What caused the price of home appliances to decline?

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Abstract

Recent research has linked declining home appliances prices to the rise in employment of married women in the twentieth century. We propose a two-sector general equilibrium model to explore possible causes for the decline in home appliances prices. Given our assumptions for preferences and income distribution, we show that total factor productivity growth and a narrowing in the gender wage gap each contributed to the decline in home appliances prices relative to the prevailing market wage. As a result, a new mechanism for explaining the rise in employment of married women is presented where changes in market wage level affect women's decision to work. Simulations show that total factor productivity growth in the market sector has the largest impact on home appliances prices and thus women's employment rates.

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1 Introduction

A recent line of research in household economics studies the relationship between declining home appliances prices and women's emancipation during the twentieth century. Embedding household production theory *à* la Becker (1991) into neoclassical models, the authors show that the gradual decline in home appliances prices relative to median household income can account for a significant fraction of the rise in employment of married women (Greenwood, Seshadri, and Yorukoglu, 2005), the increase in divorce rates (Greenwood and Guner, 2004), and changes in fertility decisions (Greenwood, Seshadri, and Vandenbroucke, 2005).

In the aforementioned papers, however, firms' decisions in the home appliances sector are not explicitly modeled and the decline in home appliances price is fully identified by increases in total factor productivity in this sector. In addition, no feedback loop from household decisions is considered and the home appliances sector is assumed to be perfectly competitive.

In this paper, we study the appliances sector in more detail. First, we focus on two measures of competitiveness for different sub-industries, including refrigerator and freezer, cooking appliances, vacuum cleaners, etc. We find that few firms compete in each sub-industry and that concentration ratios and Herfindahl-Hirshman index are higher than commonly accepted critical values for perfectly competitive markets. Second, we propose a simple two-sector general equilibrium model of women's employment and home appliances adoption decisions where firms that produce home appliances interact strategically. In our model, more than one factor can cause home appliances prices to vary, including total factor productivity (TFP) growth in the market sector and changes in the gender wage gap.

Given our assumptions for preferences and income distribution, our main theoretical result is that TFP growth in all sectors and a narrowing of the gender wage gap contributed to the decline in home appliances price relative to the prevailing market wage. As a result, a new mechanism is proposed for the rise in employment of married women. In contrast to existing models of home production where women's employment depends on the earning gap between husband and wife (Benhabib et al., 1991 or Jones et al., 2003), we find that changes in market wage level affect women's decision to work due to general equilibrium effects on home appliances prices.

We simulate our model given realistic parameter values for productivity gains at home, the gender wage gap, and the economy growth rate. Interestingly enough, TFP growth in the market sector has by far the largest impact on both women's employment and home appliances prices compared to the impact of TFP growth in the appliances sector or narrowing of the gender wage gap.

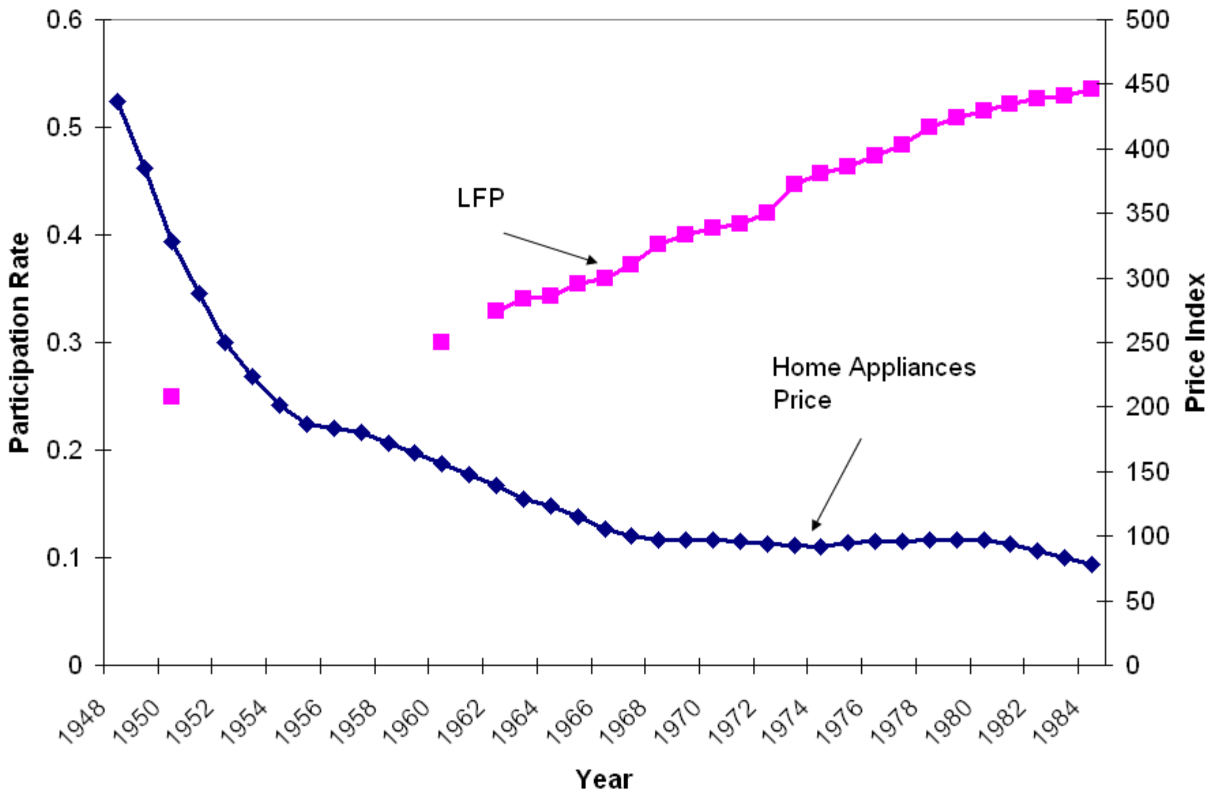
The remainder of the paper is organized as follows. In Section 2, we briefly review the main facts pertinent to our study, including the rise in employment of married women, the historical decline in the price of home appliances, changes in the gender wage gap, and concentration ratios in the home appliances sector. In Section 3 and 4, we present our model, define an equilibrium, and study its qualitative properties. In Section 5, we discuss model simulations. Finally, we offer concluding remarks in Section 6.

2 Data

2.1 Women labor supply and the price of home appliances

In Figure 1, we present changes in the labor force participation (LFP) of married women and a price index for home appliances between 1948 and 1984. Data for women's LFP for the years 1950 and 1960 are from the U.S. census and we use annual data from the Current Population Survey (CPS) for any year between 1962 and 1984. We included women between the age 18 to 64, who are married, not in school, and are either working or actively looking for a job. Data for the price of home appliances comes from Table 7.23 on page 314 in Gordon (1990). The index represents a weighted average of eight major household appliances prices: refrigerator, room air conditioners, automatic washing machines, clothes dryers, TV sets, dishwasher, and microwave ovens, and VCR. Prices are adjusted for changes in energy efficiency and repair costs.

Fig. 1: Labor force participation and home appliances prices



Women's LFP increased by 29 percentage points and more than doubled from 25 percent in 1950 to 54 percent in 1984. Over the same period of time, the price index decreased at an annual average rate of 2.3 percent from 437 in 1948 to 78 in 1984. Greenwood, Seshadri, and Yorokoglu (2005) (later GSK) study the impact of declining home appliances prices on women's work decisions in a neoclassical framework that embeds household production theory *à* la Becker (1991). The fraction of households that buys labor-saving home appliances increases when the price of these appliances declines relative to median household income. In turn, since labor productivity at home goes up, women have more time available to allocate to other activities, including work. The proposed mechanism is quantitatively important as more than half of the increase in women's LFP can be accounted for by declines in home appliances prices. In GSK's model, however, the decline in home appliances price is fully identified by increases in total factor productivity in this sector and the home appliances sector is assumed to be perfectly competitive. In the next section, we review micro-evidence for two measures of competitiveness in the home appliances sector.

2.2 Competitiveness of the home appliances sector

In Table 1, we present the 4-firm concentration ratio as well as the 50-firm Herfindahl-Hirshman index (HHI) for four home appliances: household vacuum cleaner, cooking appliances, refrigerator and home freezer, and automatic washing machines. Data about concentration ratios and Herfindahl-Hirshman index are from manufacturing reports published by the Census Bureau (2001). The 4-firm concentration ratio is defined as the percentage of market output generated by the four largest firms in the industry. The 50-firm Herfindahl-Hirshman index (HHI) is a measure of the size of firms in relationship to the industry and is defined as the sum of the squares of the market shares of 50 largest firms.

Tab. 1: Average concentration and Herfindahl-Hirshman index for the period 1940-1990

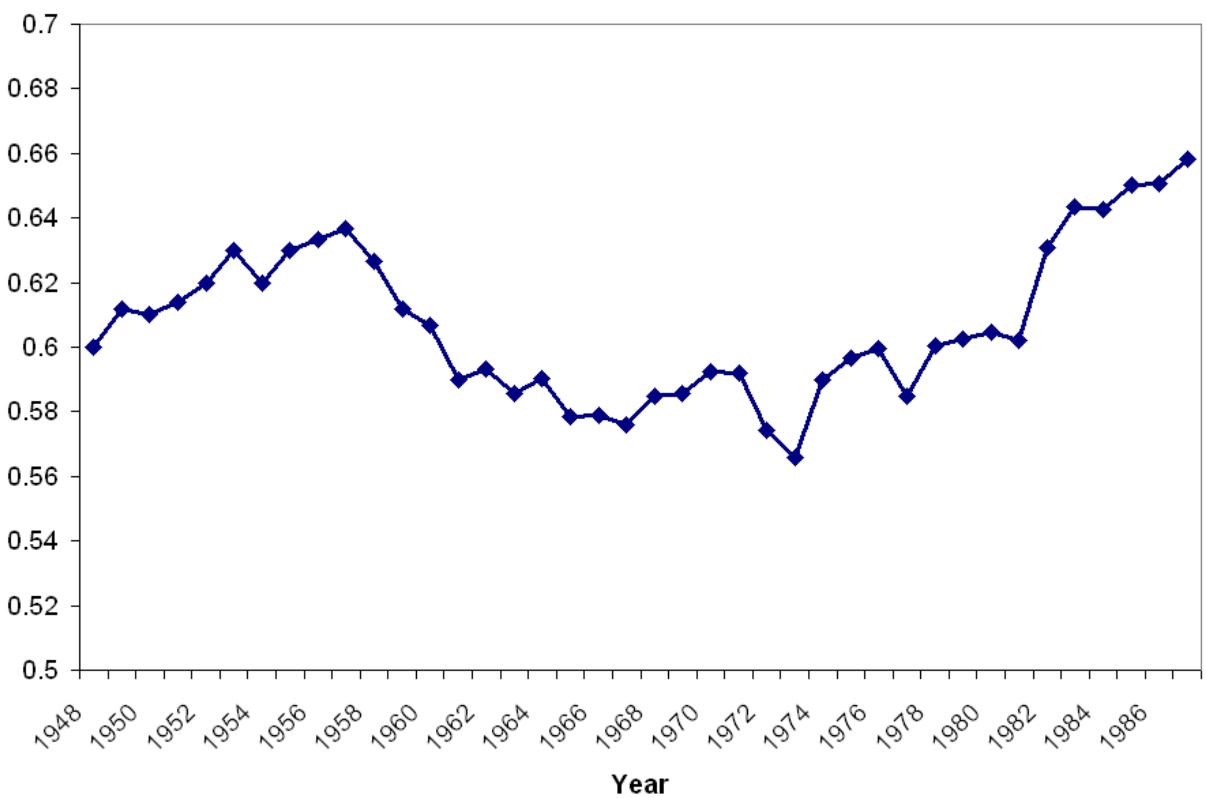
Appliances Type	Concentration Ratio (4 largest firms)	Herfindahl-Hirshman Index (50 largest firms)
Household Vacuum Cleaner	77.9	2096.3
Cooking Appliances	48.3	856.5
Refrigerator and Home Freezer	84.5	1988.5
Laundry Equipment	93.4	-

Concentration ratios range from 48.3 for cooking appliances to 93.7 for laundry equipment, while HHI for household vacuum cleaner and refrigerator are greater than 1900. Although there are no strict cutoffs or guidelines, an industry is considered perfectly competitive when the 4-firm concentration ratio is less than 15 percent, monopolistic competition when concentration is less than 40 percent, and oligopolistic when concentration is greater than 40 percent. Alternatively, an industry is considered fairly competitive when HHI is less than 1,000, imperfectly competitive when HHI is less than 2000, and monopolistic when HHI is greater than 2000. Both concentration ratios or HHI suggest that competition in the home appliances sector is not perfectly competitive.

2.3 Gender wage gap

Finally, we present data about woman-to-man median wage ratio. Our data about wages comes from the historical income table P-36 of the Census bureau. Wages are for men and women who work full-time all-year around. The wage ratio increases by 10 percent from 0.6 in 1950 to 0.66 in 1987.

Fig. 2: Woman-to-man median wage - Full-time year-round workers



Even though changes in the gender wage gap are small, Jones et al. (2003) show that they can have a large impact of the labor supply decisions of married women because of endogenous specialization among married couples and human capital accumulation. Within a neoclassical model of labor supply, they find that small decreases in the gender wage gap can explain simultaneously the significant increases in the average hours worked by married women and the relative constancy in the hours worked by single women, and single and married men. After presenting our model in the next section, we assess the impact of changes in the gender wage gap on the price of home appliances and thus married women's decision to work.

3 The model

3.1 Households

Time is discrete and infinite, $t = 1, 2, ...$ There is a continuum of households of mass one. Households are made up of a man and a woman, who derive utility from consuming market goods, c_{mt}, home goods, c_{ht}, and leisure, l_t. Their preferences are given by:

$$U(c_{mt}, c_{ht}, l_t) = \alpha \ln(c_{mt}) + \beta \ln(c_{ht}) + (1 - \alpha - \beta) \ln(l_t) \tag{1}$$

with $(\alpha, \beta) \in [0, 1] \times [0, 1]$ and $\alpha + \beta < 1$.

Households must choose between two technologies to produce the home good. If the first (labor-intensive) technology is operated, the production of one unit of output requires the purchase of one unit of durable good (appliances) and a fraction $\rho\eta$ of household's total time endowment, with $0 < \rho\eta < 1$ and $\rho > 1$. In contrast, the second (labor-saving) technology only uses one unit of durable goods and a fraction $\frac{\eta}{\kappa}$ of households' time with $\kappa > 1$.

We denote by $a_t \in \{0, 1\}$ and $e_t \in \{0, 1\}$ household's decision for appliances adoption and women's work, respectively. Note that both decisions are made at the extensive margin with $a_t = 1$ when households operate the capital-intensive technology and $a_t = 0$ when households use the labor-intensive technology. Similarly, $e_t = 1$ when women work.

Assuming that men and women are both endowed with one unit of time, the time and budget constraints of households are given by:

$$\begin{aligned} c_{mt} + p_{at}a_t &= w_t(\lambda_m + \lambda_f e_t) \\ l_t + t_w(1 + e_t) + \eta(1 + (\rho - 1)(1 - a_t)) &= 2 \end{aligned} \tag{2}$$

where t_w is a fixed parameter representing the length of the workweek, w_t the real market wage, p_{at} the appliances price, and finally, λ_m and λ_f are men's and women's ability, respectively.[1] Given the price of labor-saving appliances and the market wage, households choose women's employment and whether to adopt the new technology to maximize utility (1) subject to the budget and time constraints (2).

3.2 Firms

3.2.1 Appliances sector

The appliances sector is oligopolistic and firms play a Cournot game. Home appliances are produced with a linear technology and operating firms incur a fixed cost, χ, which creates natural entry barriers.

We let $y_{a,i,t}$, Y_{at}, and $Y_{a,-i,t}$ represent the output of firm i, total output in the appliances sector, and the output of all firms except for firm i, respectively. Given the market wage and the demand for appliances, $p_{at}(Y_{at})$, firm i chooses output and employment level, $l_{a,i,t}$, to maximize profits taking as given $Y_{a,-i,t}$.

$$\begin{aligned} \max_{(y_{a,i,t}, l_{a,i,t}) \geq 0} \quad & \Pi_{a,i,t} = p_{at}(Y_{a,-i,t} + y_{a,i,t})y_{a,i,t} - w_t l_{a,i,t} - \chi \\ \text{s.t.} \quad & y_{a,i,t} \leq A_{at} l_{a,i,t} \end{aligned} \tag{3}$$

[1] We made the following assumptions for the budget and time constraints. First, market and home goods are public goods within the household. Second, and without loss of generality, we use the price of the market good as the numeraire and impose $p_{mt} = 1$. Finally, the labor-intensive technology can be operated at zero cost since the adoption decision only depends on the relative price between the two technologies.

where A_{at} represents total factor productivity in the appliances sector.

Since all firms have access to the same technology, we restrict our analysis to symmetric equilibrium where $y_{a,i,t} = y_{a,t}$ for all i. Operating firms maximize profits when the following first-order condition is met:

$$p'_{at}(Y_{at})y_{a,t} + p_{at}(Y_{at}) = \frac{w_t}{A_{at}} \tag{4}$$

In addition, the free-entry condition implies that operating firms make non-negative profits, while firms outside the market expect to make negative profits if they enter. The zero-profit condition is given by:

$$p_{at}(Y_{a,t})y_{a,t} - \frac{w_t y_{a,t}}{A_{at}} = \chi \tag{5}$$

3.2.2 Market sector

The market sector is perfectly competitive and output is produced with a constant returns to scale technology. Given the market wage, firms choose the output level, y_{mt}, and labor input, l_{mt}, to maximize profits:

$$\max_{(l_{mt}, y_{mt}) \in \Re^2_+} \quad \Pi_{mt} = A_{mt} l_{mt} - w_t l_{mt} \tag{6}$$

where A_{mt} represents total factor productivity in the market sector. The solution to the firm's problem is given by $w_t = A_{mt}$ implying that the labor demand is perfectly elastic and firms' profits are equal to zero.

3.3 Equilibrium definition

In this section, we propose a definition of equilibrium for our economy. We derive the demand for home appliances and the aggregate labor supply of women assuming that matching of ability between men and women is perfectly assortative. This assumption implies that the ratio of women's to men's ability, $\varphi = \frac{\lambda_f}{\lambda_m}$, is constant across households. However, it does not preclude wage discrimination towards women as the ratio between women's and men's ability is not necessarily equal to one.

We denote by $a(\lambda_m, \frac{p_{at}}{w_t})$ and $e(\lambda_m, \frac{p_{at}}{w_t})$ the optimal household decision for appliances adoption and work which depends on the relative price of appliances and men's ability. The aggregate demand for home appliances in every period, $\mathcal{D}^a$, is equal to the measure of households which adopts the new technology:

$$\mathcal{D}^a(\frac{p_{at}}{w_t}) = \int_0^{+\infty} a(\lambda_m, \frac{p_{at}}{w_t}) f(\lambda_m) d\lambda_m \tag{7}$$

where $f(\lambda_m)$ denotes the probability density function of men's market ability distribution.

On the other hand, women's and men's labor supply, $\mathcal{S}^f$ and $\mathcal{S}^m$, are equal to:

$$\mathcal{S}^f(\frac{p_{at}}{w_t}) = \varphi \int_0^{+\infty} \lambda_m e(\lambda_m, \frac{p_{at}}{w_t}) f(\lambda_m) d\lambda_m, \quad \mathcal{S}^m(\frac{p_{at}}{w_t}) = \varphi \int_0^{+\infty} \lambda_m f(\lambda_m) d\lambda_m \tag{8}$$

Definition 1. *Given an exogenous sequence for total factor productivity in market and appliances sectors,* $\{(A_{mt}, A_{at})\}_{t=1}^{+\infty}$ *and a market ability gender gap,* φ*, a general equilibrium for our economy is a sequence of prices* $\{p_{at}, w_t\}_{t=1}^{+\infty}$ *and allocations for households,* $\{(a_t, e_t)\}_{t=1}^{+\infty}$*, and firms,* $\{(y_{mt}, y_{at}, l_{mt}, l_{at})\}_{t=1}^{+\infty}$*, such that:*

1. *Given prices, households choose* $\{(a_t, e_t)\}_{t=1}^{+\infty}$ *to maximize utility* (1) *subject to the budget and time constraints* (2)*. Firms in both sectors choose labor and output level,* $\{(y_{mt}, y_{at}, l_{mt}, l_{at})\}_{t=1}^{+\infty}$ *to maximize profits and the zero-profit condition in equation* (5) *is satisfied.*

2. *Labor and home appliances market clear:*

   (a) $l_{at} + l_{mt} = \mathcal{S}^f(\frac{p_{at}}{w_t}) + \mathcal{S}^m(\frac{p_{at}}{w_t})$,

   (b) $Y_{at} = \mathcal{D}^a(\frac{p_{at}}{w_t})$.

4 Equilibrium properties

In this section, we characterize the equilibrium properties, assuming that men's market ability follows a log-normal distribution with mean μ and standard deviation σ. We use the following thresholds for relative ability between men and women in the next proposition:

$$\begin{aligned}\bar{\varphi}_1 &= (\frac{2-\eta-t_w}{2-\eta-2t_w})^{\frac{(1-\alpha-\beta)}{\alpha}} - 1,\\ \bar{\varphi}_2 &= (\frac{2-\rho\eta-t_w}{2-\rho\eta-2t_w})^{\frac{(1-\alpha-\beta)}{\alpha}} - 1 \\ \phi(\varphi) &= 1 - (\frac{2-\rho\eta-t_w}{2-\eta-2t_w})^{\frac{(1-\alpha-\beta)}{\alpha}}(\frac{1}{\kappa})^{\frac{\beta}{\alpha}} + \varphi\end{aligned} \tag{9}$$

Proposition 1 (Households' Optimal Decisions)**.** *Assume that the relative ability between men and women satisfies $\bar{\varphi}_1 \leq \varphi \leq \bar{\varphi}_2$. Then, the optimal employment and adoption decisions of households are given by:*

$$e(\lambda_m, \frac{p_{at}}{w_t}) = a(\lambda_m, \frac{p_{at}}{w_t}) = 1 \Leftrightarrow \lambda_m \geq \frac{p_{at}}{w_t\phi(\varphi)} \tag{10}$$

Proof. See the Appendix. □

According to the previous proposition, the decisions of home appliances adoption and women work are interconnected and depend on the gap between husband's earning ability and the relative price of home appliances.[2] When husband's market ability is greater than the threshold, households decide to buy home appliances and women work. On the other hand, when households cannot afford to buy the home appliances, women prefer to operate the labor-intensive technology to produce the home good. They also decide not to work because their marginal utility of leisure is greater than the wage offer they receive.

We let $x_t = \frac{p_{at}}{\phi(\varphi)w_t}$ denote the market ability of the marginal household that adopts the home appliances. We rewrite the first-order condition and the free-entry condition in equations (4) and (5) as:

$$A_{at}\phi(\varphi)(-\frac{y_{at}}{f(x_t)} + x_t) = 1 \tag{11}$$

[2]Note that home appliances are first bought by richer households, which is supported by the data (Day, 1992, Table 8, p.319).

$$A_{mt}y_{at}(\phi(\varphi)x_t - \frac{1}{A_{at}}) = \chi \quad (12)$$

with $f(x) = \frac{1}{x\sqrt{2\pi}\sigma}e^{-\frac{(\ln(x)-\mu)^2}{2\sigma^2}}$.

Eliminating y_{at} from equations (11) and (12), the market ability of the marginal household that adopts the home appliances is determined as the solution to the following equation:

$$(\phi(\varphi)x_t - \frac{1}{A_{at}})^2 f(x_t) = \frac{\chi\phi(\varphi)}{A_{mt}} \quad (13)$$

The economic mechanism that links technological progress and the gender wage gap to women's employment and the decision to buy home appliances is summarized in equation (13). The impact of technological progress in the market sector on x_t is unclear, however, because of general equilibrium effects. On the one hand, households buying power goes up as their market wage increases. On the other hand, the price of home appliances also increases because of greater demand. We clarify the impact of technological progress in the market sector on women's employment and household appliances adoption decision in the next proposition.

Proposition 2. *Assume that total factor productivity in the market sector grows at rate $z_m > 1$, while total factor productivity in the appliances sector is constant. Then, there exists a technology threshold level, $\bar{A}_m$, such that equation* (13) *has no solution when $A_{mt} < \bar{A}_m$. When $A_{mt} \geq \bar{A}_m$, equation* (13) *has at least one solution that satisfies $\frac{\partial \hat{x}_t^m}{\partial A_{mt}} \leq 0$.*

Proof. See the Appendix. □

When total factor productivity is below the threshold $\bar{A}_m$, households choose to operate the labor-intensive technology for home production because the cost of home appliances is very high relative to the market wage. No home appliances are produced and output in the appliances sector is equal to zero. As technological progress in the market sector unfolds, the price of home appliances gradually declines relative to the market wage since $\frac{p_{at}}{w_t} = \phi(\varphi)\hat{x}_t^m$ and $\frac{\partial \hat{x}_t^m}{\partial A_{mt}} \leq 0$. As a result, a positive fraction of the population, $1 - F(\hat{x}_t^m)$, can afford to adopt the new technology and this fraction increases over time.

Note that the fraction of women joining the labor force increases as the market wage goes up since more households buy home appliances (see proposition 1). The general equilibrium effect of market wage on women's decision to work is interesting because it contrasts with the predictions of existing neoclassical models of home production where women's employment decisions primarily depend on the earning gap between husband and wife (see Benhabib et al., 1991 or Jones et al., 2003). In these models, changes in the market wage level have no impact on women's employment decisions.

Proposition 3. *Assume that total factor productivity in the market sector is constant, while total factor productivity in the appliances sector grows at rate* $z_a > 1$*. Then, there exists a technology threshold level,* $\bar{A}_a$*, such that equation* (13) *has no solution when* $A_{at} < \bar{A}_a$*. When* $A_{at} \geq \bar{A}_a$*, equation* (13) *has at least one solution,* $\hat{x}_t^a$ *that satisfies* $\frac{\partial \hat{x}_t^a}{\partial A_{at}} \leq 0$.

Proof. See the Appendix. □

When total factor productivity A_{at} is below the threshold $\bar{A}_a$, there are no operating firms in the appliances industry due to high entry cost and output is equal to zero. As total factor productivity increases, a positive number of firms enter, which fosters competition and results in price of home appliances decline. A positive fraction of the population, $1 - F(\hat{x}_t^a)$, can afford to adopt the new technology and a corresponding fraction of women join the labor force (see proposition 1).

Proposition 4. *Assume that total factor productivity in the market and homes appliances sectors are constant. Then, equation* (13) *has at least one solution,* $\hat{x}_t^\varphi$ *that satisfies* $\frac{\partial \hat{x}_t^\varphi}{\partial \varphi} \leq 0$.

Proof. See the Appendix. □

As in GSK and Jones et al. (2003), a narrowing of the gender wage gap implies that more women join the labor force. Everything else equal, the opportunity cost of staying at home for women goes up when the earning gap between husband and wife narrows. However, in order for women to work, households need to buy home appliances. As the threshold market ability for men declines, more household buy home appliances and the fraction of women working goes up.

5 Simulations

In this section, we simulate our model for a chosen set of parameter values. First, we fix the time spent on the job as well as parameters for home appliances technology. Adults are endowed with a total of 112 hours per week (excluding sleep) to be divided between work, house chores, and leisure. The number of hours spent on house chores decreased from 58 in 1900 to 18 were in 1975 (GSK). In addition, if full-time workers spend 40 hours on the job, we have $t_w = \frac{40}{112} = 0.36$, $\eta = \frac{18}{112} = 0.16$, and $\rho = \frac{58}{18} = 3.22$.

Second, the per-capita stock of appliances was equal to \$66 in 1925 and increased to \$528 in 1980 (GSK). As a result, we set $\kappa = \frac{\$528}{\$66} = 8$.

Third, Knowles (1999) estimates the standard deviation of men's income distribution within a dynamic general equilibrium model and finds that $\sigma = 0.9$. We choose his value for the standard deviation and normalize the mean of men's ability distribution to be equal to 100, which implies that $\mu = 4.2 = -\frac{0.9^2}{2} + \ln(100)$.

Fourth, we fix $\varphi = 0.6$ as this is the value for the women-to-men wage ratio in 1948 (see data section). We also set the preferences parameters to $\alpha = \beta = \frac{1}{3}$.

Finally, we calibrate the fixed cost χ to match the employment rate of married women in 1950 which is equal to 25 percent. Accordingly, the threshold ability of the marginal household that buys home appliances is equal to $x_{1950} = F^{-1}(0.75; 4.2, 0.9) = 122.37$. Normalizing $A_{m,1950} = A_{a,1950} = 1$, the fixed cost parameter is obtained from equation (13):

$$\chi = \frac{(\phi(\varphi)x_{1950} - 1)^2 f(x_{1950})}{\phi(\varphi)} = 63 \tag{14}$$

We present a summary of the baseline parameter values in Table 2.

We perform three numerical experiments. First, we assume that TFP in the market sector grows at an annual rate $z_m = 1.02$, while there is no TFP growth in the home

Tab. 2: Baseline parameters

t_w	η	ρ	κ	σ	μ	φ	α	β	x_{1950}	χ
0.36	0.16	3.22	8.0	0.9	4.2	0.6	$\frac{1}{3}$	$\frac{1}{3}$	122.37	63

appliances sector and the gender wage gap is fixed at its 1948 value. We solve for x_t^m in equation (13) for all years between 1948 and 1987 with $A_{mt+1} = z_m A_{mt}$, $A_{at+1} = A_{at} = 1$, and $\varphi = 0.6$. Women's labor force participation is equal to $1 - F(x_t^m)$, while the ratio of home appliances to the prevailing wage is equal to $\phi(\varphi)x_t^m$. Second, we assume that TFP in the home appliances sector grows at an annual rate $z_a = 1.02$, while there is no TFP growth in the market sector and the gender wage gap is fixed at its 1948 value. Finally, we assume that woman-to-man ratio increases from 0.6 to 0.66 (see the data section) and that there is no TFP growth in either the market or home appliances sector. We present our results for women's participation and the rate of decline for the ratio of home appliances to market wage in Figures 3 and 4, respectively.

TFP growth in the market sector has by far the largest impact on both women's employment and home appliances prices (see Table 3). For the entire period between 1948 and 1987, women's participation increases by 38 percentage points compared to more modest 2 and 5 percentage points increases for TFP growth in the home appliances sector and gender wage gap. Similarly, the ratio of home appliances price to market wage declines by 60 percent compared to 4 and 12 percent for TFP growth in the home appliances sector and gender wage gap. Note that changes in the gender wage gap have a smaller impact on women's employment rates compared with Jones et al. (2003). This result is expected since our model does not allow for accumulation of human capital which provides an additional incentive for women to work and thus increases women's labor supply elasticity.

Fig. 3: Employment rate of married women

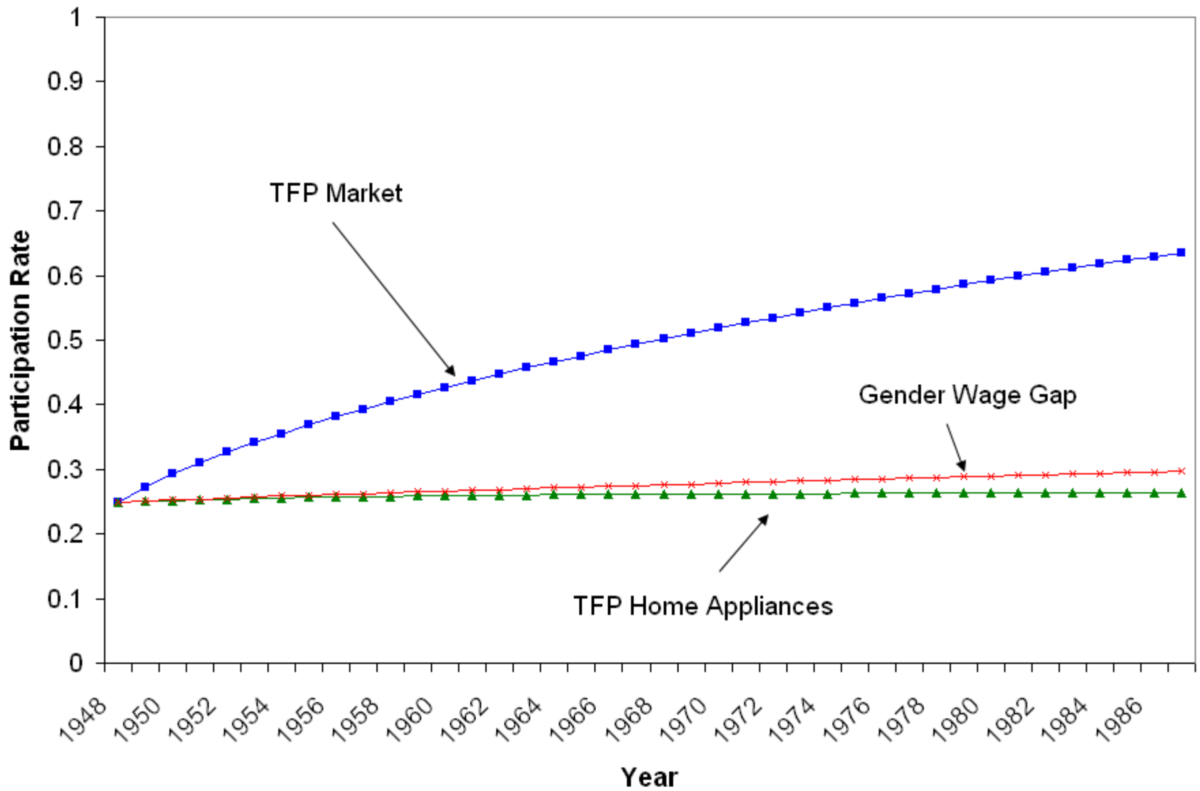
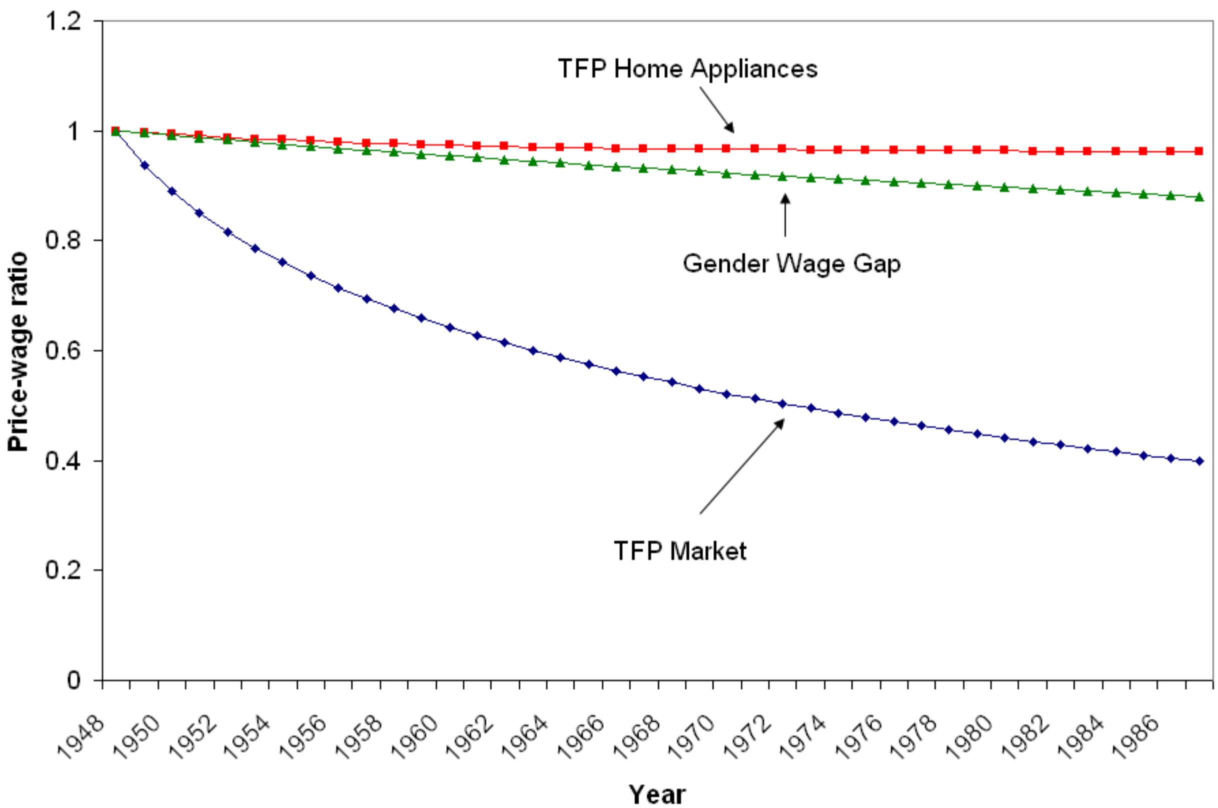


Fig. 4: Home appliances price relative to the market wage



Tab. 3: Simulation results

	TFP market	TFP home appliances	Gender Gap
Change in women's participation	+38%	+2%	+5%
Change in ratio of home appliances to wage	-60%	-4%	-12%

6 Concluding remarks

Recent research has linked declining home appliances prices to the rise in employment of married women in the twentieth century. We proposed a two-sector general equilibrium model to explore possible causes for the decline in home appliances prices. We found that TFP growth in the market and home appliances sector and changes in the gender wage gap all contributed to the decline in home appliances prices relative to the prevailing market wage. As a result, a new mechanism for explaining the rise in employment of married women is presented where changes in market wage levels affect women's decision to work. Simulations also showed that TFP growth in the market sector had the largest impact on women's employment rates and the price of home appliances.

We believe that our paper brings us closer to a unified theory of women's labor supply. So far, proposed explanations considered the impact of declining home appliances prices on women's decisions to work. However, a different reading of economic history is that home appliances were introduced in response to women's increased desire to work. Whether declining home appliances prices caused women to work or vice versa is still an open question which needs to be addressed urgently in future research.

References

[1] Gary S. Becker. *A Treatise on the Family*. Cambridge, Mass.: Harvard University Press, 1991.

[2] Jess Benhabib, Richard Rogerson, and Randall Wright. Homework in macroeconomics: Household production and aggregate fluctuations. *Journal of Political Economy*, 99(6):1166–87, December 1991.

[3] Tanis Day. Capital-labor substitution in the home. *Technology and Culture*, 33:302–327, April 1992.

[4] Robert J. Gordon. *The Measurement of Durable Goods Prices*. Chicago: University of Chicago Press, 1990.

[5] Jeremy Greenwood and Nezih Guner. Marriage and divorce since WWII: Analyzing the role of technological progress on the formation of households. *Research Report No. 8*, Economie D'Avant-Garde, July 2004.

[6] Jeremy Greenwood, Ananth Seshadri, and Guillaume Vandenbroucke. The baby-boom and baby-bust. *American Economic Review*, 95(1):183–207, March 2005.

[7] Jeremy Greenwood, Ananth Seshadri, and Mehmet Yorukoglu. Engines of liberation. *The Review of Economic Studies*, 72(1):109–133, January 2005.

[8] Larry E. Jones, Rodolfo Manuelli, and Ellen S. McGrattan. Why are married women working so much? *Federal Reserve Bank of Minneapolis Staff Report*, May 2003.

[9] John A. Knowles. *Parental Decisions and Equilibrium Inequality*. PhD thesis, 1999. University of Rochester.

[10] U.S. Census Bureau. Concentration ratios in manufacturing in 1997, June 2001.

7 Appendix: Proofs

7.1 Proposition 1

Proof. Given its employment and adoption decision, the utility of a household of type (λ_m, λ_f) is equal to:

$$
\begin{aligned}
&\text{Do not work; do not adopt: } U^{NW,NA} = \alpha \ln(w_t\lambda_m) + (1-\alpha-\beta)\ln(2-t_w-\rho\eta)\\
&\text{Do not work; adopt: } U^{NW,A} = \alpha \ln(w_t\lambda_m - p_{at}) + \beta\ln(\kappa) + (1-\alpha-\beta)\ln(2-t_w-\eta)\\
&\text{Work; do not adopt: } U^{W,NA} = \alpha \ln(w_t(\lambda_m+\lambda_f)) + (1-\alpha-\beta)\ln(2(1-t_w)-\rho\eta)\\
&\text{Work; adopt: } U^{W,A} = \alpha \ln(w_t(\lambda_m+\lambda_f) - p_{at}) + \beta\ln(\kappa) + (1-\alpha-\beta)\ln(2(1-t_w)-\rho\eta)
\end{aligned} \tag{15}
$$

Comparing the above choices pairwise, we can derive the following "conditional" thresholds. First, given the household's adoption decision, a_t, women work ($e_t = 1$) if and only if $\varphi \geq \phi^w(\frac{p_{at}}{\lambda_m w_t}; a_t)$ where:

$$
\begin{aligned}
\phi^w(\frac{p_{at}}{\lambda_m w_t}; 0) &= (\frac{2-\rho\eta-t_w}{2-\rho\eta-2t_w})^{\frac{(1-\alpha-\beta)}{\alpha}} - 1 \quad (U^{NW,NA} = U^{W,NA})\\
\phi^w(\frac{p_{at}}{\lambda_m w_t}; 1) &= (1-\frac{p_{at}}{\lambda_m w_t})[(\frac{2-\eta-t_w}{2-\eta-2t_w})^{\frac{(1-\alpha-\beta)}{\alpha}} - 1] \quad (U^{NW,A} = U^{W,A})
\end{aligned} \tag{16}
$$

Second, given women's employment decision, e_t, households adopt the technology ($a_t = 1$) if and only if $\chi_t \leq \phi^a(\varphi; e_t)$ where:

$$
\begin{aligned}
\phi^a(\varphi; 0) &= 1 - (\frac{2-\rho\eta-t_w}{2-\eta-t_w})^{\frac{(1-\alpha-\beta)}{\alpha}}(\frac{1}{\kappa})^{\frac{\beta}{\alpha}} \quad (U^{NW,NA} = U^{NW,A})\\
\phi^a(\varphi; 1) &= (1+\varphi)[1 - (\frac{2-\rho\eta-2t_w}{2-\eta-2t_w})^{\frac{(1-\alpha-\beta)}{\alpha}}(\frac{1}{\kappa})^{\frac{\beta}{\alpha}}] \quad (U^{W,A} = U^{W,NA})
\end{aligned} \tag{17}
$$

Notice that $\phi^w(0;0)$ does not depend on the price of home appliances. As a result, it is always optimal for women to work whenever $\varphi > \phi^w(0;0)$. In order to guarantee that women's employment decision is not trivial and depends on the appliances price, we let $\bar{\varphi}_2 = (\frac{2-\rho\eta-t_w}{2-\rho\eta-2t_w})^{\frac{(1-\alpha-\beta)}{\alpha}} - 1$ and we assume that $\varphi < \bar{\varphi}_2$. Moreover, we let $\bar{\varphi}_1 = (\frac{2-\eta-t_w}{2-\eta-2t_w})^{\frac{(1-\alpha-\beta)}{\alpha}} - 1$.

When $\bar{\varphi}_1 < \varphi < \bar{\varphi}_2$, we can show that the following is true:

$$\begin{aligned} \frac{p_{at}}{\lambda_m w_t} &< \phi^a(\varphi; 0) \Rightarrow a_t = e_t = 1 \\ \frac{p_{at}}{\lambda_m w_t} &> \phi^a(\phi^w(0; 0); 1) \Rightarrow a_t = e_t = 0 \end{aligned} \tag{18}$$

When $\phi^a(\varphi; 0) \leq \frac{p_{at}}{\lambda_m w_t} \leq \phi^a(\phi^w(0; 0); 1)$, we can use the conditional thresholds to rule out most of the choices. In the end, we must compare the alternatives (NW, NA) and (W, A). We have:

$$\phi^a(\varphi; 0) \leq \frac{p_{at}}{\lambda_m w_t} \leq \phi^a(\phi^w(0; 0); 1) \Rightarrow \left(a_t = e_t = 1 \Leftrightarrow \frac{p_{at}}{\lambda_m w_t} \leq \phi(\varphi)\right) \tag{19}$$

where $\phi(\varphi) = 1 - (\frac{2-\rho\eta-t_w}{2-\eta-2t_w})^{\frac{(1-\alpha-\beta)}{\alpha}}(\frac{1}{\kappa})^{\frac{\beta}{\alpha}} + \varphi$.

Notice that $\phi(\phi^w(0; 1)) > \phi^a(0; 0)$ and $\phi(\phi^w(0; 0)) = \phi^a(\phi^w(0; 0); 1)$. As a result, we have:

$$\forall(\lambda_m, p_{at}, w_t), \quad e(\frac{p_{at}}{\lambda_m w_t}) = a(\frac{p_{at}}{\lambda_m w_t}) = 1 \Leftrightarrow \lambda_m \geq \frac{p_{at}}{w_t \phi(\varphi)} \tag{20}$$

□

7.2 Proposition 2

Proof. For all $x > \frac{1}{A_{at}\phi(\varphi)}$, let $g(x) = (\phi(\varphi)x - \frac{1}{A_{at}})^2 f(x)$ where the function f denotes the probability density function of the log-normal distribution with parameter μ and σ. The function g is differentiable and its first-derivative satisfies:

$$\frac{xg'(x)}{g(x)} = \frac{1}{A_{at}} + \frac{2}{A_{at}\phi(\varphi)x - 1} - \frac{\ln(x) - \mu}{\sigma^2} \tag{21}$$

Define the function $h(x) \equiv \frac{\ln(x)-\mu}{\sigma^2} - \frac{2}{A_{at}\phi(\varphi)x-1} - \frac{1}{A_{at}}$. The function h is continuously differentiable on the interval $(\frac{1}{A_{at}\phi(\varphi)}, +\infty)$ and is increasing since $h' \geq 0$. In addition, since $\lim_{x \to \frac{1}{A_{at}\phi(\varphi)}^+} h(x) = -\infty$ and $\lim_{x \to +\infty} h(x) = +\infty$, the intermediate value theorem of calculus guarantees that the equation $h(x) = 0$ has a unique solution that we call x_0. Since h is increasing, we have $h(x) < 0$ when $\frac{1}{A_{at}\phi(\varphi)} < x < x_0$ and $h(x) \geq 0$ when $x \geq x_0$. Since g is positive, we have $g'(x) > 0$ when $\frac{1}{A_{at}\phi(\varphi)} < x < x_0$ and $g'(x) < 0$ when $x > x_0$. This implies that the function g is increasing for $\frac{1}{\phi(A_{at}\varphi)} < x < x_0$, decreasing for $x > x_0$, and reaches its maximum at $x = x_0$.

We define the threshold $\bar{A}_m$ as:

$$\bar{A}_m = \frac{\chi\phi(\varphi)}{(\phi(\varphi)x_0 - \frac{1}{A_{at}})^2 f(x_0)} \tag{22}$$

When $0 < A_{mt} < \bar{A}_m$, we have $\frac{\phi(\varphi)\chi}{A_{mt}} > (\phi(\varphi)x_0 - \frac{1}{A_{at}})^2 f(x_0)$. Hence there is no x_t such that equation (13) is satisfied. On the other hand, since the function g has a $\cap$-shape, equation (13) has at least one solution when $A_{mt} \geq \bar{A}_m$. In what follows, we call $\hat{x}_t^m$ the solution which satisfies $\hat{x}_t^m \leq x_0$.

We can now show the second part of the theorem. Take logarithm of equation (13). Then differentiate $\hat{x}_t^m$ with respect to A_{mt}:

$$\frac{\partial \hat{x}_t^m}{\partial A_{mt}} = \frac{\hat{x}_t^m}{A_{mt} h(\hat{x}_t^m)} \tag{23}$$

Since $\hat{x}_t^m \leq x_0$, we know that $h(\hat{x}_t^m) \leq 0$. As a result, $\frac{\partial \hat{x}_t^m}{\partial A_{mt}} \leq 0$. □

7.3 Proposition 3

Proof. For all $x > \frac{1}{A_{at}\phi(\varphi)}$, let $g(x; A_{at}) = (\phi(\varphi)x - \frac{1}{A_{at}})^2 f(x)$. We already established the properties of the function g in the proof of the previous proposition. It is continuously differentiable, has a $\cap$-shape, and reaches its maximum at x_t^0 which is determined by the following equation:

$$\frac{1}{A_{at}} + \frac{2}{A_{at}\phi(\varphi)x_t^0 - 1} - \frac{\ln(x_t^0) - \mu}{\sigma^2} = 0 \tag{24}$$

Note that, when $A_{at+1} > A_{at}$, we have $g(x; A_{at}) < g(x; A_{at+1})$ for all x in the domain. In particular, we have $x_t^0 = \underset{x}{sup}\|g(x; A_{at})\| < x_{t+1}^0 = \underset{x}{sup}\|g(x; A_{at+1})\|$.

For a given A_{mt}, let the unique $\bar{A}_a$ which satisfies $(\phi(\varphi)x^0 - \frac{1}{\bar{A}_a})^2 f(x^0) = \frac{\chi\phi(\varphi)}{A_{mt}}$. By definition of x^0 and since x_t^0 is increasing in A_{at}, it is easy to see that equation (13) has no solution when $A_t < \bar{A}_a$ and at least one solution when $A_t \geq \bar{A}_a$. We denote by $\hat{x}_t^a$ the solution which satisfies $\hat{x}_t^a \leq x_t^0$ when $A_t \geq \bar{A}_a$.

Take logarithm of equation (13). Then differentiate $\hat{x}_t^a$ with respect to A_{at}:

$$\frac{A_{at}}{\hat{x}_t^a}\frac{\partial \hat{x}_t^a}{\partial A_{at}} = \frac{1}{h(\hat{x}_t^a)}\frac{2}{A_{at}\phi(\varphi)\hat{x}_t^a - 1} \tag{25}$$

where the function h is defined in the proof of proposition 2. Since $\hat{x}_t^a \leq x_t^0$, we know that $h(\hat{x}_t^a) \leq 0$. As a result, $\frac{\partial \hat{x}_t^a}{\partial A_{at}} \leq 0$. □

7.4 Proposition 4

Proof. Assuming that equation (13) has at least a solution, we denote by $\hat{x}^\varphi$ the solution which satisfies $\hat{x}^\varphi \leq x^0$. Take logarithm of equation (13). Then differentiate $\hat{x}^\varphi$ with respect to φ:

$$\frac{1}{\hat{x}^\varphi}\frac{\partial \hat{x}^\varphi}{\partial \varphi} = \frac{1}{h(\hat{x}^\varphi)}\frac{2A_{at}\hat{x}^\varphi}{A_{at}\phi(\varphi)\hat{x}^\varphi - 1} \tag{26}$$

where the function h is defined in the proof of proposition 2. Since $\hat{x}^\varphi \leq x^0$, we know that $h(\hat{x}^\varphi) \leq 0$. As a result, $\frac{\partial \hat{x}^\varphi}{\partial \hat{x}^\varphi} \leq 0$. □