Home production, government policy, and the labor supply of mothers

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\textbf{Abstract:}
We study the interaction between home production of food, the market for industrialized food, government policy and mothers' labor supply. For this purpose, we introduce a model of child nutrition by two substitutes, home produced food and industrialized food manufactured in an imperfectly-competitive market. Home produced food, although superior in quality, is time-consuming and thus entails opportunity costs on mothers. We derive the market equilibrium, accounting for the consequences of possible asymmetric information between firms and mothers about the quality of the industrialized food. In this framework, we analyze the implications of various government policy tools in the product market and their effects on the labor supply of mothers. Our results suggest that both entry barriers and quality standards, as well as technological changes, may boost the labor supply of mothers, promote the product quality and benefit the firms. Though, much caution is needed in the implementation of lump-sum subsidies.

\textbf{Keywords:} Asymmetric information, Government policy, Home production, Labor supply, Product quality.

\textbf{JEL:} D13, I18, J22, L15

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1. Introduction

One of the most documented changes in the 20th century is the increase in the labor force participation of mothers with young children. This notable change was accompanied by the diffusion of industrialized substitutes for home-produced goods (Aguiar & Hurst, 2007; González Chapela, 2011), and a reduction in the time dedicated to home production of goods (Aguiar & Hurst, 2007; Etilé & Plessz, 2018; Ramey & Francis, 2009).

Several technologies have afforded women the unprecedented freedom to plan childbearing, facilitate child-rearing, and convert home production into labor time (Becker, 1965; Gronau, 1977, 1997). Two examples are the diffusion of the birth control pill (Bailey, 2006; Goldin & Katz, 2002) and the labor-saving household technologies (Greenwood, Seshadri, & Yorukoglu, 2005). Attanasio, Low, & Sánchez-Marcos (2008) studying the life-cycle of three cohorts of American women, conclude that a decrease of more than 15 percent in childcare costs played an essential role in explaining the dynamics of participation rates and average wages observed for the 1950s cohort (see also Eckstein & Lifshitz, 2011).

Our model focuses on child nutrition, though our results are applicable to other home-produced goods. In the past, the home production of food was a traditional task of mothers. Babies depended on their mother's milk for nourishment at least in their first year of life, and the rest of the family consumed home-cooked meals. During the 20th century however, there has been a worldwide movement to infant milk substitutes and the home-produced food was gradually replaced by industrialized food, significantly reducing the child care cost and boosting the labor supply of mothers (Albanesi & Olivetti, 2016). The commercially produced substitutes are now numerous and easily available.\(^1\)

While these products have improved over the years, there is however an ongoing debate surrounding the issue of not only their nutritional value but also the quality and safety of the commercially produced substitutions. Sadly, there were instances around the world where health and safety controls of these products have failed, resulting in death and injury.\(^2\)

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1 At the beginning of the 20th century, typical mothers were nursing their children for approximately third of the time between ages 23-33, accounting for 35%-43% of their potential labor time. According to the CDC (Center of Disease Control and Prevention, 2016) in 2016, 44.5% of the mothers exclusively breastfed their infant three months after birth and 22.3% of the mothers breastfed their infant 6 months after birth.

2 In the United States, recalls in major food companies occur daily (see the FDA website, https://www.fda.gov/Safety/Recalls/default.htm). A most notorious scandal is the melamine contaminated infant formula distributed in China in 2008 causing kidney damage to 300,000 infants and death to 6 infants (Gossner et al. 2009; Sharma and Paradakar, 2010). Another scandal involved an impaired infant formula distributed in Israel in 2003, causing the death of 4 infants and long-term damages to others (Hatsor and Shurtz, 2018).
The potential health and safety risks are typically addressed by heavy regulation in these markets. This study is the first, to the best of our knowledge, to introduce a model aimed at examining the consequences of government policy in the product market on the labor supply of mothers and their home production of goods.

Even in the absence of safety risks, home produced food is superior in quality compared to industrialized substitutes. For example, using propensity score matching, Borra, Iacovou, and Sevilla (2012) suggest that four weeks of breastfeeding have substantial implications on the health of children and their cognitive (SATs) and non-cognitive outcomes in England (See also the American Academy of Pediatrics, 2005; Barber-Madden, Petschek, & Pakter, 1987; Oddy et al., 2010; Ruhm, 2000; World Health Organization (WHO), 2003). Also, industrialized food often fail to meet the World Health Organization diet recommendations (Anderson, Wrieden, Tasker, & Gregor, 2008; Remnant & Adams, 2015).

We introduce an economy with altruistic mothers who derive utility from their child nutrition, which is based on either home-produced food or industrialized food. Mothers allocate their time between work and home production of food and their income between consumption and purchases of industrialized food. Following the empirical literature, we assume that home production of food, like other home production tasks, comes at the expense of labor time (reflected in extended maternity leaves, part-time jobs, and reduced working hours).

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3 Regulatory quality standards ensure the safety of products and prevent malpractice of firms, e.g., infant formulas must meet thorough dietary requirements by the FDA, the European Commission, or UNICEF, depending on the country. Dranove and Jin (2010) review the literature on the market response to certification and quality disclosure programs.


5 Breastfeeding and 'time with mom' also contribute to the child long-term cognitive and non-cognitive development. For example, Berger et al. (2005) find a causal relationship between maternity leave periods and child health as well as externalizing behavior problems at age 3-4. Ruhm (2004) suggests that maternal employment has a small negative effect on the verbal ability of 3-4-year old children and a substantial impact on the reading and math achievement of 5-6-year old children. Neidell (2000) suggests that parental time investments for up to one year offer lasting benefits, particularly for non-cognitive skills. See also Baum (2003), Belfield and Kelly (2012), Bernal (2008), Bernard et al. (2013), Cunha et al. (2010), Cunha and Heckman (2007), Gregg et al. (2005), Burdumy (2005), Quigley et al. (2012), Rothstein (2013).

6 See dietary recommendations of the WHO on https://www.who.int/news-room/fact-sheets/detail/healthy-diet.

7 For example, Chatterji & Frick (2005), using the NLSY indicate that returning to work within 3 months is associated with a 16%-18% reduction in the probability to initiate breastfeeding and a reduction of 4-5 weeks in the length of breastfeeding. Based on a survey 40,015 U.S. mothers, Ryan, Zhou, & Arensberg (2006) conclude that by 6 months after delivery mothers working part-time or not working are more likely to breastfeed (36.6%
Using these assumptions, we first characterize the equilibrium in the short-run and in the long-run when the product quality is exogenously determined by regulatory quality standards. Second, we add information asymmetry to the market for industrialized food by assuming that mothers know the mean quality of the products in the market, but not the quality of the specific product they purchase, and firms endogenously choose the product quality. In this framework, we study the interactions between home production, the quality and quantity of the industrialized food and the labor supply of mothers. We illustrate the well-known result that asymmetric information lowers the incentives of firms to invest in the product quality (Akerlof, 1970; Tirole, 1996). We further show that the lower product quality of industrialized food triggers an increase in home production and reduces the labor supply of mothers.

Next, we examine the effects of government policy in the product market on the labor supply of mothers, where our regulator plays the traditional role of alleviating market failures and acting in the public interest (Pigou, 1954). We show that regulatory quality standards (as well as subsidies that reduce the marginal cost of production or technological changes) may increase the labor supply of mothers. The labor supply of mothers is also positively affected by government policies that restrict the number of firms in the market (for example, entry barriers, permits, licensing, or other regulations levied upon firms). As the number of firms declines, each firm better internalizes its effect on the mean product quality, and thereby on the aggregate demand. Consequently, firms are encouraged to increase their products' quality. In turn, mothers increase their purchases of industrialized substitutes and labor time, at the expense of the time dedicated to home production. We further suggest that government lump-sum subsidies have offsetting effects on the labor supply of mothers, and therefore much caution is needed in executing them.

The rest of the paper is organized as follows: In section 2, we present the model, derive the equilibrium and consider information asymmetry. Then, we consider the effect of government policy in the product market on the labor supply of mothers. Section 3 concludes.


8 The Capture Theory provides a theoretical foundation for the 'producer protection' view, that producers gain from legislation (and legislation is 'captured' by producers) (see the pioneering work of e.g., Stigler (1971) and Peltzman (1976).
2. The Model

2.1. Short-run equilibrium under certainty

To study the tradeoffs between home production of goods, their industrialized substitutes, and the labor supply of mothers, we introduce a model of child nutrition. Consider a continuum of households \( \Omega = [0,1] \). Each household consists of a mother and her offspring and is characterized by a family name \( \omega \in [0,1] \). A mother \( \omega \) derives utility from her own lifetime consumption, \( c(\omega) \), and her offspring’s nutrition. A mother nourishes her offspring by a combination of home-produced food, \( b(\omega) \geq 0 \), and industrialized substitutes, \( f(\omega) \geq 0 \). The quality of the industrialized food is denoted by \( \theta \) (whereas \( 1-\theta \) measures the quality of home-produced food). Following the broad worldwide consensus that home production of food is healthier and safer than its industrialized substitutes, we assume that \( 0 < \theta < \frac{1}{2} \). Also, for simplicity the quality of consumption is normalized to the quality units of the industrialized food \( \theta \).

The preferences of a mother \( \omega \) are represented by the following utility function,

\[
u(\omega) = \theta \left( 2\kappa f(\omega) - f(\omega)^2 \right) + (1-\theta) \left( 2\kappa b(\omega) - b(\omega)^2 \right) + \theta \alpha c(\omega),
\]

where \( \alpha > 0 \) denotes the relative importance of consumption relative to child nutrition. The utility function exhibits two desirable properties. First, the utility from home-produced food and the utility from industrialized food take quadratic forms, and thus the marginal utilities are declining. Second, we assume that mothers value the quality of the products, and therefore the utilities from industrialized food, consumption, and home-produced food are multiplied by their qualities, \( \theta \) and \( 1-\theta \), respectively.

We assume that \( \kappa > 0 \) is the offspring’s nutrition requirement. That is the child’s diet must contain \( \kappa > 0 \) calories,

\[
b(\omega) + f(\omega) = \kappa
\]

\[\text{Note that if } \kappa = 1, \text{ then } b(\omega), f(\omega) \text{ denote the shares of home-produced food and industrialized food in the child nutrition.}\]
The decision of mothers on the shares of home-produced food and industrialized food in their offspring's diet affects their labor supply. Formally, we assume that each mother, $\omega$, is endowed with one unit of time to divide between labor, $l(\omega)$, and home production of food, $zb(\omega) \ (0 < zb(\omega) < 1)$. The parameter $z > 0$ translates the quantity of home-produced food (in calories) into a measure of time. Note that $z$ may capture not only the absence of mothers from the labor market while cooking (or producing food at home), but also possible negative effects on their lifetime careers. Thus, the time constraint of mothers is given by

$$ l(\omega) + zb(\omega) = 1. \quad (3) $$

This time constraint accounts for the fact that home production of food is time-consuming and interrupts mothers’ labor time.10 Combining the time constraint (3) with the offspring's diet constraint (2) yields a positive relationship between the use of industrialized food and the labor supply of each mother,

$$ l(\omega) = 1 - z(\kappa - f(\omega)) . \quad (4) $$

Specifically, when mothers purchase another unit of industrialized food, they shift their time from producing food at home to their labor supply. The lifetime consumption of mother $\omega$, $c(\omega)$, is obtained from the income constraint,

$$ c(\omega) = wl(\omega) - pf(\omega), \quad (5) $$

where $wl(\omega)$ is the mother's labor income, $w > 0$ is the wage rate per unit of labor,11 $pf$ is the price per calorie of industrialized food, and $pf(\omega)$ is the mother's expenditure on industrialized food.

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10 For example, breastfeeding is associated with lower mothers' employment, reflected in delaying the return to work after childbirth or working in part-time jobs. For simplicity, we assume that consumption of industrialized food is not time-consuming for mothers. A more realistic assumption, that industrialized food is less time-consuming than home cooking, would not change our qualitative results. Similarly, the assumption that home-produced food is less expensive rather than free would not change our qualitative results.

11 We consider an open small economy, thus assume that $W$ is exogenously given in the market.
The industrialized food is produced in an imperfectly competitive market consisted of \( n \) identical firms, where each firm \( i \) produces \( f_i \) products. Increasing the quality of products is typically costly to the firms (requires, e.g., expensive inputs, self-monitoring, and investment in research and development). Accordingly, we assume that the marginal cost of production of each firm takes the form \( \lambda \theta \), where \( \lambda > 0 \) is an exogenous parameter that measures the marginal cost of production per unit of quality. Therefore, the cost function of a firm \( i \) is given by

\[
c_i(\theta, f_i) = \begin{cases} 
0 & \text{if } f_i = 0 \\
\lambda \theta f_i + A & \text{if } f_i > 0,
\end{cases}
\]  

(6)

where \( A > 0 \) denotes the fixed cost of production. The profit function of firm \( i \), assuming that it produces a positive amount of industrialized food, is

\[
\pi_i = p_f(F, \theta) f_i - \lambda \theta f_i - A
\]  

(7)

While \( f_i \) is the quantity of industrialized food produced by firm \( i \), \( F_i \) is the total quantity of industrialized food produced by the rest of the firms, and \( F = f_i + F_i \) denotes the total production of industrialized food in the market.

Using Equations (1) - (7), we define the 'benchmark equilibrium':

**Definition: 'The benchmark equilibrium.'**

Given the wage rate, \( w \), the relative quality of the home-produced food, \( \theta \), the offspring's nutrition requirement, \( K \), and the number of firms, \( n \),

\[
\{ f_i^*, f^*(\omega), b^*(\omega), l^*(\omega), c^*(\omega) \} \in \mathbb{R}^*_+, \quad \{ p_f^* \} \in \mathbb{R}_+^n
\]

constitutes a symmetric Cournot-Nash equilibrium if:

1. \( \{ f^*(\omega), b^*(\omega), l^*(\omega), c^*(\omega) \} \) maximize the utility of each mother \( \omega \) (equation (1)) subject to the constraints (2) – (5).

2. Each firm \( i \) chooses its production \( \{ f_i^* \} \) to maximize its profits (equation (7)) given the production of the other firms, \( F_i^* \).
(3) The price, \( p^*_j \), clears the market. That is, the aggregate demand for the industrialized food, \( \int_{\omega \in \Omega} f^*(\omega) d\omega \), equals the total production of firms, \( F^* = \eta f^*_j \). ■

We derive the equilibrium starting from the mothers' demand for industrialized food (which determines their home production of food and their labor time). Mothers maximize their utility subject to their time constraint (equation (3)), income constraint (equation (5)), and their offspring's nutrition requirement (equation (2)). The first-order conditions yield the demand for industrialized food,

\[
f(\omega) = \frac{\theta}{2}(\kappa + \alpha(wz - p_f)).
\]  

(8)

The demand for industrialized food illustrates the key factors underlying the time allocation of mothers between labor time and home production. Mothers face a tradeoff between the financial cost of industrialized food, \( p_f \), and the time cost of home-produced food, \( wz \). Note that a sufficient condition for the purchase of industrialized food is that its price is relatively low, or specifically, \( wz - p_f \geq 0 \). By differentiating the demand for industrialized food (equation (8)), we obtain corollary 1,

**Corollary 1**

\[
\frac{\partial f(\omega)}{\partial (wz - p_f)} > 0, \quad \frac{\partial f(\omega)}{\partial \theta} > 0, \quad \frac{\partial f(\omega)}{\partial \alpha} > 0. \quad ■
\]

Corollary 1 captures several causes for a potential increase in the demand for industrialized food (at the expense of home-produced food) and correspondingly in mothers' labor supply. The changes, documented in the 20th century, include technological improvements in the quality of industrialized food (an increase of \( \theta \) ) and a decline in the price of industrialized food relative to the time cost of home-produced food (an increase of \( wz - p_f \) ) (see Albanesi and Olivetti, 2016). Also, according to corollary 1, when consumption becomes more important to mothers (\( \alpha \) increases), in order to increase their labor supply, mothers purchase more industrialized substitutes at the expense of home production. By rearranging equation (8) and aggerating over all mothers, we derive the inverse aggregate demand for industrialized food,
Each firm $i$ chooses its level of production, $f_i$, to maximize its profits (equation (7)), taking the aggregate demand for industrialized food (equation (9)) and the production of the other $n-1$ firms as given. The production level of each firm $i$ at the Cournot-Nash equilibrium is

$$f_i^* = \frac{\theta(2\kappa + \alpha(wz - \lambda \theta))}{2(1+n)}.$$  \hspace{1cm} (10)

In the sequel, we focus on interior solutions, $f_i > 0 \ \forall \ i$, using the following assumption,

Assumption 1: $\theta < \frac{2\kappa + \alpha wz}{\alpha \lambda}$. \hspace{1cm} ■

Assumption 1 guarantees that we refrain from the trivial case in which the industrialized food market does not exist. By aggregating the production of industrialized food (equation (10)), $F^* = nf_i^*$, and inserting into the inverse aggregate demand for industrialized food (equation (9)), we obtain the equilibrium price of industrialized food,

$$p_f^* = \frac{2\kappa + \alpha(wz + \lambda n \theta)}{\alpha(1+n)}.$$ \hspace{1cm} (11)

Using the price and quantity at equilibrium (equations (10) - (11)), we obtain firm $i$’s profits,

$$\pi_i^* = \frac{\theta(2\kappa + \alpha(wz - \lambda \theta))^2}{2\alpha(1+n)^2} - A.$$ \hspace{1cm} (12)

The aggregate labor supply at equilibrium, $L' = \int_{\omega \in \Omega} l(\omega) d\omega$, is obtained by aggregating equation (4) over all mothers,

$$L' = 1 - z(\kappa - F^*).$$ \hspace{1cm} (13)

Proposition 1 describes the effect of the parameters of the model on the product market and on the labor supply of mothers.
Proposition 1:

\[
\frac{\partial f_i^*}{\partial w_{z}}, \frac{\partial f_i^*}{\partial w_{z}} > 0, \quad \frac{\partial f_i^*}{\partial \lambda}, \frac{\partial f_i^*}{\partial \lambda} < 0, \quad \frac{\partial F^*}{\partial n}, \frac{\partial F^*}{\partial n} > 0
\]

\[
\frac{\partial p_{i}^*}{\partial w_{z}} > 0, \quad \frac{\partial p_{i}^*}{\partial \lambda} > 0, \quad \frac{\partial p_{i}^*}{\partial n} < 0
\]

Proof: The proof is easily obtained by differentiating equations (10) – (11) with respect to the model's parameters.

According to proposition 1, the labor supply of mothers expands together with their use of industrialized food as a result of:

a) Technological changes that reduce the marginal cost of production (per unit of quality), \( \lambda \), or an increase in the number of producers in the market, \( n \), augment the aggregate supply of industrialized food along with a reduction in the equilibrium price.

b) An increase in the time cost of home-produced food, \( w_{z} \), potentially through a decline in the gender wage gap or granting income tax credits for working mothers, augments the aggregate demand for industrialized food along with an increase in the equilibrium price.

Next, we discuss the effect of regulatory quality standards in the market for industrialized food.

2.1.1. Regulatory quality standards and the labor supply of mothers

In this section, we describe the effect of quality standards (exogenously given by government regulation, for now) on the labor supply of mothers and their use of industrialized food.
**Proposition 2:**

(a) The labor supply of mothers, the production of industrialized food and firms' profits are concave in the product quality $\theta$, and $\frac{\partial p^*_i}{\partial \theta} > 0$.

(b) The labor supply of mothers and the production of industrialized food are maximized at $\theta^{ML} = \frac{2\kappa + wz\alpha}{2\lambda\alpha}$, whereas the profits of each firm are maximized at a lower quality level, $\theta^{MP} = \frac{2\kappa + wz\alpha}{3\lambda\alpha}$.

**Proof:** The proof is easily obtained by differentiating equations $(10) – (11)$ with respect to the product quality, $\theta$. Given assumption 1 (interior solution), it is easy to verify that

\[
\frac{\partial^2 \pi^*_i}{\partial \theta^2} = \frac{\lambda(\alpha wz + 2\kappa)}{(1+n)^2} < 0. \]

The results of Proposition 2 are illustrated by the numerical example in Figure 1. Changing the parameter values would not change the figure qualitatively.

[Insert Figure 1 Here]

Figure 1 shows (consistent with proposition 2(a)) that when the regulatory quality standard is relatively low, the production of industrialized food, the labor supply of mothers and firms' profits increase with the product quality, whereas if the product quality is sufficiently high this pattern reverses.

The reason for the concavity of these variables is that the product quality, $\theta$, has two offsetting effects. On the one hand, an improvement in the product quality augments the demand of mothers for industrialized food (equation $(8)$ and Corollary 1). On the other hand, a higher quality standard is costly for the firms. The increase in their marginal cost of production, $\lambda \theta$, leads to a decline in the supply of industrialized food. When the quality
standard is low, the demand effect offsets the supply effect, while the opposite occurs for sufficiently high values of $\theta$. Proposition 2(b) further indicates that the product quality that maximizes the firms' profits is lower than the one that maximizes the labor supply of mothers (in the numerical example in Figure 1, $\theta^{MP} = 0.265$ is lower than $\theta^{ML} = 0.398$).

These insights are useful for government policy decisions. Assume that the regulatory quality standard $\theta^*$ is lower than $\theta^{MP} < \theta^{ML} < \frac{1}{2}$. Then, setting a larger quality standard achieves two goals, it is beneficial for both the firms' profits and the labor supply of mothers as long as $\theta^* < \theta^{MP}$. Note, though, that a quality standard of $\theta^{MP}$ is not socially optimal if the government's aims to maximize the labor supply of mothers. In this case, setting a larger quality standard in the range $[\theta^{MP}, \theta^{ML}]$ would boost the labor supply of mothers but harm the firms' profits, whereas setting the quality standard above $\theta^{ML}$ would harm both.

### 2.2. Long-run equilibrium under certainty

So far, we have treated the number of firms in the market as exogenous. In this sub-section, we derive the long-run equilibrium, letting the number of firms to be determined endogenously by the zero-profit condition. At the long-run equilibrium firms enter the market until their profits decrease to zero. Using equation (12) we obtain that number of firms at the long-run equilibrium,

$$n^{LR} = -1 + \frac{\sqrt{\theta}(2\kappa + \alpha(wz - \lambda \theta))}{\sqrt{2 A \lambda}}.$$  \hspace{1cm} (14)

We assume that at least one firm is active in the market, i.e.,

**Assumption 2:** $\frac{\sqrt{\theta}(2\kappa + \alpha(wz - \lambda \theta))}{\sqrt{2 A \lambda}} \geq 2$.

Using equations (10) and (14), we further obtain the aggregate production of industrialized food and the labor supply of mothers at the long-run equilibrium:

$$F^{LR} = -\frac{A \alpha \theta}{2} + \frac{\theta(2\kappa + \alpha(wz - \lambda \theta))}{2}.$$  \hspace{1cm} (15)
\[ L^{LR} = 1 - z\left(\kappa - F^{LR}\right) = 1 - z\left(\kappa + \sqrt{\frac{\Gamma \alpha \theta}{2} - \theta\left(2\kappa + \alpha(wz - \lambda \theta)\right)}\right). \] (16)

From equations (14) - (16) we derive the effect of the production costs (the fixed costs, \(A\), as well as the marginal costs, \(\lambda\)) and the time cost of home-produced food, \(wz\), on the key variables at the long-run equilibrium.

**Proposition 3:**

\[
\begin{align*}
\frac{\partial n^{LR}}{\partial wz} &> 0, \quad \frac{\partial F^{LR}}{\partial wz} > 0, \quad \frac{\partial L^{LR}}{\partial wz} > 0, \\
\frac{\partial n^{LR}}{\partial \lambda} &< 0, \quad \frac{\partial F^{LR}}{\partial \lambda} < 0, \quad \frac{\partial L^{LR}}{\partial \lambda} < 0, \quad \Box \\
\frac{\partial n^{LR}}{\partial A} &< 0, \quad \frac{\partial F^{LR}}{\partial A} < 0, \quad \frac{\partial L^{LR}}{\partial A} < 0
\end{align*}
\]

The effects of the key variables in the long-run equilibrium are similar to their effects in short-run equilibrium, except for changes in the number of firms. Accordingly, when the time cost of home-production of food, \(wz\), rises, the increase in mothers' demand for industrialized food induces the entry of more firms to the market. A similar effect occurs when the costs of production (the fixed costs, \(A\), or the marginal costs, \(\lambda\)) decline, e.g., as a result of technological improvements or a reduction in government fees, permits, or regulations levied upon firms by the government. The effect of the product quality on the labor supply of mothers (and the total production of industrialized food) is similar to the short run, as Figure 2 illustrates.

[Insert Figure 2 Here]

To extend this discussion, in the following section we depart from the assumption that the quality of the industrialized food, \(\Theta\), is exogenously given. Instead, we assume more realistically, that firms can endogenously choose their product quality and analyze their decision in the presence of asymmetric information.
2.3. **Short-run equilibrium under asymmetric information.**

In many instances, firms know the quality of their products while consumers do not readily acquire this information. Typically, asymmetric information about the product quality may pose potential health and safety risks to consumers, who are not informed about the quality of the specific product they purchase. One of the most sensitive issues centers around industrialized food, and specifically, child nutrition.

In this section, we incorporate asymmetric information about the product quality and assume that firms endogenously determine the quality of their products (discarding our former assumption that a quality standard is exogenously set by the government). Then, we verify that asymmetric information harms the incentives of firms to produce high-quality products and examine the underlying forces behind the choice of product quality by the firms.

We assume that each firm $i$, chooses a technology characterized by a mean product quality of $\bar{\theta}_i \in [\theta^l, \theta^u]$. That is, the quality of a specific product of firm $i$, $\theta_i$, is drawn from a distribution with a mean $\bar{\theta}_i$ and a variance $\sigma^2_\theta$. Each firm chooses its production level, $f_i$, and its mean product quality, $\bar{\theta}_i$, to maximize its profits (equation (7)) taking the other firms' production level, $F_{-i}$, and their mean qualities, $\bar{\Theta}_{-i}$, as given. The mean quality of industrialized food in the market (or the market product quality), is a weighted average of the mean product quality of each firm,

$$\bar{\theta} = \frac{f_i}{f_i + F_{-i}} \bar{\theta}_i + \frac{F_{-i}}{f_i + F_{-i}} \bar{\Theta}_{-i}.$$  \hspace{1cm} (17)

While mothers observe the market product quality, $\bar{\theta}$, and take it into account in their decisions about their home production of food and their labor supply, they cannot detect the mean product quality of each firm or the quality of a specific product they purchase. Accordingly, mothers use the market product quality, $\bar{\theta}$, when forming their demand for the industrialized food (equation (8)).

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12 See the vast literature on ‘credence goods’ dating back at least to (Nelson, 1970) and (Darby & Karni, 1973), Emons, (1997) and the literature on ‘experience goods’, e.g., Dulleck and Kerschbamer (2006), Hörner, (2002), and Shapiro (1983).
To obtain the equilibrium under asymmetric information (referred to hereinafter also as the asymmetric information equilibrium or AIE), we incorporate the inverse aggregate demand for industrialized food (equation (9)) into the firm’s profits (equation (7)). Each firm $i$ maximizes its profits by choosing its production level, $f_i$, and the mean quality of its products, $\bar{\theta}_i$.

\[
\pi_i = \left[ wz + \frac{2\kappa}{\alpha} - \frac{2(f_i + F_i)}{\alpha \bar{\theta}} \right] f_i - \lambda \bar{\theta}_i f_i - A.
\]  

(18)

By differentiating the firm’s profits (equation (18)) with respect to $f_i$ and $\bar{\theta}_i$, considering that the firms are identical, we derive the level of production and the mean product quality of each firm $i$ at the equilibrium:

\[
f_{i}^{AIE} = \frac{(2\kappa + \alpha w_z)^2}{2\lambda \alpha (n + 2)} \forall i
\]  

(19)

\[
\bar{\theta}_{i}^{AIE} = \frac{2\kappa + \alpha w_z}{(n + 2) \lambda \alpha} \forall i
\]  

(20)

Since firms are identical, the quality of their products is identical at equilibrium, which determines the market product quality as $\bar{\theta}^{AIE} = \bar{\theta}_{i}^{AIE}$. Equation (20) suggests that the mean product quality chosen by the firms (equation (20)) is always positive since firms are ‘disciplined’ by mothers’ demand to industrialized food. That is, increasing the mean product quality although costly, augments demand, which compensates the firms for their investment in quality.

Next, we examine how the choice of product quality by the firms in the AIE is affected by the parameters of the model. We also briefly discuss the determinants of the production of industrialized food, the mean product quality, and the labor supply of mothers, referring the readers to our thorough discussion in proposition 1.

**Proposition 4:**

\[
\frac{\partial \bar{\theta}_{i}^{AIE}}{\partial w_z} > 0, \quad \frac{\partial \bar{\theta}_{i}^{AIE}}{\partial \lambda} < 0, \quad \frac{\partial \bar{\theta}_{i}^{AIE}}{\partial \alpha} < 0, \quad \frac{\partial \bar{\theta}_{i}^{AIE}}{\partial n} < 0 \quad \forall i.
\]
\[
\frac{\partial f_i^{\text{AIE}}}{\partial wz}, \frac{\partial l^{\text{AIE}}(\omega)}{\partial wz}, \frac{\partial f_i^{\text{AIE}}}{\partial \lambda}, \frac{\partial l^{\text{AIE}}(\omega)}{\partial \lambda} > 0, \quad \frac{\partial F^{\text{AIE}}(\omega)}{\partial n}, \frac{\partial l^{\text{AIE}}(\omega)}{\partial n} < 0, \quad \text{if } n \leq 2 \\
\frac{\partial F^{\text{AIE}}(\omega)}{\partial n}, \frac{\partial l^{\text{AIE}}(\omega)}{\partial n} > 0, \quad \text{if } n > 2
\]

**Proof:** The proof is obtained by differentiating equations (19)-(20) with respect to the model's parameters.

According to Proposition 4, an improvement in the market product quality may be driven by several changes:

1) **An increase in the time cost of home-produced food, \( wz \):**

A decline in the gender wage gap or granting income tax credits for working mothers, augment the aggregate demand for the quality and quantity of industrialized food, and in turn, increase the labor supply of mothers.

2) **Importance of nutrition:**

Policies that emphasize the importance of child nutrition change mothers' preferences towards a larger weight on child nutrition (\( \alpha \) declines), boost their demand for the quality and quantity of industrialized food, and in turn, increase their labor supply.

3) **Technological changes or subsidies that reduce the marginal cost of production (per unit of quality):**

When \( \lambda \) declines, the supply of quality and quantity of industrialized food rises. As a result, prices decline, and in turn the purchase of industrialized food and the labor supply of mothers grow.

4) **The number of firms:**

A surprising insight concerns the number of firms in the market, \( n \). In our framework, the market product quality at equilibrium improves as the number of firms declines, or when there are more entry barriers and regulatory licensing requirements in the market. The reason is that under asymmetric information, the demand of mothers for industrialized food is
affected by the market product quality and not by the mean quality of each firm. Therefore, as the number of firms declines, the effect of each firm on the market product quality becomes larger, and in turn, the response of mothers to the quality level chosen by a specific firm becomes stronger. Consequently, each firm better internalizes its effect on the market product quality, and in turn, is encouraged to increase the mean quality of its products.

Therefore, while in the absence of information asymmetry an increase in the number of firms always augments the production of industrialized food and in turn boosts the labor supply of mothers, under information asymmetry this effect remains only in the case of one or two firms. Otherwise, an increase in the number of firms encourages firms to lower the quality of their products, and as a result both the demand for industrialized food and mothers’ labor supply decline. In the following sub-section, we discuss the implications of regulatory quality standards in the AIE.

2.3.1. Regulatory quality standards and the labor supply of mothers

Next, it is easy to verify that the market product quality endogenously determined at the AIE is typically lower than the one that maximizes firms' profits in the absence of asymmetric information. This implies that implementing a larger quality standard by the government may promote both the labor supply of mothers and the profits of firms.

Proposition 5:

$$\bar{\theta}^{AIE} < \theta^{MP} \text{ for all } n > 1, \quad \frac{\partial \bar{\theta}^{AIE}}{\partial n} < 0, \quad \forall i \quad \text{ and}$$

$$\bar{\theta}^{AIE} = \theta^{MP} \text{ for } n = 1.$$  

Proof: Proposition 5 is easily verified since $\theta^{MP} = \frac{2\kappa + wz\alpha}{3\lambda\alpha}$ and $\bar{\theta}_i^{AIE} = \frac{2\kappa + \alpha wz}{(n + 2)\lambda\alpha}.$

Proposition 5 illuminates the role of asymmetric information in our model. In the case of a monopoly there is no asymmetric information because the market product quality perfectly reflects the choice of quality by the monopoly. Therefore, it is not surprising that the level of quality chosen by the monopoly maximizes its profits.
However, when there is more than one firm in the market, the product quality is always lower than the one that maximizes firms’ profits in the absence of asymmetric information, that is, $\tilde{\Theta}^{AIE} < \Theta^{MP} < \Theta^{ML}$. The reason is that in the presence of asymmetric information mothers cannot observe the mean product quality of each firm, but only the market product quality. Consequently, the larger the number of firms is, the less each firm internalizes its effect on the market product quality, and thus the more it is encouraged to reduce its mean product quality (which negatively affects the demand for industrialized food and the labor supply of mothers).

Therefore, in the presence of asymmetric information, and as the number of firms is larger, a regulated quality standard, higher than the one endogenously determined at the AIE, is beneficial both for the firms and to promote the labor supply of mothers, at least to the extent that it is still lower than $\Theta^{MP}$. The regulatory quality standard plays a role of coordination between the firms which, in contrast to coordination on prices, is desirable for the economy. Nevertheless, setting the quality standard to a higher level, specifically in the range of $[\Theta^{MP}, \Theta^{ML}]$, decreases the firms’ profits (because of their augmented production costs) but at the same time still augments the labor supply of mothers (and increases their demand for industrialized food). An additional increase of the quality standard potentially reduces the labor supply of mothers.

2.4. Long-run equilibrium under information asymmetry

According to the free entry condition, we equate equation (18) to zero to obtain the number of firms at the long-run equilibrium.

$$n^{ML} = \frac{2\kappa + \alpha wz}{\left(2A\alpha \lambda^2\right)^{\frac{1}{3}}} - 2$$  \hspace{1cm} (21)

To ensure that at least one firm is active in the market we replace assumption 2 with the following assumption,

Assumption 3: $\frac{2\kappa + \alpha wz}{\left(2A\alpha \lambda^2\right)^{\frac{1}{3}}} \geq 3$. 

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Using equations (19)-(21) we obtain the market product quality and the production level of industrialized food at the long-run equilibrium.

\[
\theta^{\text{AIL}} = \left( \frac{1}{\lambda} \right)^{\frac{2}{3}} \left( \frac{2A}{\alpha} \right)^{\frac{1}{3}}
\]  

(22)

\[
F^{\text{AIL}} = f^{\text{AIL}} n^{\text{AIL}} = A^2 \left( \frac{\alpha}{2\lambda} \right)^{\frac{1}{3}} \left( \frac{2\kappa + \alpha w_z}{(2A\alpha \lambda^2)^{\frac{1}{3}}} - 2 \right)
\]  

(23)

**Proposition 6:**

At the long-run equilibrium under information asymmetry,

(i) The market product quality increases with the fixed costs and decreases with the marginal cost of production (per unit of quality), \(\lambda\).

(ii) The labor supply of mothers (and the total production of industrialized food)

- a. increase with the time cost of home-produced food, \(w_z\)
- b. decrease with the marginal cost of production, \(\lambda\)
- c. is concave in the fixed costs, \(A\), and maximized when the fixed costs are:

\[
A = \frac{(2\kappa + \alpha w_z)^3}{128\alpha \lambda^2}
\]

**Proof:** The proof follows by differentiating equations (22)-(23).

From proposition 6 and consistent with the results of propositions 1 and 5, it is easy to see that entry barriers, in the form of substantial fixed costs, reduce the number of firms in the market, which promotes the market product quality at the long run equilibrium. Consequently, there are two offsetting effects on the total production and the labor supply of mothers. On the one hand, given the market product quality, the decline in the number of firms reduces the supply of industrialized food. On the other hand, the augmented market product quality boosts the mothers’ demand for industrialized food. The first effect prevails for fixed costs larger than \(\frac{(2\kappa + \alpha w_z)^3}{128\alpha \lambda^2}\), while the second effect prevails otherwise.

Note that the number of firms at the long-run equilibrium under information asymmetry is greater or equal than the number of firms at the AIE. The reason is that in the short-run firms
can choose to produce and earn positive profits, or not to produce and earn zero profits. Therefore, in the long-run the number of firms can only grow (to satisfy the zero profits condition). Consequently, with a larger number of firms, the market product quality is lower than in the short-run, \( \bar{\sigma}^{AIL} \leq \bar{\sigma}^{AIF} < \theta^{MP} < \theta^{ML} \). Then, setting a regulatory quality standard larger than \( \bar{\sigma}^{AIL} \) would have positive effects on the firms' profits and on the labor supply of mothers as long as it is lower than \( \theta^{MP} \). A larger quality standard still boosts the mothers' labor supply in the range of \([\theta^{MP}, \theta^{ML}]\), whereas a quality standard above \( \theta^{ML} \) would have negative effects both on the labor supply of mothers and on the firms' profits (recall proposition 2).

2.5. Government policy and the labor supply of mothers

In this section, we study the effect of several government policy tools in the industrialized food market on the labor supply of mothers. In particular, we focus on policy tools aimed at increasing the labor supply of mothers.

With no government intervention, assume that the market is at the long-run equilibrium under information asymmetry. The government can use several policy tools that may shift the market to the other equilibria previously discussed.

A regulatory quality standard

Assume that the government sets a product quality standard higher than the one that prevails in the market. By setting the quality standard, the government eliminates the uncertainty associated with the asymmetric information between the mothers and the firms, and the market reaches the long-run equilibrium under certainty.

As previously discussed, the government should set quality standards with discretion. A quality standard higher than the long-run one may increase the labor supply of mothers since their demand for the industrialized food rises. Nevertheless, setting a 'too high' quality standard may reduce the labor supply of mothers (see equation (14)), because the growing production costs of the firms reduce their supply of industrialized food.

Changing the number of firms

The government can affect the number of firms in the industry directly through licensing or indirectly through the firms' cost structure.
Without government intervention, the number of firms in the food industry is determined according to equation (21). According to proposition 6 the government can increase the number of firms and the labor supply of mothers by lowering the firms' marginal cost of production. This policy can be implemented, for example, through subsidization. The government can also affect the number of firms by increasing the fixed costs of the firms, for example, by charging fees or imposing regulations such as costly requirements on self-monitoring or self-inspection. Increasing the firms' fixed costs reduces the number of firms in the industry, which reduces the supply of industrialized food on the one hand, and increases the market product quality, and in turn the demand for industrialized food on the other hand. According to Proposition 6, as long as the increase in the firm's fixed costs is not "too severe" the second effect prevails, and the labor supply of mothers increases.

A government can directly control the number of firms by requiring permits. In this case, the market is shifted to the short-run equilibrium under information asymmetry. From Proposition 4 we conclude that if the number of firms is larger than 2, then reducing the number of firms is expected to increase the labor supply of mothers through an increase in the product quality that boosts the demand for the industrialized food (offsetting the decline in the supply of industrialized food).

**A regulatory quality standard and a restriction on the number of firms**

If the government directly restricts the number of firms and imposes a quality standard on the industry, the market shifts to the short-run equilibrium under certainty.

By Proposition 2, the government should set a quality standard equals to $\Theta^{ML}$ in order to maximize the labor supply of mothers. Proposition 1 shows that the number of firms is positively correlated with the labor supply of mothers. Nevertheless, equation (14) shows that the number of firms cannot exceed $n^{LR}(\Theta^{ML})$.

**Lowering the marginal costs of production**

Lowering the marginal cost of production can be achieved through subsidies, reducing taxes, or reducing the regulatory requirements that affect the marginal cost of production, $\lambda$.

Lowering the marginal cost of production, $\lambda$, leads to an increase in the supply of industrialized food, and in turn lower equilibrium prices and larger labor supply of mothers.
3. Conclusions

In this paper we develop a theoretical model to study the interactions between the industrialized food market, government policy, and the labor supply of mothers. To consider the ongoing concern for product quality and public health, we add information asymmetry between firms and mothers.

Within this framework, we study the underlying forces behind the substantial changes in the 20th century in the labor force participation of mothers, home production and child nutrition. We analyze the effect of several policies, implemented by the government in the market of industrialized food, on the labor supply of mothers. We specify several policies that may boost the labor supply of mothers, including regulatory quality standards, entry barriers, and certain subsidies. While not in the scope of this article, future study may investigate the effect of these policies on public health, which on the one hand benefits from the rising quality of the industrialized food, but on the other hand is harmed by the shift of mothers from (the superior) home production to industrialized food.

Our framework can be used in future studies to further analyze the interactions between firms’, households’, and governments’ decisions in the product market and the labor market and at home.
References


Figure 1: The effect of a regulatory quality standard – the short-run equilibrium

Note: We plot a numerical simulation, setting the parameter values to $\kappa = 1$, $\alpha = 3$, $w = 1.6$, $z = 0.4$, $\lambda = 1.64$, $n = 3$ to illustrate the results of Proposition 2. Changing the parameter values would not change the figure qualitatively.
Figure 2: The labor supply of mothers – The long-run equilibrium

Note: we plot a numerical simulation, setting the parameter values to \( \kappa = 1, \alpha = 3, w = 1.6, z = 0.4, \lambda = 1.64, A = 0.05 \). Changing the parameter values would not change the figure qualitatively.