) \right].$$

Its elasticity at the steady state is

\[(A56) \quad \frac{d \ln(\Lambda_2)}{d \ln(M^P)} = \frac{(\epsilon - 1)\phi}{\epsilon + (\epsilon - 1)\phi} \cdot \bar{\sigma} \equiv \Omega_2.\]

We also introduce the auxiliary function

$$\Lambda_3(x) = 1 - \delta\gamma + \delta x.$$

Its elasticity is

$$\frac{d \ln(\Lambda_3)}{d \ln(x)} = \frac{\delta x}{\Lambda_3} \equiv \Omega_3.$$

The right-hand side of (A41) (abstracting from the expectation operator) can be written $RHS = \Lambda_3(\Lambda_1(M(t + 1)) \cdot \Lambda_2(M^P(t + 1))$. Hence, around the steady state the log-linear approximation of $RHS$ is

\[(A57) \quad \ln(RHS) - \ln(RHS) = \Omega_3 \cdot \left[ \Omega_1 \hat{m}(t + 1) + \Omega_2 \hat{m}^P(t + 1) \right],\]

where the elasticity $\Omega_3$ is evaluated at $\bar{\Lambda}_3 = \bar{RHS} = \bar{LHS} = \bar{E} \cdot \bar{\Lambda}_1$ and $\bar{x} = \bar{\Lambda}_1 \cdot \bar{\Lambda}_2$. This implies that in (A57) we have

\[(A58) \quad \Omega_3 = \frac{\delta \bar{\Lambda}_1 \cdot \bar{\Lambda}_2}{\bar{E} \cdot \bar{\Lambda}_1} = \delta \gamma \frac{\epsilon + (\epsilon - 1)\phi}{\epsilon + (\epsilon - 1)\gamma \phi}.\]

We now bring these results together. Equation (A41) can be written $LHS = \mathbb{E}_t(RHS)$. This equation also holds in steady state so $\bar{LHS} = \bar{RHS}$. Combining these two equations, we infer

$$\exp\left( \ln(LHS) - \ln(LHS) \right) = \mathbb{E}_t\left( \exp\left( \ln(RHS) - \ln(RHS) \right) \right).$$

Around $x = 0$, we have $\exp(x) = 1 + x$. Applying this approximation to both sides of the previous
We now divide this equation by \( \Omega \) and use the results in (A/five.lf/five.lf) and (A/five.lf/seven.lf):

\[
\Omega \hat{m}(t) + \Omega_0 \hat{\rho}(t) = \Omega_3 \cdot \left[ \Omega_1 \mathbb{E}_t(\hat{m}(t + 1)) + \Omega_2 \mathbb{E}_t(\hat{\rho}(t + 1)) \right].
\]

We divide this equation by \( \Omega_0 \); insert the values of \( \hat{m}(t) \) and \( \hat{m}(t + 1) \) given by (A50); and insert the value of \( \hat{\rho}(t + 1) \) given by (A51). We obtain

\[
\frac{(1 + \eta)\Omega_1}{\Omega_0} \hat{n}(t) + \hat{\rho}(t) = -\frac{(1 + \eta)\Omega_2\Omega_3}{\Omega_0} \mathbb{E}_t(\hat{n}(t + 1)) + \frac{\gamma\Omega_3\Omega_2}{\Omega_0} \mathbb{E}_t(\hat{\pi}(t + 1) + \hat{\rho}(t)).
\]

Using (A53), (A54), (A56), and (A58), we find that

\[
\frac{(1 + \eta)\Omega_1}{\Omega_0} = (1 + \eta) \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{1 - \delta} \epsilon \phi \equiv \lambda_1
\]

\[
\frac{(1 + \eta)\Omega_2\Omega_3}{\Omega_0} = (1 + \eta) \delta \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{1 - \delta} \epsilon \phi \equiv \lambda_2
\]

\[
\frac{\gamma\Omega_3\Omega_2}{\Omega_0} = \delta \gamma^2 \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{\epsilon} \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{\epsilon} \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{\epsilon} \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{\epsilon} \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{\epsilon} \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{\epsilon} \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{\epsilon} \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} \frac{1}{\epsilon} \epsilon + (\epsilon - 1)\phi \frac{\bar{\phi}}{\phi} = \delta \gamma.
\]

Bringing these results into (A59), we obtain the short-run Phillips curve:

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

**Proof of lemma 6.** The law of motion (12) for the perceived price markup comes from (A51). The expression of the perceived price markup as a discounted sum of past inflation rates is obtained by iterating (A51) backward; and by noting that \( \lim_{T \to \infty} \gamma^T \cdot \hat{\rho}(t - T) = 0 \) as \( \gamma \in (0, 1) \) and \( \hat{\rho} \) is bounded.

**Proof of proposition 2.** The short-run Phillips curve (13) comes from (A60). The hybrid expression of the short-run Phillips curve is obtained by combining (13) with (12).

**Blanchard-Kahn representation.** To complete the description of the log-linearized equilibrium, we combine the equilibrium conditions (A51), (A52), and (A60) into a dynamical system of the form proposed by Blanchard and Kahn (1980). Such system is useful to determine the existence
and uniqueness of an equilibrium, and to solve numerically for the unique equilibrium when it exists.

We first combine (A51), (A52), and (A60) into a linear dynamical system:

\[
\begin{bmatrix}
\gamma & \gamma & 0 \\
0 & \psi & \alpha \\
0 & 0 & \lambda_1
\end{bmatrix}
\begin{bmatrix}
\hat{m}(t-1) \\
\hat{\pi}(t) \\
\hat{n}(t)
\end{bmatrix}
= \begin{bmatrix}
1 & 0 & 0 \\
0 & 1 & \alpha \\
1 - \delta \gamma & -\delta \gamma & \lambda_2
\end{bmatrix}
\begin{bmatrix}
\hat{m}(t) \\
E_t(\hat{\pi}(t + 1)) \\
E_t(\hat{n}(t + 1))
\end{bmatrix}
- \begin{bmatrix}
0 \\
1 \\
\zeta(t)
\end{bmatrix}
\]

where

\[
\zeta(t) = \hat{\iota}_0(t) + \hat{a}(t) - E_t(\hat{a}(t + 1))
\]

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

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

Premultiplying the dynamical system by the inverse matrix, we obtain the Blanchard-Kahn form of the system:

\[
\begin{bmatrix}
\hat{m}(t) \\
E_t(\hat{\pi}(t + 1)) \\
E_t(\hat{n}(t + 1))
\end{bmatrix}
= \begin{bmatrix}
\gamma & \gamma & 0 \\
\frac{(1 - \delta \gamma) \alpha}{\lambda_2 + \alpha \delta \gamma} & \frac{\lambda_2 \psi + \alpha \gamma (1 - \delta \gamma)}{\lambda_2 + \alpha \delta \gamma} & \frac{(\lambda_2 - \lambda_1) \alpha}{\lambda_2 + \alpha \delta \gamma} \\
\frac{-\delta \gamma - 1}{\lambda_2 + \alpha \delta \gamma} & \frac{\delta \gamma}{\lambda_2 + \alpha \delta \gamma} & \frac{\lambda_1 + \alpha \delta \gamma}{\lambda_2 + \alpha \delta \gamma} \\
\frac{\lambda_2 - \lambda_1 \gamma}{\lambda_2 + \alpha \delta \gamma} & \frac{\lambda_2 - \lambda_1 \gamma}{\lambda_2 + \alpha \delta \gamma} & \frac{\lambda_2 - \lambda_1 \gamma}{\lambda_2 + \alpha \delta \gamma}
\end{bmatrix}
\begin{bmatrix}
\hat{m}(t-1) \\
\hat{\pi}(t) \\
\hat{n}(t)
\end{bmatrix}
+ \begin{bmatrix}
0 \\
\frac{\lambda_2}{\lambda_2 + \alpha \delta \gamma} \\
\frac{\delta \gamma}{\lambda_2 + \alpha \delta \gamma}
\end{bmatrix} \zeta(t).
\]

This dynamical system determines perceived price markup \( \hat{m}(t) \), inflation \( \hat{\pi}(t) \), and employment \( \hat{n}(t) \). All the other variables directly follow.

Under the calibration in table 4, the Blanchard-Kahn conditions are satisfied, so the equilibrium exists and is determinate. Indeed, under such calibration, the eigenvalues of the matrix in the Blanchard-Kahn system are 0.30, 1.02 + 0.03i, and 1.02 − 0.03i: one eigenvalue is within the unit circle, and two are outside the unit circle. Further, the dynamical system has one predetermined variable at time \( t \) (\( \hat{m}(t-1) \)) and two nonpredetermined variables (\( \hat{n}(t) \) and \( \hat{\pi}(t) \)). As the number of eigenvalues outside the unit circle matches the number of nonpredetermined variables, there exists a unique solution to the dynamical system (Blanchard and Kahn 1980, proposition 1).
B.5. Calibration

We now calibrate the fairness-related parameters of the New Keynesian model. We do so by matching the cost passthroughs estimated in microdata and those obtained by simulating the behavior of a single firm facing a stochastic marginal cost.

Firm problem. This is a simplified version of the New Keynesian firm problem, which abstracts from hiring decisions. The firm chooses price $P(t)$ and output $Y(t)$ to maximize the expected present-discounted value of profits

$$
\mathbb{E}_0 \sum_{t=0}^{\infty} \delta^t [P(t) - C(t)] Y(t),
$$

subject to the demand

$$(A61) \quad Y^d(P(t), C^p(t-1)) = P(t)^{-\epsilon} F\left(\left(\frac{\epsilon}{\epsilon - 1}\right)^{1-\gamma} \left[\frac{P(t)}{C^p(t-1)}\right]\right)^{\epsilon-1}$$

and to the law of motion (7) for the perceived marginal cost $C^p(t)$. The nominal marginal cost $C(t)$ is exogenous and stochastic.

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

$$
\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \delta^t \left\{ [P(t) - C(t)] Y(t)
+ \mathcal{H}(t) \left[ Y^d(P(t), C^p(t-1)) - Y(t) \right]
+ \mathcal{K}(t) \left[ C^p(t-1)^\gamma \left( \frac{\epsilon - 1}{\epsilon} P(t) \right)^{1-\gamma} - C^p(t) \right] \right\},
$$

where $\mathcal{H}(t)$ is the Lagrange multiplier on the demand constraint in period $t$, and $\mathcal{K}(t)$ is the Lagrange multiplier on the perceived marginal cost's law of motion in period $t$.

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

$$
\mathcal{H}(t) = P(t) \left[ 1 - \frac{C(t)}{P(t)} \right],
$$

which is the same equation as (A32) and thus can be rewritten as (A33).
**First-order condition with respect to price.** The first-order condition with respect to \( P(t) \) is \( \partial L / \partial P(t) = 0 \), which gives

\[
0 = Y(t) + \mathcal{H}(t) \frac{\partial Y^d}{\partial P} + (1 - \gamma) \mathcal{K}(t) \frac{C^p(t)}{P(t)}.
\]

This equation is the same as (A34); therefore, it can be re-expressed as (A35).

**First-order condition with respect to perceived marginal cost.** Finally, the first-order condition with respect to \( C^p(t) \) is \( \partial L / \partial C^p(t) = 0 \), which yields

\[
0 = \delta \mathbb{E}_t \left( \mathcal{H}(t + 1) \frac{\partial Y^d}{\partial C^p} + \gamma \mathcal{K}(t + 1) \frac{C^p(t + 1)}{C^p(t)} \right) - \mathcal{K}(t).
\]

Using the elasticity given by (A18), we get

\[
\mathcal{K}(t) = \delta \mathbb{E}_t \left( \mathcal{H}(t + 1) \frac{Y(t + 1)}{C^p(t)} \left[ E(M^p(t + 1)) - \epsilon \right] + \gamma \mathcal{K}(t + 1) \frac{C^p(t + 1)}{C^p(t)} \right).
\]

Next we multiply the equation by \( C^p(t) / [Y(t)P(t)] \), and we insert the perceived price markups \( M^p(t) = P(t)/C^p(t) \) and \( M^p(t + 1) = P(t + 1)/C^p(t + 1) \). We get

\[
\frac{\mathcal{K}(t)}{Y(t)M^p(t)} = \delta \mathbb{E}_t \left( \frac{Y(t + 1)P(t + 1)}{Y(t)P(t)} \left[ \mathcal{H}(t + 1) \left[ E(M^p(t + 1)) - \epsilon \right] + \gamma \frac{\mathcal{K}(t + 1)}{Y(t + 1)M^p(t + 1)} \right] \right).
\]

To conclude, we multiply the equation by \( 1 - \gamma \); and we eliminate \( \mathcal{H}(t + 1) \) using (A33) and \( \mathcal{K}(t) \) and \( \mathcal{K}(t + 1) \) using (A35). We obtain the following pricing equation:

\[
(A62) \quad \frac{M(t) - 1}{M(t)} E(M^p(t)) = 1 + \delta \mathbb{E}_t \left( \frac{Y(t + 1)P(t + 1)}{Y(t)P(t)} \left\{ \frac{M(t + 1) - 1}{M(t + 1)} \left[ E(M^p(t + 1)) - (1 - \gamma) \epsilon \right] - \gamma \right\} \right).
\]

In steady state, this equation becomes (A44) and can therefore be written as (A46).

**Firm pricing.** The firm’s pricing behavior is described by four variables: the price \( P(t) \), markup \( M(t) \), output \( Y(t) \), and perceived markup \( M^p(t) \). These four variables are determined by four conditions: the pricing equation (A62), \( M(t) = P(t)/C(t) \), the demand curve (A61), and the perceived markup’s law of motion (A42).

**Simulations.** We start from a steady-state situation. To be consistent with the simulations of figures 1 and 2, we assume that steady-state inflation is zero, so the marginal cost \( C \) is constant.
The cost passthrough represents the percentage increase in price when the marginal cost increases by 1%. The empirical estimates of the cost passthrough (0.4 and 0.7) are obtained in section 5.3. The simulations are obtained from the pricing model in appendix B.5 under the calibration in table 4.

in steady state. Then we impose an unexpected permanent 1% increase in C. We compute the price response to this shock by solving the nonlinear dynamical system of four equations that describes firm's pricing. We then obtain the dynamics of the cost passthrough by calculating the percentage change in price over time:

\[ \beta(t) = \frac{P(t) - \bar{P}}{\bar{P}} \times 100. \]

**Calibration procedure.** As explained in section 5.3, we set the shape of the fairness function to (6). We also set the discount factor to \( \delta = 0.99 \). Then, using the simulations, we calibrate the three main parameters of the model: the concern for fairness, \( \theta \), the degree of underinference, \( \gamma \), and the elasticity of substitution between goods, \( \epsilon \). Our goal is to produce an instantaneous cost passthrough of \( \beta = 0.4 \) and a two-year cost passthrough of \( \beta = 0.7 \), together with a steady-state price markup of \( \bar{M} = 1.5 \).

Our calibration procedure starts by initializing \( \theta \) and \( \gamma \) to some values. Using these values and the target \( \bar{M} = 1.5 \), we compute \( \epsilon \) from (A46). In (A46) we use (A8), which holds because the fairness function is (6), and because customers are acclimated in steady state as there is no inflation.
Using the values of $\theta$, $\gamma$, and $\epsilon$, we simulate the dynamics of the cost passthrough. We repeat the simulation for different values of $\theta$ and $\gamma$ until we obtain a passthrough of 0.4 on impact and 0.7 after two years. We reach these targets with $\theta = 9$ and $\gamma = 0.8$; the corresponding value of $\epsilon$ is 2.2. The dynamics of the cost passthrough under this calibration are displayed in figure A1.

Appendix C. Textbook New Keynesian model

We describe the textbook New Keynesian model used as benchmark in the simulations of figures 1 and 2. The model is borrowed from Gali (2008). The pricing friction in the model is the staggered pricing of Calvo (1983). The literature alternatively use the price-adjustment cost of Rotemberg (1982). However, both pricing frictions yield the same linearized Phillips curve around the zero-inflation steady state, so the simulations are the same in both cases (Roberts 1995, pp. 976–979).

The model’s dynamics around the zero-inflation steady state are governed by an IS equation and a short-run Phillips curve. The IS equation is given by (A52), as in the model with fairness. This IS equation is obtained from equation (12) in Gali (2008, chap. 3), by using logarithmic consumption utility, and by incorporating the production function (A49) and the monetary-policy rule (9).

The short-run Phillips curve is given by

$$\hat{\pi}(t) = \delta \hat{E}_t(\hat{\pi}(t + 1)) + \kappa \hat{n}(t),$$

where

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

and $\xi$ is the fraction of firms keeping their prices unchanged each period. This Phillips curve is obtained from equation (21) in Gali (2008, chap. 3), by using logarithmic consumption utility, and by replacing the output gap by $a\hat{n}(t)$.21

The IS equation and short-run Phillips curve jointly determine employment $\hat{n}(t)$ and inflation $\hat{\pi}(t)$. The other variables directly follow from $\hat{n}(t)$ and $\hat{\pi}(t)$. Output $\hat{y}(t)$ is given by (A49). The real interest rate $\hat{r}(t)$ is given by (A48). The price markup $\hat{m}(t)$ is given by (A50). And since households observe both prices and costs, perceived and actual price markups are equal: $\hat{m}_p(t) = \hat{m}(t)$.

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21The output gap is the logarithmic difference between the actual and natural levels of output. The natural levels of output and employment are reached when prices are flexible, so when the price markup is $\epsilon/(\epsilon - 1)$. Since $\epsilon/(\epsilon - 1)$ is also the steady-state price markup, we infer from (A40) that the natural level of employment equals steady-state employment. Hence, we infer from (8) that the natural level of output is $Y^n(t) = A(t)\bar{N}^\alpha$. Consequently the output gap is $\ln(Y(t)) - \ln(Y^n(t)) = \alpha[\ln(N(t)) - \ln(\bar{N})] = a\hat{n}(t)$. 

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