Rise of Women in Unified Growth Theory: French Development Process and Policy Implications

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ABSTRACT

Rise of Women, industrialization and demographic transition are integral components in a nation's development. We posit a two-sector unified growth model with endogenous female empowerment to study the interrelationship between women and development. Female empowerment would hamper fertility, lower agricultural employment share, and decelerate development; development that checks fertility would raise female labor-force participation and women's (economic) power. Our model reconciles French development process during AD1400-AD2100, including women's distinctive fall-and-rise socio-economic status, absence of a Post-Malthusian regime, fertility control and innovation's roles in modern growth. We also study the implications for policies promoting gender equality and innovation in Madagascar today.

Keywords: Female Empowerment; Women's Economic History; French Economic History; Unified Growth Theory

JEL Codes: E1, N1, O5

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"Could I forget that precious half of the republic that assures the happiness of the other and whose sweetness and goodness maintain its peace and good morals?" (Jean-Jacques Rousseau 1994[1754], 11)

1 INTRODUCTION

We restore women to development history and restore development history to women.[1] In the past two centuries, we have witnessed per capita income growth takeoff (Industrial Revolution) and fertility decline (Demographic Revolution) in present-day developed countries across the global North. On the other hand, such transitions took place later in today's developing countries in the global South, contributing to the North-South income gap nowadays (Great Divergence). The two revolutions are of vital importance in shaping our lives in modern times, and the unified growth theories (Galor and Weil 2000; Galor and Moav 2002) have been devoted to the study of this issue. However, the rise of feminism, one major event that went along with wealth amplification and demographic change in developed countries, has not been adequately addressed in the literature. It is our central thesis that female empowerment and demographic-economic aggregates are integrated entities that co-evolve in a system throughout a nation's development. We organize our thesis in three steps: (1) to develop a unified growth model with endogenous female empowerment; (2) to show that our model captures the long-run development patterns in France, a developed country today; and (3) to study the policy implications of our model on Madagascar, a developing country today.

In section 4, to explore the interrelationship between women and development, we develop a unified growth model with endogenous female empowerment. In the model, there are two sectors (agriculture and manufacturing) in the economy, where technological progresses are fueled by learning-by-doing externalities. Each household consists of one wife and one husband, both of whom supply labor hours to earn wage income in the market. Child-rearing requires both (agricultural) goods cost and wife's time cost, and the wife desires fewer children than her husband. The wife and husband bargain within the household to make consumption and fertility decisions, and the wife's bargaining power is determined endogenously from her wage income compared to her husband's. Our model captures the two-way relationship between women and development: in one direction, female empowerment would hamper fertility, move production factors out of agriculture and decelerate development. In the other direction, development that checks fertility, such as wage increases and relative agricultural price rises, would raise female labor-force participation and hence women's power.

In section 5, we calibrate the model and simulate socio-demographic-economic development in France during AD1400-AD2100. We pay particular attention to women's economic history. Women have their own economic history that is distinctive from men's. Men's economic history, like aggregate economic history, is characterized by income stagnation and subsequent takeoff.

[1] This is adapted from Kelly-Gadol (1976, 809)'s statement: "Women's history has a dual goal: to restore women to history and to restore our history to women."

Women's economic history, in contrast, is featured with first a fall and later a rapid rebound. In the early stages of development, because production concentrates on agriculture, agricultural technological progress is fast relative to the manufacturing one, leading to declines in relative agricultural price and goods cost of child-rearing. Fertility rises in response; women devote more time to raising children and withdraw from market work, implying a fall in women's income. As time goes by, the rising real wage that increases women's time cost of child-rearing, together with structural transformation towards manufacturing that raises relative agricultural price, will depress fertility. This will liberate women's time for market work. With substantive wage growth since industrialization, this implies a rapid rise in women's income. Female labor-force participation and women's power also display similar U-shaped evolution patterns.

The divergence between women and men's economic history poses an important question to traditional unified growth theories regarding whose economic history they are paying attention to, and whether their implications fail to apply to one entire gender (see Jean-Jacques Rousseau's quote ahead of the Introduction). Besides reconciling the fall and rise of women, our simulation replicates two other distinctive features of the French development process: France did not go through a Post-Malthusian regime in its development. Fertility control and innovation have played important roles in French modern economic growth.

In section 6, the calibrated model also sheds light on how policies targeted at improving gender equality (World Bank 2012) and innovation processes (World Bank 2008; UNIDO 2013) affect development from a dynamic general equilibrium perspective. We examine four development policies: preferential treatment, reducing child-rearing cost, promoting agricultural innovation and promoting manufacturing innovation in Madagascar, a former French colony. We investigate whether the four policies accelerate economic development and improve gender equality in Madagascar in both the short and long run.

The next section reviews the relevant literature. Section 3 presents historical facts about French development. Section 4 develops the unified growth model with female empowerment. Section 5 applies the model to reconcile French development history. Section 6 studies the effects of the four aforementioned development policies on Madagascar. Section 7 highlights some discussion. Section 8 concludes.

2 RELATED LITERATURE

2.1 Unified growth theories

Unified growth theories aim to explain the transitions of an economy throughout its development. Particular attention has been paid to the transitions from per capita income stagnation to sustainable growth (Industrial Revolution) and from high to low fertility (Demographic Revolution). Pioneering works include Galor and Weil (2000) and Galor and Moav (2002). They emphasized the three-regime development process: the inherent interaction between population (size or composition) and technology level in the Malthusian regime accelerates technological progress and eventually triggers the Industrial Revolution; the economy then enters the Post-Malthusian regime. Sooner or later the demand for human capital will rise to

a level that, through child quality-quantity tradeoff, the Demographic Revolution will set in; the economy will then enter the Modern Growth regime.

Unified growth theories have paid attention to the roles of human capital formation (Galor and Weil 2000; Galor and Moav 2002), physical capital accumulation (Galor and Weil 1996), inequality (Galor and Moav 2004; Galor et al. 2009), trade (Galor and Mountford 2006; 2008), mortality (Lagerlöf 2003a; Soares 2005), child labor laws (Hazan and Berdugo 2002; Doepke 2004), structural transformation (Hansen and Prescott 2002; Strulik and Weisdorf 2008) and geography (Strulik 2008) in facilitating growth takeoff and demographic change.[2] However, one important phenomenon that went along with the two transitions but has not been adequately addressed by the literature is the rise of feminism (Diebolt and Perrin 2016). Becker (1991[1981], 140) linked these three events together:

> "*I believe that the growth in the earning power of women during the last hundred years in developed countries is a major cause of both the large increase in labor force participation of married women and the large decline in fertility*."

Our unified growth model will encompass living standard, fertility, female labor-force participation and women's power. We will examine how the model reconciles historical socio-demographic-economic development in France (sections 5.1 and 5.4).[3]

2.2 Women and Development

We highlight some theoretical papers which studied the role of women in development.[4] Galor and Weil (1996) posited that an increase in capital-labor ratio in the economy will raise women's relative wages, because capital is more complementary to women's labor input than to men's during the production process. This will encourage female labor-force participation and reduce fertility, and in turn lead to a rise in capital-labor ratio again. Such a loop can generate a demographic transition accompanied by accelerated output growth. In Lagerlöf (2003b), as women's human capital becomes more equal to men's over time, their time turns more expensive. Spouses will respond by substituting child quality for child quantity, fertility will decline and per capita income growth rate will rise.

The above models did not capture the change in women's ability in making decisions (female empowerment). Basu (2006), Rees and Riezman (2011) and Komura (2013) incorporated female empowerment in intra-household bargaining models without economic growth. Basu (2006) emphasized that female labor supply is both a cause and a consequence of women's changing power within the household. The interaction between the two can lead to multiple equilibrium outcomes. Hence an exogenous change in women's wage can have a dramatic effect on female labor supply and women's power. Rees and Riezman (2011) suggested that, if globalization provides relatively more market opportunities for women, women's power will rise. Given that

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[2] See Galor (2005) and Galor (2010) for surveys on unified growth theories.

[3] In our model, there are eight key endogenous socio-demographic-economic variables: two socio-variables: female labor-force participation rate and women's power; one demographic-variable: fertility; five economic variables: per capita income, agricultural and manufacturing productivity growth rates, agricultural employment share and relative food price.

[4] See Duflo (2012) for an empirical survey on the bidirectional relationship between women empowerment and economic development.

women have a weaker preference for child quantity, fertility will fall. Komura (2013) demonstrated that heterogeneity in spouses' preferences for child quantity together with marriage market externality can generate multiple equilibrium outcomes on fertility and female empowerment, and studied the model's implication on child allowance and childcare subsidies policies on fertility rate.

Diebolt and Perrin (2013a, 2013b) were probably the first to incorporate female empowerment in a unified growth model, that captures the co-evolving nature of female empowerment and demographic-economic development. They proposed a one-sector model with endogenous living standard, fertility, skill composition of population and gender equality. When skill-biased technological progress occurs, returns to skilled human capital increase and will eventually incentivize women to acquire education. Higher investment on women's education will on the one hand raise the opportunity cost of having children, and reduce fertility; on the other hand it will improve gender equality. Over time, the economy will move from an equilibrium with low income, high fertility, small fraction of skilled labor, and low gender equality to one with opposite features. We will construct an alternative unified growth model with female empowerment that simulates the historical fall and rise of women's power throughout the development process (sections 3.8 and 5.2), which is not featured in Diebolt and Perrin (2013a, 2013b)'s model.[5]

2.3 French Development Process

We will apply our unified growth model to simulate French development process. This contributes to the strand of literature that quantitatively applies unified growth theories to historical growth experience. Some examples include Jones (2001), Hansen and Prescott (2002), Gollin et al. (2002, 2004, 2007), Lord and Rangazas (2006), Desmet and Parente (2012), O'Rourke et al. (2013) and Yang and Zhu (2013). These works either applied unified growth models to British/United States or the world as a whole.[6] We choose France because it is an important European power that has not received attention in parallel to Britain in the research of unified growth theories. Also, the fact that France went through its Demographic Revolution before its Industrial Revolution (Chesnais 1992, ch.11) offers a development process that distinguishes from the British one and draws our interest (sections 5.1 and 5.3).

Besides reconciling demographic and economic chronologies in France, our unified growth model simulates the U-shaped evolution of female labor-force participation (Goldin 1990, 1995; Mammen and Paxson 2000; Tam 2011). In addition, we examine the impact of several development policies mentioned in the Introduction (section 6). Similar work has been performed by Doepke (2004), who studied the effect of education subsidy and child labor restriction on fertility in Brazil, South Korea and England.

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[5] See section 7.1 for a comparison of our model with Diebolt and Perrin (2013a, 2013b)'s one.

[6] One exception is Voigtländer and Voth (2006). They showed that the higher initial per capita income in England, through raising capital-intensive manufacturing production and the scope of capital externality, explained England's higher chance to escape from Malthusian constraints than China's in the eighteenth century.

3 HISTORICAL BACKGROUND IN FRANCE

In this section, we present the historical evolution of eight socio-demographic-economic variables that our unified growth model aims to capture: per capita income, fertility, agricultural and manufacturing productivities, agricultural employment share, relative food price, female labor-force participation rate and gender equality in France.

3.1 Per capita income

Figure 1 depicts Maddison (2008)'s estimates of per capita income (left) and its 10-year average growth rate (right) from AD1000 to AD2008. There is a structural break in per capita income growth rate in AD1820. We interpret it as the year that France began its Industrial Revolution. The 10-year average per capita income growth rate during AD1821-AD1830 was 0.55%. We take it as the criterion for the occurrence of French Industrial Revolution.

INSERT FIGURE 1 HERE

Weir (1997) also stated estimates for per capita income growth rate as 0.3% per annum in AD1750-AD1820 and 1.3% per annum in AD1820-AD1913. Since AD1820, France has turned from a relatively stagnating economy to one with sustainable per capita income growth.

3.2 Fertility

Figure 2 (blue sold line) depicts Chesnais (1992) and Mitchell (2007)'s estimates of birth rate in France throughout AD1750-AD2003. French birth rate started to decline in AD1786, around the time of AD1789 French Revolution.[7] We take AD1780 as the year of French Demographic Revolution.

INSERT FIGURE 2 HERE

Chesnais (1992, 333-335) listed three reasons accounting for the fertility decline: the revolution of ideas, the political climate and the agrarian question. First, around the French Revolution, maternal feelings developed and children became the objects of attention. Birth restriction became one chief instrument towards the "rationalization of sexual life". Second, since the turn of the nineteenth century, France witnessed the death of over a million men during the Revolutionary and Napoleonic Wars, creating a sense of deadlock in the country. Third, "France had for some time been a populous land, cultivated and cleared to its last corners. High demographic growth during the whole of the eighteenth century only exacerbated the food problem", catalyzing the change in demographic regime. We will focus on the third factor in this paper.[8]

3.3 Agricultural productivity

[7] Cummins (2013) placed the time of French demographic transition in AD1776.

[8] We will not consider individual preference change and mortality decline as causes of fertility decline in our model. Figure 1 (red dotted line) depicts the death rate in France during AD1750-AD2003. During the nineteenth century when fertility declined, mortality stayed roughly constant (except during the Franco-Prussian War in AD1870-AD1871).

Figure 3 depicts Dennison and Simpson (2010)'s estimates of agricultural productivity level in France during AD1600-AD1800. In general agricultural productivity was improving.[9]

INSERT FIGURE 3 HERE

Allen (2003, 409) stated that rising agricultural productivity promoted economic development in early Modern Europe through three channels: (1) supplying food, wool and flax to support the non-agricultural sector, (2) releasing labor to the manufacturing sector, and (3) providing surplus to finance investment. Our model captures the first two channels.

3.4 Manufacturing productivity

Figure 4 depicts Mitchell (2007)'s estimates of real money wages in Industry in France during AD1800-AD1913. We use them as proxies for the manufacturing productivity levels in France during the corresponding time frame. Manufacturing productivity was in general rising.[10]

INSERT FIGURE 4 HERE

3.5 Agricultural employment share

Figure 5 depicts Allen (2000) and Mathias and Todorov (2005)'s estimates of agricultural employment share in France from AD1750 to AD1992. Agricultural employment share was declining throughout this period.[11]

INSERT FIGURE 5 HERE

The pace of industrialization was slower in France than in Britain. By AD1870, the British agricultural employment share had fallen to 23%, compared to 49% in France (Mathias and Todorov 2005, 91). Henderson (1967, ch.IV(ii)) stated that one reason for this was the slow population growth in France relative to Britain during the nineteenth century, which limited the size of the home market that French manufacturing sector could sell its goods to.[12] On the other hand, after the Napoleonic Wars, Britain captured a large share of the world supply of international services (Crouzet 2003, 235-236).

3.6 Relative food price

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[9] The French Revolution had probably accelerated agricultural productivity growth. It introduced a unified system of assigned property rights, spurring investment in agricultural technological innovation. The introduction of potatoes (Dennison and Simpson 2010) and the development of sugar beets (Jodidi 1911) occurred around the same time.

[10] There have been debates about the performance of French industry in the nineteenth century. The earlier view among economic historians was that the French industry was relatively backward (Kindleberger 1964; Landes 1969), and its labor productivity failed to catch up with Britain's (Dormois 2004). The revisionist historians argued that French industrial labor productivity was higher than Britain's in most of the nineteenth century (O'Brien and Keyder 1978, 91), and the French economy performed very well when compared to other industrializing nations (Cameron and Freedeman 1983).

[11] Kuznets (1966, 88-89) provided estimates of agricultural income share in France from AD1789/1815 to AD1962. The share declined from 50% to 9%, again showing the relative decline of French agriculture within the time frame.

[12] Henderson (1967) also mentioned that the highly centralized French administration system, loss of Lorraine during the Franco-Prussian War, slow construction of French railway and port systems, failure to attract sufficient capital, slow development of mass production techniques and industrial protection from foreign competition also contributed to the slow French industrialization.

Figure 6 depicts Lévy-Leboyer and Bourguignon (1985) and INSEE (2016)'s estimates of relative food price (agricultural price over industrial price) in France during AD1820-AD1992. Relative food price was in general rising throughout AD1820-AD1913.

INSERT FIGURE 6 HERE

Comparing Figure 6 with Figure 2, we hypothesize that the rising relative food price was one reason underlying the fertility decline during AD1820-AD1913. Malthus (1826, 18) stated that, during the season of distress (falling price of labor and rising food price), "the discouragements to marriage and the difficulty of rearing a family are so great, that the progress of population is retarded".[13]

3.7 Female labor-force participation rate

For the early Modern Period, Davis (1975, 94) stated that,

> "*[French] women suffered for their powerlessness in both Catholic and Protestant lands in the late sixteenth to eighteenth centuries as changes in marriage laws restricted the freedoms of wives even further, as female guilds dwindled, as the female role in middle-level commerce and farm direction contracted, and as the differential between male and female wages increased*".

Female labor-force participation rate probably went down in those three centuries. Since the mid-nineteenth century, we have such estimates. Figure 7 depicts Deldycke et al. (1969) and the Federal Reserve Bank of St. Louis (2016)'s estimates of female labor-force participation rate in France during AD1856-AD2012, which was in general rising.

INSERT FIGURE 7 HERE

We hypothesize that the increase in female labor-force participation rate was both a cause and a consequence of the fertility decline. On the one hand, the increase in female labor-force participation rate raised women's income relative to men's, improving their bargaining position within household. Given that women desire fewer children than men, fertility fell. On the other hand, the fertility decline liberated women's time into market work.

3.8 Gender equality

Kelly-Gadol (1977; 1982, 23) stated that, in early Modern France, state formation promoted the emergence of "the preindustrial, patriarchal household as the basic social unit, as well as the economic unit of postfeudal society", eroding women's power before the French Revolution. Norberg (2004, 266) also mentioned that, women of the Old Regime in France had a "history of exclusion and steadily diminishing opportunities".

The French Revolution was a hallmark of French feminism. The AD1789 Women's March on Versailles (October Days) was one of the most important events in the French Revolution, showing that "the collective power of women was emerging" (Moses 1984, 12). Two years following the Declaration of the Rights of Man and of the Citizen, the Declaration of the Rights of Woman and the Female Citizen was published in AD1791 to express the failure of the French

[13] Malthus (1826, 12) also stated that, "[t]he ultimate cheek to population appears then to be a want of food, arising necessarily from the different ratios according to which population and food increase".

Revolution to address the gender equality issue. In essence, the latter declaration was an imitation of the former except highlighting the role of women; for example, in response to the first sentence in the former declaration, "Men are born free and equal in rights", the latter reads "Women are born free and equal to men in rights". In AD1791, the Revolutionary Constitution recognized marriage as a civil contract between consenting spouses (Rose 1995, 198). In AD1793 the Convention extended equal inheritance rights in all kinds of properties to all offspring, regardless of sex or birth order (Desan 1997, 598). The French Revolution set the stage for the continuous feminist movement in the nineteenth century, such as the demands for the right to participation in the government, the right to work, the right to equality in marriage, and so forth. (Moses 1984, 14-15).

We take literacy rate as a simple indicator of gender equality. Davis (1975, 72) mentioned that there was a "dramatic drop" in education level and of mere literacy among city women in early Modern France. Figure 8 depicts Diebolt and Perrin (2013a) and the World Bank (2016)'s estimates of female-to-male enrollment rate in primary school in France from AD1837 to AD2012, which was in general rising. We take the above together as evidence of a fall and rise in women's power throughout the French history.[14]

INSERT FIGURE 8 HERE

Now we have reviewed the important socio-demographic-economic trends in French development history (Figures 1-8). In the coming section we will construct a unified growth model that can broadly replicate these trends.

4 THE MODEL

We extend Strulik and Weisdorf (2008)'s unified growth model to incorporate intra-household bargaining (Basu 2006). Consider an overlapping generation economy where its economic activities continue over infinite discrete time periods, indexed by t. Each individual lives for two stages: childhood and adulthood. There are two groups of individuals: "female" (denoted by $i = 1$) and "male" (denoted by $i = 2$) with equal size. Although preferences differ across the two groups, individual preferences are identical within each group. An adult female ("woman" or "wife") and an adult male ("man" or "husband") form a household and jointly make consumption and fertility decisions. In the process the wife and the husband resolve their preference conflicts through cooperative bargaining. The economy produces two goods: agricultural goods (food) and manufacturing goods. The former is for child-rearing while the latter is for adult consumption.

[14] Starting from AD2006, the World Economic Forum has been publishing the Global Gender Gap Index, which assesses gender equality based on four areas: economic participation and opportunity, education attainment, health and survival, and political empowerment. The index ranges from zero to one scale. The Global Gender Gap Index for France rose from 0.6520 to 0.761 over AD2006-AD2015 (World Economic Forum 2006, 2015).

4.1 Households

Consider a generation-t individual, in the first stage of his/her life (time $t-1$), he/she does not work and makes no choice. To survive to adulthood, he/she consumes one unit of agricultural goods, which is paid by his/her parents, and a fraction $\varphi \in (0,1)$ of his/her mother's time. In the second stage of his/her life (time t), he/she marries. A woman (wife) and a man (husband) form a household. They are each endowed with one unit of time, which can be supplied to the market to earn wage income; a fraction φ of a wife's time is devoted to rear each of her child. The wife and husband will combine their wage incomes to purchase manufacturing goods for their own consumption, and food to feed their children. [15]

Preference of a generation-t individual is defined over his/her household's manufacturing goods consumption m_t, and the number of children n_t during adulthood. Women and men's individual utility functions, u_t^1 and u_t^2, are respectively: [16]

(1) $\quad u_t^1 = m_t + \gamma^1 \log n_t \;\; ; \;\; \gamma^1 > 0 \;\; ;$

(2) $\quad u_t^2 = m_t + \gamma^2 \log n_t \;\; ; \;\; \gamma^2 > 0 \;\; .$

Note that individuals' childhood food consumption does not enter the utility functions. (We might think of this as utility derived from childhood food consumption being normalized to zero.)

Trivers (1972) proposed that, the inherent biological imbalance in breeding cost and male-male competition to fertilize more sex cells create male-female conflict over child quality versus child quantity - men desire more children than women. Population surveys on the ideal number of children in Africa tended to support Trivers hypothesis (Short and Kiros 2002; Gebreselassie 2008; Westoff 2010). We make assumption (A1) to capture this preference difference: [17]

(A1) $\quad \gamma^1 < \gamma^2 \;\; .$

So, in our model, women and men have two inherent biological differences: first, women bear the entire time cost of child-rearing within household; second, women have a weaker reproductive preference for number of children.

Each household maximizes a household welfare function U_t, which is a weighted average of the wife and husband's individual utility functions (1) and (2):

(3) $\quad U_t = \lambda_t u_t^1 + (1-\lambda_t) u_t^2 \;\; ;$

where $\lambda_t \in [0,1]$ is a measure of women's power at time t: the higher λ_t is, the more bargaining power the wife has within the household's decision making process. In the extreme cases, if $\lambda_t = 1$, household's decisions always conform to wife's preference. [18] If $\lambda_t = 0$, household's decisions are always in line with husband's individual choices.

The household chooses manufacturing goods consumption and number of children to

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[15] We assume adults have no demand for food. We might think of this as children storing some of their food for adulthood. Letting adults demand food would not change the qualitative results.

[16] We adopt the quasi-linear description of utility function, which provides the strongest form of a hierarchy of needs (Strulik and Weisdorf 2008). As wage increases, the adults will spend a higher income fraction on manufacturing goods consumption.

[17] Komura (2013, 952) stated that, "[i]t is quite natural that women would hesitate to have many children in comparison to men considering their physical and mental strain attendant upon the frequent childbirth and the fact that the longer period of childrearing is likely to narrow the range of women's occupational choices."

[18] In our model, the maximum value λ_t can take is 0.5. This is directly implied from (6).

maximize U_t subject to a budget constraint. The total wage income of a generation-t household is $[1 + (1 - \varphi n_t)]w_t = (2 - \varphi n_t)w_t$, where w_t is the market wage rate at time t, φ is time cost per child (Galor and Weil 1996). Since leisure has no value in our model, the husband will always supply one unit of time to the market, while the wife will supply all her time aside from child-rearing to the market. The household divides the total wage income into purchase of manufacturing and agricultural goods. We make the price of manufacturing goods the numéraire in the economy for all time periods, and let p_t be the price of agricultural goods relative to manufacturing goods (relative food price) at time t. The budget constraint for a generation-t household is:

(4) $$m_t + p_t n_t = (2 - \varphi n_t)w_t \ .$$

Maximizing (3) subject to (4) gives the optimal household fertility choice:

(5) $$n_t = \frac{\gamma^2 + (\gamma^1 - \gamma^2)\lambda_t}{\varphi w_t + p_t} \ .$$

Fertility decreases with women's power (given $\gamma^1 < \gamma^2$), market wage rate and relative food price.

We assume that the relative power between wife and husband depends on their relative wage income. This corresponds to Engels (1909[1902], 99)'s assertion that the "supremacy of man in marriage is simply the consequence of his economic superiority".[19] In our model, wives and husbands are price takers in the labor market. There is no sex discrimination and they face the same market wage rate.[20] Therefore the relative wage income between wife and husband equals the ratio of individual labor hours they supply to the market. Hence:

(6) $$\frac{\lambda_t}{1-\lambda_t} = \frac{FLFP_t \cdot w_t}{1 \cdot w_t} \quad \text{or} \quad \lambda_t = \frac{FLFP_t}{1 + FLFP_t} \ ;$$

where $FLFP_t$ is female labor-force participation rate at time t. It equals the amount of time each wife supplies to the market:

(7) $$FLFP_t = 1 - \varphi n_t \ .$$

Household equilibrium (Basu 2006) will be attained when (5)-(7) hold in the economy.

4.2 Population dynamics

At each time t, a generation consists of L_t adults, where half of them are women L_t^1 and the other half are men L_t^2:[21]

(8) $$L_t = L_t^1 + L_t^2 \ .$$

The initial populations of women and men, L_1^1 and L_1^2, are historically given.

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[19] This is similar to Komura (2013): women's bargaining power within household depends on women's income relative to men's. Folbre (1983, 272) stated that, "differences in women's and men's access to wealth and income reduce the economic bargaining power of individual women within the family, thus making it possible for husbands to impose their own family size decisions on wives".

[20] Historically, sex discrimination in the labor market did exist. Even up until the twentieth century, "women's employments remain[ed] concentrated in sectors requiring few qualifications, in the continuity of domestic labor, and offering low wages." (Diebolt and Perrin 2013a, 17). In this paper, we abstract from this issue and focus on the interaction between fertility, female labor-force participation and women's power.

[21] In other words, at each time t, half of the newborns are female and half are male.

Adult population grows at gross rate $\frac{n_t}{2}$:[22]

(9) $$L_{t+1} = \frac{n_t}{2} L_t \ .$$

There is no mortality in the model. The net population growth rate at time t, g_t^{pop}, is given by:

(10) $$g_t^{pop} \equiv \frac{L_{t+1} + L_{t+1} \cdot \frac{n_{t+1}}{2}}{L_t + L_t \cdot \frac{n_t}{2}} - 1 \ .$$

Note that $L_t \cdot \frac{n_t}{2}$ is the number of children at time t.

4.3 Production

There are two production sectors in the economy: agricultural and manufacturing sectors. Technological progresses are fueled by learning-by-doing externality (Arrow 1962; Matsuyama 1992).

4.3.1 The Agricultural sector

At each time t, agricultural goods (food) are produced according to a Cobb-Douglas technology, using labor hours and land as inputs:

(11) $$Y_t^A = \mu (A_t)^{\varepsilon} (H_t^A)^{\alpha} (T)^{1-\alpha} \ ; \ \mu > 0, \ \varepsilon \in (0,1), \ \alpha \in (0,1) \ ,$$

where A_t is agricultural productivity or agricultural technology level at time t, H_t^A is labor hours employed by the agricultural sector at time *t*, both of which are endogenously determined. We assume total amount of land to be fixed and normalize it to one: $T = 1$ for all time t. The parameter restriction $\alpha \in (0,1)$ entails diminishing returns to labor hours in agricultural production.

We assume a simple one-to-one form of agricultural technological progress originating from learning-by-doing during agricultural production:

(12) $$A_{t+1} - A_t = Y_t^A = \mu (A_t)^{\varepsilon} (H_t^A)^{\alpha} \ .$$

The restriction $\varepsilon \in (0,1)$ asserts diminishing returns to learning in the agricultural sector.

The agricultural productivity growth rate at time t, g_t^A, is defined as:

(13) $$g_t^A \equiv \frac{A_{t+1} - A_t}{A_t} = \mu (A_t)^{\varepsilon - 1} (H_t^A)^{\alpha} \ .$$

The higher the agricultural technology level is, the slower the agricultural productivity growth rate would be. The labor hours employed by the agricultural sector exert a positive scale effect on agricultural technological progress.

4.3.2 The Manufacturing sector

At each time t, manufacturing goods are produced according to a constant-to-returns technology, using labor hours as the sole input:

(14) $$Y_t^M = \delta (M_t)^{\phi} H_t^M \ ; \ \delta > 0, \ \phi \in (0,1),$$

where M_t is manufacturing productivity or manufacturing technology level at time t, H_t^M is labor hours employed by the manufacturing sector at time *t*, both of which are endogenously determined. There are no diminishing returns to labor hours in manufacturing production.

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[22] Each household chooses fertility n_t. Since each household contains two adults, on average each adult possesses fertility $\frac{n_t}{2}$.

Similar to the agricultural sector, we assume a simple one-to-one learning-by-doing mapping of manufacturing technological progress to manufacturing output:

(15) $M_{t+1} - M_t = Y_t^M = \delta(M_t)^{\phi} H_t^M$.

The restriction $\phi \in (0,1)$ assures diminishing returns to learning in the manufacturing sector.

The manufacturing productivity growth rate at time t, g_t^M, is defined as:

(16) $g_t^M \equiv \frac{M_{t+1}-M_t}{M_t} = \delta(M_t)^{\phi-1} H_t^M$.

Again, a higher manufacturing technology base would slow down manufacturing productivity growth. The manufacturing employed labor hours exert a positive scale effect on manufacturing technological progress.

4.3.3 Aggregate output

The aggregate output at time t, Y_t, equals the sum of values of agricultural output at time t, $p_t Y_t^A$, and of manufacturing output at time t, Y_t^M:

(17) $Y_t = p_t Y_t^A + Y_t^M$.

Note that the price of manufacturing output has been normalized to one in all time periods.

Per capita income at time t, y_t, is defined as:

(18) $y_t \equiv \frac{Y_t}{L_t + L_t \cdot \frac{n_t}{2}}$.

Per capita income growth rate at time t, g_t^y, is defined as:

(19) $g_t^y \equiv \frac{y_{t+1}-y_t}{y_t}$.

4.4 Market clearing

We impose three market clearing conditions to close the model:

4.4.1 Labor market clearing

At each time t, the labor hours employed by the agricultural and manufacturing sectors equal the aggregate labor hours supplied by the adults:

(20) $H_t^A + H_t^M = L_t \left(\frac{2-\varphi n_t}{2}\right)$.

Note that $\left(\frac{2-\varphi n_t}{2}\right)$ is the fraction of time endowment supplied to market work per household.

4.4.2 Food market clearing

At each time t, the food demand for child-rearing purpose equals the agricultural output: $\frac{n_t}{2} L_t = \mu(A_t)^{\varepsilon}(H_t^A)^{\alpha}$. We define θ_t as the agricultural employment share (share of labor hours devoted to agriculture) at time t. Manipulating the above food market clearing condition gives:

(21) $\theta_t \equiv \frac{H_t^A}{L_t\left(\frac{2-\varphi n_t}{2}\right)} = \left(\frac{2}{2-\varphi n_t}\right)\left[\frac{n_t (L_t)^{1-\alpha}}{2\mu(A_t)^{\varepsilon}}\right]^{\frac{1}{\alpha}}$.

The agricultural employment share is increasing in fertility and population size, and is decreasing in agricultural productivity.

4.4.3 Wage equalization

At each time t, we assume labor hours to be perfectly mobile across the agricultural and manufacturing sectors. Hence wage w_t will be equalized across the two sectors. We further assume that the wage in each sector is set to the average product of labor hours:[23]

(22) $$w_t = \frac{p_t Y_t^A}{H_t^A} = \frac{Y_t^M}{H_t^M} \ .$$

Using (14) and (22), we obtain the wage equation:

(23) $$w_t = \delta(M_t)^{\phi} \ .$$

Wage increases with manufacturing productivity.

Using the food market equilibrium condition with the second equality in (22), we obtain the relative food price equation:

(24) $$p_t = \frac{\delta(M_t)^{\phi}}{[\mu(A_t)^{\varepsilon}]^{\frac{1}{\alpha}}} \cdot \left(\frac{n_t}{2} L_t\right)^{\frac{1-\alpha}{\alpha}} \ .$$

Relative food price increases with fertility, population size and manufacturing productivity; it decreases with agricultural productivity.

4.5 Equilibrium prices and allocations

The first period of the model is indexed with $t = 1$, and the initial conditions are given by $\{L_1^1, L_1^2, A_1, M_1\}$. The equilibrium constitutes sequences of household allocations $\{m_t, n_t\}_{t=1}^{\infty}$, female variables $\{\lambda_t, FLFP_t\}_{t=1}^{\infty}$, production variables $\{Y_t^A, Y_t^M, Y_t, y_t\}_{t=1}^{\infty}$, population variables $\{L_t, L_{t+1}^1, L_{t+1}^2\}_{t=1}^{\infty}$, sectoral variables $\{\theta_t, H_t^A, H_t^M\}_{t=1}^{\infty}$, price variables $\{w_t, p_t\}_{t=1}^{\infty}$, technology levels $\{A_{t+1}, M_{t+1}\}_{t=1}^{\infty}$, and growth rates $\left\{g_t^{pop}, g_t^A, g_t^M, g_t^y\right\}_{t=1}^{\infty}$ which satisfy:

(i) utility maximization conditions (4), (5);

(ii) female bargaining conditions (6), (7);

(iii) production equations (11), (14), (17), (18);

(iv) market clearing conditions – labor market (20), food market (21), wage equalization (23), (24);

(v) population evolution (8), (9), with L_t^1 and L_t^2 grow at $\frac{n_t}{2}$ $\forall t$;

(vi) technology evolution (12), (15);

(vii) growth rate definitions (10), (13), (16), (19).

4.6 Adjustment mechanisms, and Bidirectional relationship between women and development

We highlight five key adjustment mechanisms in the model, namely the income effect (Kongsamut et al. 2001), relative price effect, technology growth effect (Ngai and Pissarides 2007), population growth effect (Ho 2016a), and female empowerment effect:

4.6.1 Income effect [Mechanism 1][24]

[23] This is a type of "share economy" described by Drazen and Eckstei (1988, 437), where sectoral incomes are distributed among the working force.

[24] To be more precise, in our model with heterogeneous agents, Mechanism 1 should be called "Wage effect" instead of "Income effect".

- Mechanism: $w_t \uparrow \Rightarrow n_t \downarrow,\ m_t \uparrow,\ \theta_t \downarrow$
- *Proof:* Holding p_t and λ_t constant, by (5) an increase in w_t lowers n_t. Then by (4) m_t rises. Holding A_t and L_t constant, by (21) θ_t decreases.
- This mechanism works through household optimization channel and food market clearing. A rise in wage will increase wives' time cost of raising children. Households will respond by giving fewer births.[25] Female labor-force participation and household income will rise. Each household will spend more on manufacturing goods, and agricultural employment share will fall.

4.6.2 Relative price effect [Mechanism 2]

- Mechanism: $p_t \uparrow \Rightarrow n_t \downarrow,\ m_t \uparrow,\ \theta_t \downarrow$
- *Proof:* Holding w_t and λ_t constant, by (5) an increase in p_t lowers n_t. Then by (4) m_t increases. Holding A_t and L_t constant, by (21) θ_t falls.
- This mechanism also works through household optimization channel and food market clearing. Facing an increase in relative food price, household will substitute manufacturing goods for children. A smaller fraction of the economy's labor hours will be required to produce food for children.

4.6.3 Technology growth effect [Mechanism 3]

- Mechanism: $A_t \uparrow \Rightarrow \theta_t \uparrow$; $M_t \uparrow \Rightarrow \theta_t \downarrow$
- *Proof:* Using (11) and (14), rewrite (22) as $p_t = \frac{\delta(M_t)^{\phi}}{\mu(A_t)^{\varepsilon}} \cdot (H_t^A)^{1-\alpha} = \frac{\delta(M_t)^{\phi}}{\mu(A_t)^{\varepsilon}} \cdot \left[\theta_t L_t \left(\frac{2-\varphi n_t}{2}\right)\right]^{1-\alpha}$. Holding p_t, w_t, λ_t and M_t constant, an increase in A_t raises θ_t. Similarly, holding p_t, w_t, λ_t and A_t constant, an increase in M_t reduces θ_t.
- This mechanism works through wage equalization. Without loss of generality, consider a rise in agricultural productivity. It exerts an upward pressure on agricultural wage. Ceteris paribus, labor hours will shift to the agricultural sector to maintain wage parity between the two sectors.

4.6.4 Population growth effect [Mechanism 4][26]

- Mechanism: $L_t \left(\frac{2-\varphi n_t}{2}\right) \uparrow \Rightarrow \theta_t \downarrow$
- *Proof:* Again from the proof in Mechanism 3, $p_t = \frac{\delta(M_t)^{\phi}}{\mu(A_t)^{\varepsilon}} \cdot \left[\theta_t L_t \left(\frac{2-\varphi n_t}{2}\right)\right]^{1-\alpha}$. Holding p_t, A_t and M_t constant, an increase in $L_t \left(\frac{2-\varphi n_t}{2}\right)$ leads to a fall in θ_t.
- This mechanism also works through wage equalization. Agricultural production is

[25] Our quasi-linear utility formulations (1) and (2) have the implication that, if $\varphi = 0$, then wage change will have no effect on household fertility (equation (5)).

[26] To be more precise, in our model with adjustable working hours, Mechanism 4 should be called "Labor hours growth effect" instead of "Population growth effect".

characterized by stronger diminishing returns to labor hours than manufacturing production. Ceteris paribus, an increase in aggregate labor hours supplied will exert a greater downward pressure on agricultural wage than on manufacturing wage. Labor hours will shift out of agriculture to relieve this pressure.

4.6.5 Female empowerment effect [Mechanism 5]

- Mechanism: $\lambda_t \uparrow \Rightarrow n_t \downarrow,\ m_t \uparrow,\ \theta_t \downarrow$
- *Proof:* Holding p_t and w_t constant, by (5) an increase in λ_t lowers n_t, given $\gamma^1 < \gamma^2$. Then by (4) m_t increases. Holding A_t and L_t constant, by (21) θ_t decreases.
- This mechanism again works through household optimization channel and food market clearing. As women's bargaining power increases, household's consumption and fertility choices resemble more the outcomes that women would choose alone. Given women desire fewer children than men, this will reduce the number of births chosen by the household. More household budget will be spent on manufacturing goods, and agricultural employment share will decrease.

Coming to our key questions, first, how do women affect development? The *female empowerment effect* [Mechanism 5] provides a channel through which women's power (a social factor) can affect demography and economy. In our model, given two biological asymmetries between women and men– women desiring fewer children and bearing the full time cost of rearing children – female empowerment would reduce fertility and agricultural employment share. This contributes to the fields of "bio-founded" approach to family economics (Cox 2007, 105), feminist theory (Chafetz 1997; Upadhyay et al. 2014) as well as economic structural transformation (Kongsamut et al. 2001; Ngai and Pissarides 2007; Acemoglu and Guerrieri 2008). Note that our model denies that one gender is endowed with relatively more physical/human capital (Galor and Weil 1996) or blessed with a comparative advantage in performing tasks in a certain sector (Ngai and Petrongolo 2015). In other words, we have implicitly assumed the nonexistence of "essential difference" in women and men's abilities – women and men are "born equal" from this perspective.

Second, how does development affect women? Wage increase (Becker 1991[1981]), relative food price rise (Malthus 1826) and female empowerment are three *aggregate socio-economic developments that check fertility* [Mechanisms 1, 2, 5]. They will raise female labor-force participation and (further) improve women's power.[27] This completes the bidirectional relationship between women and development in our model. In the next section we will examine how the above mechanisms and bidirectional relationship account for the French development process and women's economic history.

5 SIMULATION: FRENCH DEVELOPMENT PROCESS

[27] See sections 2.1 and 3.6 for Becker and Malthus' quotes.

In this section, we employ the unified growth model to replicate French long-run development trends documented in section 3. Our emphases are to restore the role of women in French development process (section 5.1), and to show the distinction between women and men's economic history (section 5.2). We consider a model economy which begins in AD1400 and ends in AD2100.[28] Each model period corresponds to 20 years.

5.1 Benchmark model: Restoring women in French development process

Table 1 shows the benchmark parameter values and initial conditions.

INSERT TABLE 1 HERE

These values are selected to yield transitional dynamics which are consistent with French development patterns in AD1400-AD2000, as listed in Table 2.[29]

. INSERT TABLE 2 HERE

Figure 9 (blue solid lines) depicts the simulated development paths for (a) per capita income y_t, (b) fertility n_t, (c) agricultural productivity growth rate g_t^A, (d) manufacturing productivity growth rate g_t^M, (e) agricultural employment share θ_t, (f) relative food price p_t, (g) female labor-force participation rate $FLFP_t$, and (h) women's power λ_t from AD1400 to AD2100. Panels (a) to (h) correspond to and are broadly consistent with Figures 1-8 in section 3.

INSERT FIGURE 9 HERE

The model economy starts with low per capita income, respectable fertility, slow agricultural and manufacturing productivity growth, high agricultural employment share, and high relative food price in AD1400. Prior to AD1780, France was characterized by per capita income stagnation and rising fertility. Since AD1780, it has experienced sustainable per capita income growth and fertility decline (up till around AD2000). We denote periods prior to AD1780 as the "Malthusian era", the periods thereafter as the "Modern Growth era".

During the Malthusian era (AD1400-AD1780), the initial small French population and sectoral technology bases brought about slow technological progresses (panels (c) and (d)). Due to the initially high agricultural employment share, agricultural technological progress was fast relative to manufacturing technological progress, and pulled down the relative food price (panel (f)). Through the relative price effect [Mechanism 2] household fertility rose (panel (b)). This brought along two effects. First was the Iron Law of Wages (Ricardo 1821): the rise in fertility dissipated productivity growth so that French per capita income remained at a roughly constant level (panel (a)). Second was the diminished contribution of women to the labor force as they devoted more time to child-rearing, hampering their bargaining position within household up till AD1780 (panels (g) and (h)). For agricultural employment share, before AD1700, it stayed

[28] We choose AD1400 as the starting year of simulation. This is to avoid the period of the Black Death in the mid-fourteenth century, which might have significantly affected demographic-economic development in European countries (Ho 2016b). Also, France has in general possessed territorial integrity since the end of Hundred Years War in AD1453.

[29] We manually adjusted φ, γ^1, γ^2, μ, ε, α, δ, ϕ and M_1 to match the timings of Industrial and Demographic Revolutions, agricultural employment share in AD1760, female labor-force participation rate in AD1860, and the rise in relative food price in five consecutive periods (Table 2.2). We also set initial population and agricultural technologies so that Matlab can solve for real solution paths for the whole simulation time frame.

roughly constant (panel (e)). After AD1700, agricultural technology had stockpiled to a sufficiently high level to feed the population, so labor hours could be released from agriculture.[30] Agricultural employment share declined (panel (e)).

In AD1780, owing to the accelerated technological progresses, per capita income growth turned from negative to positive. Through the income effect [Mechanism 1], fertility reverted its heretofore rising trend in AD1780, marking the French *Demographic Revolution* and the onset of the Modern Growth era (panel (b)). Since AD1780, a virtuous cycle between fertility decline and female empowerment began. On the one hand, the fertility decline has liberated women's time from child-rearing to market work, improving their income and bargaining position within family. On the other hand, the rise in women's power has reduced fertility through the female empowerment effect [Mechanism 5]. Therefore, AD1780 did not just mark the Demographic Revolution, but also the *Rise of Women* (panel (h)). The Malthusian-Modern Growth boundary demarcated women's turning point.

The continuous fertility decline further accelerated per capita income growth after the turn of the nineteenth century (panel (a)). By construction, AD1820 was the year of French *Industrial Revolution* when the model's simulated per capita income growth rate rose significantly above zero.[31]

There were two other events that added impetus to French economic growth during the nineteenth century. The first was the rise in relative food price during AD1820-AD1920 (panel (f)), originating from population growth and acceleration of manufacturing technological progress (equation (24)). Through the relative price effect [Mechanism 2] this contributed further to the fertility decline, as well as further raising female labor-force participation rate and output growth. The second was structural transformation: wage increase, relative food price rise, manufacturing technological progress, population growth and female empowerment [Mechanisms 1-5] all pushed labor hours towards the manufacturing sector during AD1820-AD1920 (panel (e)). As production was shifting from the sector with slower technological progress (agricultural sector) to the faster one (manufacturing sector), overall productivity growth in the economy speeded up.[32] These two events boosted per capita income growth in France.

The diminishing returns to learning destined the deceleration of sectoral technological progresses. Also, the re-drop in relative food price together with the slowdown of structural transformation led to the retardation of per capita income growth during the twentieth century.[33] Without engines of growth other than learning-by-doing, per capita income, female labor-force participation rate and women's power would stabilize around higher steady state values in the

[30] This works through a mechanism not highlighted in section 4.6: when agricultural technology progresses fast relative to population growth, labor hours can be released from the agricultural sector (equation (21)). We might call this the "food problem channel".

[31] Note that positive model-simulated per capita income growth was already in place after AD1780. AD1820 was when the French economy decisively transited from stagnation to respectable growth (section 3.1).

[32] From our simulation, after AD1840, the manufacturing productivity growth rate has always been greater than the agricultural productivity growth rate.

[33] From our simulation, the agricultural and manufacturing productivity growth slowed down in AD1800 and AD1860 respectively. Relative food price started its long-run decline again in AD1940.

twenty-first century. Productivity growth in the two sectors and agricultural employment share would converge to zero, and fertility would converge to replacement level.[34]

To summarize the benchmark model, we have *restored the role of women* in French development process. Women affected development through the female empowerment effect; in particular after AD1780 female empowerment added impetus to fertility decline and structural transformation. Aggregate socio-economic development – wage increase, relative food price rise and Rise of Women after AD1780 – reduced fertility and liberated women's time to market work, (further) improving their power in modern times (section 4.6). The opposites were true before AD1780. Hence, throughout history, female labor-force participation and women's power displayed U-shaped evolution patterns (panels (g) and (h)). One drawback of the benchmark model is that per capita income growth would run out of gas in the twenty-first century. We will address this issue in section 5.4.

5.2 Women's economic history versus Men's economic history

Women's economic history differs from men's. We first restore economic history to women and men. Figure 10 depicts the simulated women's wage income (panel (a)) and men's wage income (panel (b)) throughout French development. Men's wage income is characterized by a stagnation followed by a sustainable growth since AD1780, replicating the evolution pattern of per capita income in the aggregate economy (panel (c)).[35] Hence aggregate economic history, where Malthusian stagnation is followed by sustainable growth (Clark 2007), can represent men's economic history.

INSERT FIGURE 10 HERE

However, the same cannot be said for women's economic history. Observing from Figure 10 (panel (a)), that women's wage income is featured with a decay rather than stagnation in the early stages of development. This is caused by wage stagnation together with women's falling labor-force participation in the Malthusian era. Things went on the opposite way after industrialization. After AD1780, while men's economic history is characterized with wage amplification, women's one is with wage amplification *and* rise in participation. Therefore women's income has been rising faster than men's in the Modern Growth era. To summarize the two eras, aggregate economic history cannot represent women's economic history.

This poses an important question on traditional unified growth theories (Galor and Weil 2000; Galor and Moav 2002): whose economic history are the theories capturing? Can their implications be applied to both genders? Constituting half of the human race, women's economic history is too significant to be ignored by "unified" growth theories or economic history (or "herstory").[36]

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[34] See Appendix 1 for the derivation of the properties of the benchmark economy in its balanced growth path.

[35] To be more precise, in the Malthusian era, the simulated men's income followed a mild rise, while the simulated per capita income followed a mild decline.

[36] Note that if we turn our attention to economic history from the angle of labor-force participation, women's economic history ($FLFP_t$) is also distinctive from men's one (always 1), but now the aggregate economic history ($1 + FLFP_t$) represents women's instead of men's economic history. In the same vein, it is almost from definition that women's social history (reflected by λ_t in our

In our theory, the fall and rise of women's status also applies to female labor-force participation and women's power, which are also endogenously determined.[37] Our work complements the literature to explain the falling portion of those U-shaped evolution patterns: spouses' intra-household bargaining together with evolving economic environment, rather than the social stigma against women working outside home (Goldin 1990, 1995) or state formation eroding women's authority (Kelly-Gadol 1977, 1982), could predict the fall in women's labor-force participation and power during the early stages of development.[38] The family sphere, in additional to the social sphere and the politics sphere, would be an important arena to understand both genders' development history.[39]

5.3 Other French Development Process

Based on our benchmark simulation and historical facts, we highlight three additional features of French development process. The first is the *absence of a Post-Malthusian regime*. Galor and Weil (2000) defined Malthusian regime as a status where "income per capita was roughly constant" (806), Post-Malthusian regime as a status where "[i]ncome per capita grew", while the "[positive] relationship between income per capita and population growth was still in place" (807), and Modern Growth regime as a status where "sustained income growth" occurs, and "there is a negative relationship between the level of output and the growth rate of population" (806). In our simulation, per capita income was falling (or stagnating) up till AD1780, while population growth rate declined only after AD1760. There is not a period when per capita income and population growth rate rose simultaneously. France transited directly from the Malthusian regime to the Modern Growth regime. Hence our model points out that a nation needs not go through the three-regime development process described by Galor and Weil (2000) and Galor and Moav (2002) within a unified growth framework (section 2.1).

Second, we note the distinction between French and British development processes. The French Demographic Revolution began in the late-eighteenth century and its Industrial Revolution in the nineteenth century, whereas the chronology was reversed in Britain (Chesnais 1992, 321). The chronology suggests that France relied more on *fertility reduction as a way to raise its per capita income* in comparison to Britain at the turn of the nineteenth century. Actually, this statement generalizes well into the early-twenty-first century. Using Maddison (2008)'s estimates, France indeed outperformed Britain in terms of economic growth during AD1820-AD2008. Their annualized per capita income growth rates were 1.59% and 1.41%

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model) differs from men's social history (reflected by $1-\lambda_t$).

[37] The U-shaped evolution of female labor-force participation was also evidential in the United States time series study (Goldin 1990, 1995), cross-sectional analysis (Mammen and Paxson 2000) and panel data regression (Tam 2001).

[38] In our model, there is no sex discrimination in the labor market, and women's power depends solely on spouses' relative incomes.

[39] Marx and Engels (1910[1848], 37) criticized bourgeois family system's exploitation of women:

> "*The bourgeois sees in his wife a mere instrument of production. He hears that the instruments of production are to be exploited in common, and, naturally, can come to no other conclusion, than that the lot of being common to all will likewise fall to the women.*"

Engels (1909[1902], 98) argued that, only after the abolition of capitalism and the property relations created by it, could full freedom of marriage be attained.

respectively. One reason behind this was that France had better demographic control than Britain. Within AD1820-AD2008, the French annualized population growth rate was 0.38%, compared with 0.56% in Britain. This French development style seems to have emerged by the turn of the nineteenth century. In the long run, it has not put the prosperity of the country at a disadvantage when compared to the other side of the English Channel. In AD2008, per capita incomes of France and Britain were similar, at $22,223 and $23,742 respectively.[40]

Lastly, we note that the French Revolution occurred in AD1789. The French Revolution did not break out in a period when the society and the economy were static – as Tocqueville (1856, 215) noted, "[n]o one in 1780 had any idea that France was on the decline; on the contrary, there seemed to be no bounds to its progress". This is consistent with relative deprivation theory (Morrison 1971, 688; Gurr 2011): rebellion and revolution occur at times when social changes that "create expectations faster than opportunities for reaching the expectations are created, resulting in relative deprivation". France was experiencing rapid socio-demographic-economic changes in the late-eighteenth century that caught the old political regime at a catastrophe.

5.4 Extended model with innovation

To generate sustainable per capita income growth in the long run, solely relying on learning-by-doing is not enough; we need the economy to *innovate*.[41] North (1981, 162) stated that:

> *"Learning by doing can explain the technology developed during the Industrial Revolution, but only scientific experimentation can account for the development of nuclear power or the petrochemical industry ... [in] the last hundred years".*

Since the late-nineteenth century, there has been a proliferation of science-based technological breakthroughs which improved agricultural and manufacturing productivities. For example, during the Second Industrial Revolution (AD1870-AD1914), in agriculture, the extended uses of chemical fertilizers, steel implements and tractors improved productivity of food supply. In manufacturing, the production of cheap steel, explosives and dynamite revolutionized construction processes. The use of electricity provided an efficient supply of industrial power. Oil cracking provided gasoline and lubricants. The invention of the internal combustion engine fostered development of the automobile industry.[42]

We consider a simple extension of the benchmark model. We incorporate innovation in the form of exogenous sectoral productivity growth since the Second Industrial Revolution. As exogenous productivity growth are "measure[s] of our ignorance" (Abramoritz 1956, 11), they capture all factors other than learning-by-doing that could raise factor productivities in the two sectors (for example, improvements in transportation, finance, health, education, institution, and so

[40] Lévy-Leboyer (1964) was probably the first to stress that France followed a modernization path distinct from the British one. Adapting to economic disasters during the revolutionary and Napoleonic periods, unfavorable factor endowments and its comparative advantage in skilled labor, France first developed its quality, fashion and luxury goods industries in the early-nineteenth century, and integrated backwards to modernize its basic industries later (Crouzet 2003, 224-225).

[41] In technical terms, the requirement for the model to exhibit long-run growth is the possession of a difference equation that is linear (Jones 2005, 1103).

[42] See Mokyr (1998) and Vaclav (2005) for surveys on the Second Industrial Revolution.

forth). Technological progress equations (12) and (15) are replaced by:

$$(25)\qquad \begin{cases} A_{t+1} - A_t = Y_t^A & from\ AD1400\ to\ AD1859 \\ A_{t+1} - A_t = \eta A_t + Y_t^A & from\ AD1860\ onwards \end{cases},\ \eta > 0\ ;$$

$$(26)\qquad \begin{cases} M_{t+1} - M_t = Y_t^M & from\ AD1400\ to\ AD1859 \\ M_{t+1} - M_t = \kappa M_t + Y_t^M & from\ AD1860\ onwards \end{cases},\ \kappa > 0\ ,$$

where η and κ are exogenous innovation rates in the agricultural and manufacturing sectors respectively. We choose $\eta = (1.037)^{20} - 1$ and $\kappa = (1.052)^{20} - 1$. See Appendix 2 for how these values are derived.

Figure 9 (red dashed lines) depicts the simulation results for the extended model. We pay attention to how the inclusion of innovation affects the simulated development paths after AD1860. Innovation refueled productivity growth in the two sectors which otherwise began to exhaust their momentum due to diminishing learning-by-doing (panels (c) and (d)). It allowed sustainable per capita income growth (panel (a)), which in turn promoted the continuous rise in women's labor-force participation rate and power [Mechanism 1] (panels (g) and (h)). Through the strengthened income effect and female empowerment effect [Mechanisms 1 and 5], these further reduced fertility and agricultural employment share (panels (b) and (e)).[43]

After incorporating innovation, our model predicts per capita income in France would grow by a factor of 24.1 throughout AD1820 to AD2000, which is a bit larger than the factor 18.0 implied by Maddison (2008)'s estimates. Innovation has become a more and more important engine of growth in France, as panel (a) shows that the simulated per capita income gap between the benchmark model (with only learning-by-doing) and the extended model (with learning-by-doing and innovation) widened as time goes by in the late-nineteenth and twentieth centuries. This conforms to Acemoglu et al. (2006)'s argument that innovation rather than imitation would become a more important source of growth when a country moves closer to the world technology frontier, which describes France at least since the mid-twentieth century.[44]

To conclude, innovation has been the key to sustainable economic growth in France since the late-nineteenth century. It has also contributed to the rises in women's labor-force participation and power, as well as declines in fertility, agricultural employment share and relative food price.

5.5 Female empowerment as development decelerator

Using the extended model, we perform a counterfactual experiment to test the implication of imposing social norms that act against the rise in feminism.[45] Suppose that in the counterfactual patriarchy economy, the wife always conforms to her husband's preference. In terms of our

[43] The weakness of the extended model is that it predicts a counterfactual drop in relative food price during AD1860-AD1920 (panel (f)).

[44] Wolff (1991) found evidence for TFP-convergence among G7 countries during AD1870-AD1979. In particular, in AD1950 French TFP was 0.54 of the United States level. In AD1979 its TFP level was nearly on par with the United States level.

[45] The World Bank (2006, 51-54) stated that one cause of gender inequality is the "inequality trap", in which the social norms reinforce the existing segmented roles between women and men: the female is delineated for homecare and housework; the male is for market work and social interactions. This reinforces women and men's different access to assets and opportunities, hampering women's ability to influence household decisions.

model, we reset $\gamma^1 = \gamma^2 = 3.4$ in Table 1. Figure 11 (green dotted lines) depicts the evolution of per capita income and fertility for the patriarchy economy during AD1400-AD2100. Note that the red dashed lines replicate the results from Figure 9 (extended model).

INSERT FIGURE 11 HERE

Figure 11 shows that, the patriarchy economy (green dotted lines) underwent Demographic Revolution and Industrial Revolution earlier.[46] This is the implication of male quantity-biased reproductive preference together with learning-by-doing. As husbands desire more children than wives, giving husbands absolute power in making household decisions would raise fertility and population stock in the economy when compared to the cooperative bargaining case. The larger population stock would intensify output production and accelerate learning-by-doing, eventually allow the patriarchy economy to take off earlier. In other words, female empowerment acts as a build-in decelerator for development process in our model.

To summarize section 5, we have applied the unified growth model with female empowerment to France. Female empowerment is determined along with demographic-economic aggregates of a nation. Our model replicates the key features of French development process, including the chronologies of Demographic and Industrial Revolutions, women's distinctive fall-and-rise socio-economic status (female labor-force participation, income and power), the absence of a Post-Malthusian regime, the role of fertility control and innovation in French modern growth. Female empowerment also acts as a development decelerator.

6 POLICY IMPLICATIONS

In this section, we employ the unified growth model to examine four development policies: preferential treatment, reducing child-rearing cost, promoting agricultural innovation and promoting manufacturing innovation on Madagascar. Madagascar is a former French colony and is still stuck in the Malthusian Trap nowadays. Table 3 shows the comparison of per capita income, population size and land area in AD1500 France and AD2000 Madagascar. It is interesting to observe the similarity of the three aspects in France five hundred years ago and in AD2000 Madagascar.

INSERT TABLE 3 HERE

We assume the two countries share the same parameter values and directly apply the calibrated benchmark model from section 5.1 to Madagascar. What we need to change is just the time frame, from AD1400-AD2100 to AD1900-AD2600 (five hundred years delay). By doing so we have implicitly assumed that learning-by-doing is the sole engine of growth in Madagascar today.

Figure 12A (blue solid lines) depicts the simulated development paths for Madagascar from AD1900 to AD2600. Basically it is just the evolution paths in Figure 9 (blue solid lines) being

[46] The counterfactual economy went through the Demographic and Industrial Revolutions in AD1760 and AD1800, 20 years earlier than the extended model in section 5.4 did.

delayed by five hundred years. We take this as the "baseline case" in Madagascar. We then consider the four aforementioned policy options. We will pay particular attention on the policy effects on Madagascar's economic (per capita income) and gender equality development, which are summarized in Table 4.

INSERT TABLE 4 HERE

The bidirectional relationship between women and development we highlighted in section 4.6 [Mechanisms 1, 2, 5] will be key to explaining the simulation results.

6.1 Policy 1: Preferential treatment

We first consider the effect of preferential treatment.[47] Consider a policy which exogenously raises women's bargaining power for given male and female labor-force participation rates by 10% since AD2000. In terms of our model, we modify (6) by:

$$(27) \qquad \begin{cases} \lambda_t = \frac{FLFP_t}{1+FLFP_t} & from\ AD1900\ to\ AD1999 \\ \lambda_t = \frac{1.1FLFP_t}{1+FLFP_t} & from\ AD2000\ onwards \end{cases}.$$

Figure 12A (red dashed lines) depicts the policy effect. While the policy improves women's power since AD2000 (panel (h)), there is visually no effect on Madagascar's development process (panels (a)-(g)). Actually economic development first accelerates a bit, because of fertility decline resulting from the female empowerment effect [Mechanism 5]. It then slows down relative to the baseline case, due to the adverse impact of smaller population size on learning-by-doing.

INSERT FIGURE 12A HERE

Comparing panel (h) in Figure 9 and Figure 12A, promoting sustainable economic growth would be a more effective approach than preferential treatment to improve women's power in the long run. This corresponds to Doepke and Tertilt (2009)'s conclusion that gender equality might be achieved more easily through promoting economic development (for example public school program) than imposing legal reforms on women's rights.

6.2 Policy 2: Reducing child-rearing cost

We then consider the effect of reducing child-rearing cost.[48] Suppose the policy successfully lowers the time cost per child by 10% since AD2000. We set:

$$(28) \qquad \begin{cases} \varphi = 0.255 & from\ AD1900\ to\ AD1999 \\ \varphi = 0.255 \times 0.9 & from\ AD2000\ onwards \end{cases}.$$

Figure 12A (green dotted lines) depicts the policy effect. The policy liberates women's time into market work and female labor-force participation rate increases (panel (g)). Together with the resulting initial rise in fertility, aggregate labor hours supplied rise. Through

[47] Policy options to exogenously raise women's power include reforming laws over property within marriage, increasing women's exit options, eliminating discriminatory inheritance laws and wisdoms, and reducing domestic violence (The World Bank 2012, ch.7).

[48] Policy options to reduce child-rearing cost include subsidies to child care services, expansion of universal public school facilities, integrated health services for children, and so forth. (The World Bank 2012, ch.7).

learning-by-doing, technological progresses in both sectors accelerate (panels (c) and (d)). As a result Demographic Revolution and Industrial Revolution set in earlier (panels (b) and (a)), enabling the economy to enjoy a superior per capita income growth path (panel (a)). Gender equality is enhanced in both the short run and long run [Mechanism 1] (panel (h)).

The key drive to female empowerment in this case is the liberation of women's time to market work. This is analogous to Greenwood et al. (2005)'s finding that the flood of new household durables in the United States during the twentieth century freed up women's time from housework, and explained more than half of the observed rise in female labor-force participation rate.

6.3 Policy 3: Promoting agricultural innovation

We consider the effect of promoting domestic agricultural innovation, or facilitating importation of foreign agricultural innovation into Madagascar.[49] In particular, consider a policy that permanently introduces an innovation term into the agricultural technological progress equation (12) since AD2000:

$$(29) \qquad \begin{cases} A_{t+1} - A_t = Y_t^A \quad or \quad g_{At} = \frac{Y_t^A}{A_t} & from\ AD1900\ to\ AD1999 \\ A_{t+1} - A_t = 0.1A_t + Y_t^A \quad or \quad g_{At} = 0.1 + \frac{Y_t^A}{A_t} & from\ AD2000\ onwards \end{cases}.$$

The economy possesses an exogenous agricultural productivity growth rate of 10% in each period from AD2000 onwards.

Figure 12B (red dashed lines) depicts the policy effect. In the short run, the enhanced agricultural technological progress exacerbates the decline in relative food price (panel (f)), thereby encouraging fertility increase [Mechanism 2] (panel (b)). The fertility increase also causes a faster drop in female labor-force participation rate (panel (g)), creating conflicting effects on learning-by-doing. The net effect is that per capita income growth first decelerates, and picks up later (panel (a)). Similarly, women's power declines in the short run, and rises in the long run [Mechanism 1] (panel (h)).

INSERT FIGURE 12B HERE

In reality, the effect of agricultural innovation on gender equality may depend on the type of agriculture getting a boost. Qian (2008) found that, in the early Chinese reform period (AD1978-AD1980), reforms increased the returns to tea and orchard crops. In areas suitable for tea cultivation, female survival rate and education attainment rose. In areas suitable for orchard cultivation, the opposite was true.

6.4 Policy 4: Promoting manufacturing innovation

Lastly we consider the effect of promoting domestic manufacturing innovation, or boosting importation of foreign manufacturing innovation into Madagascar.[50] Similar to section 6.3,

[49] The World Bank (2008, 176) suggested that research aiming at improving crop, soil, water, livestock management and developing location-specific agricultural systems are crucial in fostering productivity growth in agriculture.

[50] UNIDO (2013, ch.7) stated that governments could promote industrial innovation by financing and providing public innovation inputs or information, establishing strong links between research

consider a policy that permanently introduces an innovation term into the manufacturing technological progress equation (15) since AD2000:

$$(30) \qquad \begin{cases} M_{t+1} - M_t = Y_t^M \ \ or \ \ g_{Mt} = \frac{Y_t^M}{M_t} & from\ AD1900\ to\ AD1999 \\ M_{t+1} - M_t = 0.1M_t + Y_t^M \ \ or \ \ g_{Mt} = 0.1 + \frac{Y_t^M}{M_t} & from\ AD2000\ onwards \end{cases}.$$

The economy enjoys an exogenous manufacturing productivity growth rate of 10% in each period from AD2000 onwards.

Figure 12B (green dotted lines) depicts the policy effect. In general promoting manufacturing innovation (green dotted lines) has opposite dynamic effects on development when compared to promoting agricultural innovation (red dashed lines). The crux lies in their opposite effect on relative food price (panel (f)). Relative to the baseline case, policy 4 pushes up relative food price, and discourages fertility in the short run [Mechanism 2] (panel (b)). The resulting smaller population scale slows down learning-by-doing in the agricultural sector (panel (c)) and eventually in the manufacturing sector (panel (d)); per capita income soon suffers. Although women's power rises sharply in the short run (panel (h)), it is outperformed by the baseline case in the long run [Mechanism 1].

The short run impact of non-agricultural innovation on gender equality is historically significant. Goldin (2006, 5) stated that, the arrival of new types of information technology in the United States since the AD1900s raised the demand for office and other clerical workers, leading to the revolutionary increase in married women's labor-force participation in the early-twentieth century.

We summarize the four policies: in terms of promoting gender equality, only preferential treatment and reducing child-rearing cost are feasible policy options in both the short and long run. If the society also cares about long-run economic development, the latter is the preferred option for Madagascar.[51] The lesson from the above experiments is that, within a co-evolving socio-demographic-economic system, some development policies may bring about negative spillovers through dynamic general equilibrium effects, and can render themselves useless in addressing the issues they were intend to solve in the long run; the manufacturing innovation policy in section 6.4 stands as one example.

7 DISCUSSION

7.1 Women and Development

The central theme of this paper is that female empowerment is linked together with demographic-economic variables in a dynamic system. We highlight the bidirectional

institutions and enterprises, acting as a consumer to raise demand in strategically important industries.

[51] Note that Figure 9 demonstrates that, some policy mix, such as simultaneously promoting agricultural and manufacturing innovations, can also improve gender equality and expedite economic development in both the short and long run.

relationship between women and development (section 4.6). Without female empowerment, unified growth theories would miss out one critical event - the rise of women, that has come along with industrialization and demographic transition, and affected at least half of the population in developed countries (e.g. France) in the past two centuries, and is relevant for present-day policy formulation in developing countries (e.g. Madagascar).

We model gender equality as an equilibrium phenomenon within a unified growth framework. Diebolt and Perrin (2013a, 2013b) did so by emphasizing women's human capital acquisition in response to skill-biased technological progress in the development process. In this paper, our emphasis is on women's labor-force participation response to changes in general wage and relative price throughout development. What is similar in our theory and theirs is that the opportunity cost of having children will eventually rise and trigger fertility decline. Although our model does not include the human capital acquisition channel, it does a good job in matching French development patterns up till the mid-nineteenth century (section 5.1), especially with regard to the fall and rise of women (section 5.2) and the absence of a Post-Malthusian regime (section 5.3). We think Diebolt and Perrin (2013a, 2013b)'s human capital acquisition channel would become more important as France came to the late-nineteenth and twentieth centuries when innovation, a skill-intensive activity, became the key engine of growth (section 5.4).[52]

On the issue of long-run gender equality, our model gives an unpleasant implication: biological differences between women and men means that complete gender equality is not achievable, as long as we do not have zero fertility (i.e. humans become extinct). Perhaps the best policies to promote gender equality and economic development together are those that facilitate innovations in both sectors (section 5.4) and reduce child-rearing cost (section 6.2), rather than those that impose preferable treatments which target strict gender equality of outcomes (section 6.1).

7.2 Limitations

Last but not least, we highlight three limitations of our model. First, one crucial assumption in our analysis is that women's power depends solely on their income relative to men's income (equation (6)). In reality, women's power also depends on political and civil rights, equal opportunities to jobs and financial services, property rights on assets, education and training, access to information and networks, and so forth. If we take these factors into account, it is likely that, since industrialization, women's power has been rising faster in France (developed countries) than what our model predicts in section 5.

Second, our unified growth model does not aim to provide a one-size-fits-all evaluation on development policies in different countries nowadays (Rodrik 2010). Our model assumes nearly-perfect labor and goods markets.[53] In reality different countries are bound by different

[52] From regression analysis, Murphy (2015) found that education had a significant negative impact on French marital fertility during AD1876-AD1896. Employing an augmented Solow model, Mankiw et al. (1992) found that human capital was an important component to explain cross-country variation in standard of living during AD1960-AD1985.

[53] In our model, labor market is not exactly perfect – wages are set according to average product rather than marginal product. Ho (2016b) showed that a unified growth model with a similar setting to ours could replicate British and Chinese historical demographic-economic development.

constraints related to gender equality and economic development issues. Some might face severe sex discrimination in job markets, while others might suffer from poor public infrastructure to improve economic conditions. To some degree our model acts as a benchmark framework to explain or forecast long-run socio-demographic-economic development in a country without market imperfection. Still, we believe that our work has unearthed the dynamic interactions between selected social, demographic and economic aggregates that could shed light on development policy formulation in global South countries.

Third, as we emphasize throughout the paper, many results, including female empowerment as a development decelerator, depend on our model setting that learning-by-doing is the sole engine of growth (equations (12) and (15)). In reality, we can think of channels where female empowerment can enhance economic growth. For example, empowered women might invest more in their children's health and education, have more access to credit and lending services, participate more in formal sector activities, and so forth. Once we incorporate these factors into unified growth theories, how female empowerment and economic growth interact and co-evolve will become a more complicated issue that demands further research.[54] What our paper points to is that we should think about this kind of issues from long-run and general equilibrium perspectives, and not overemphasize short run gender and economic outcomes at the cost of their long-run counterparts. We do not just demand sustainable economic growth, but also sustainable improvement in gender equality.

8 CONCLUSION

This paper demonstrates that the advent of feminism is an integral component of development. The rise of women went along with industrialization and demographic change, and their effects persist till today. We develop a two-sector bisexual unified growth model with intra-household bargaining and structural transformation to link these historical episodes together.

Our model highlights the bidirectional relationship between women and development. In one direction, female empowerment would affect fertility, sectoral shift and decelerate development. Given that women desire fewer children, the rise of women's power reduces fertility and aggregate demand for food. This draws labor hours out of agriculture, decelerating agricultural technological progress. The resulting higher relative food price evolution path would further check population growth and productivity growth in the long run. In the other direction, development that checks fertility, including wage increases and relative food price rises, would raise female labor-force participation and hence women's power.

We apply the model to replicate French socio-demographic-economic development. During AD1400-AD1780, the Iron Law of Wages was operative. Technological progress was slow and translated into population growth, trapping French per capita income at the Malthusian level. At around the time of the French Revolution, the accelerated productivity growth turned per capita

[54] For example, taking the mentioned factors into account, whether female empowerment accelerates or decelerates development will become a parameter as well as an empirical issue.

income growth positive. The resulting wage increases incentivized women to participate in the labor market and checked fertility, marking the era of Demographic Revolution and Rise of Women. France did not go through a Post-Malthusian regime: its Industrial Revolution (AD1820) occurred later than its Demographic Revolution (AD1780). Fertility control has been a key instrument for France to support its per capita income growth since the turn of the nineteenth century. After the twentieth century, innovation has replaced learning-by-doing as the key engine of French economic growth. We restored women to development history (bidirectional women-development relationship) and restored development history to women (distinctive U-shaped evolution of women's socio-economic status: labor-force participation, income and power).

We then examine the policy implications. We apply the model to Madagascar, a former French colony, to study four development policies (preferential treatment, reducing child-rearing cost, promoting agricultural innovation and promoting manufacturing innovation). Taking dynamic general equilibrium interactions among socio-, demographic-, and economic variables into account, only the policy that reduces child-rearing cost can promote gender equality and economic development in both the short and long run. Unless we can eliminate the portion of child-rearing cost that is entirely borne by women, complete gender equality is not achievable in the long run. Exogenous preferential treatment to fix gender outcomes might bring along unintentional, negative consequences on long-run development.

"Where are the women?" This is usually the first question feminists ask in their research. Similar questions could be raised in economics research. For example, what evidence would advance the claim that economic structures are gender-biased? What are the impetus and mechanisms that perpetuate or unlock these gender structures? How do family, society, state, and the world contribute to the changing gender responsibilities in production and reproduction? Constituting half of a nation's population, women and their power are important ingredients of understanding the growth of nations from a more comprehensive perspective. The wealth of nations by itself is a complicated-enough economic issue. Once we realize that it also interacts with social issues like women's security and opportunities, how we define the welfare of a nation and improve it will remain an exciting and challenging area that deserves future study. Hopefully our paper sheds light on thinking about these issues from long-run and general equilibrium perspectives, and contributes to considerations that countries, especially those in the global South, should ponder when formulating development policies today.

Appendix 1: Balance growth path in benchmark model

The balanced growth path (BGP) is defined as a steady state in the economy where the growth rates and sectoral labor hours shares are constant. Define the value of variable Z in BGP as $(Z)^* \equiv \lim_{t\to\infty} Z_t$, and the growth rate of variable Z in BGP as $(g^Z)^* \equiv \lim_{t\to\infty} \frac{Z_{t+1}-Z_t}{Z_t}$. Given $\alpha+\varepsilon\neq 1$, $\phi\neq 1$, we have

(a) $(\boldsymbol{\lambda})^* = \frac{\mathbf{1-2\varphi}}{\mathbf{2-2\varphi}}$ **,** $(\boldsymbol{FLFP})^* = \mathbf{1-2\varphi}$**,** $(\boldsymbol{n})^* = \mathbf{2}$**.**

(b) $(\boldsymbol{g^Z})^* = \mathbf{0}$**,** $= \{\boldsymbol{Y^A, Y^M, Y, y, \theta, w, p, A, M, L, pop}\}$ **.**

Proof: By the definition of BGP, $\left(g^{\theta}\right)^* = 0$. Constant population growth rate means adult population (L_t), adult work force $(L_t\left(\frac{2-\varphi n_t}{2}\right))$ and population $(L_t + L_t \cdot \frac{n_t}{2})$ grow at the same gross rate $\frac{(n)^*}{2}$ in BGP.

Rewrite (12) as $g_t^A \equiv \frac{A_{t+1}-A_t}{A_t} = \frac{\mu\left(H_t^A\right)^{\alpha}}{(A_t)^{1-\varepsilon}}$. In BGP $\left(\frac{\theta_{t+1}}{\theta_t}\right)^{\alpha}\left(\frac{L_{t+1}}{L_t}\right)^{\alpha} = \left(\frac{A_{t+1}}{A_t}\right)^{1-\varepsilon}$.

From (21), in BGP $\frac{\theta_{t+1}}{\theta_t} = \left[\left(\frac{L_{t+1}}{L_t}\right)^{1-\alpha}\left(\frac{A_{t+1}}{A_t}\right)^{-\varepsilon}\right]^{\frac{1}{\alpha}}$. Combine the above two BGP equations and use $\left(g^{\theta}\right)^* = 0$, we obtain $(g^A)^* = (g^L)^*$. Plug back to the first BGP equation, $[1 + (g^L)^*]^{\alpha} = [1 + (g^L)^*]^{1-\varepsilon}$. Given $\alpha \neq 1 - \varepsilon$, we have $(g^L)^* = 0$. Hence $(g^A)^* = 0$ too.

From (9), $n_t = 2 \cdot \frac{L_{t+1}}{L_t} = 2(1 + g_t^L)$. Hence $(n)^* = 2[1 + (g^L)^*] = 2$.

By (15), $g_t^M \equiv \frac{M_{t+1}-M_t}{M_t} = \frac{\delta(1-\theta_t)L_t\left(\frac{2-\varphi n_t}{2}\right)}{(M_t)^{1-\phi}}$. In BGP $\left(\frac{1-\theta_{t+1}}{1-\theta_t}\right)\left(\frac{L_{t+1}}{L_t}\right) = \left(\frac{M_{t+1}}{M_t}\right)^{1-\phi}$. Since $(g^L)^* = (g^{\chi})^* = 0$, given $\phi \neq 1$, we have $(g^M)^* = 0$.
From (24) $(g^A)^* = (g^M)^* = (g^L)^* = 0$ implies $(g^p)^* = 0$.

From (11) and (14), $(g^A)^* = (g^M)^* = \left(g^{\theta}\right)^* = (g^L)^* = 0$ implies $\left(g^{Y^A}\right)^* = \left(g^{Y^M}\right)^* = 0$.

With $(g^p)^* = 0$, by (17) $(g^Y)^* = 0$. With $(g^L)^* = 0$ and $(n)^* = 2$, by (18) $(g^y)^* = 0$.

Also, by (18), (17) and (22), $y_t = \frac{Y_t}{L_t + L_t\frac{n_t}{2}} = \frac{Y_t}{L_t\left(1+\frac{n_t}{2}\right)} = \frac{p_t Y_t^A + Y_t^M}{\left(1+\frac{n_t}{2}\right)L_t} = \frac{1}{1+\frac{n_t}{2}}\left(\frac{p_t Y_t^A}{H_t^A} \cdot \frac{H_t^A}{L_t} + \frac{Y_t^M}{H_t^M} \cdot \frac{H_t^M}{L_t}\right) =$

$\frac{1}{1+\frac{n_t}{2}}\left(w_t\frac{H_t^A}{L_t} + w_t\frac{H_t^M}{L_t}\right) = \frac{w_t(2-\varphi n_t)}{2+n_t}$. Since $(g^y)^* = (g^n)^* = 0$, we obtain $(g^w)^* = 0$.

From (7), $(FLFP)^* = 1 - \varphi(n)^* = 1 - 2\varphi$.

From (6), $(\lambda)^* = \frac{1-2\varphi}{2-2\varphi}$.

Appendix 2: Calibrating sectoral innovation rates

In this section, we illustrate how to calibrate the agricultural innovation rate η and the manufacturing innovation rate κ in (25) and (26).

For both AD1856 and AD1991, we divide the industry money wages index (normalized to AD1975 price) (Mitchell 2007, 195-201) by consumer price indices (Mitchell 2007, 961-965) in France to obtain the real wages. We proxy agricultural employments by economically active population in agriculture, forestry and fishing in France (Mitchell 2007, 153). With the relative food price estimates from Figure 6, we plug in the real wages, agricultural employments and

benchmark parameter values from Table 1 into (22) to obtain A_t and M_t in AD1856 and in AD1991. A_t and M_t grew by factors of 579 and 16,248 during AD1856-AD1991.

From the benchmark simulation results in section 5.1 (with learning-by-doing as the sole engine of growth), agricultural and manufacturing productivities rose by factors of 4.26 and 16.87 respectively during AD1860-AD2000. So we deflate the above two growth factors by 4.26 and 16.87; the growth factors in A_t and M_t that were not caused by learning-by-doing during AD1856-AD1991 were 136 and 963 respectively.

From these two growth factors, the annualized agricultural and manufacturing productivity growth rates not caused by learning-by-doing during AD1856-AD1991 were 3.7% and 5.2% respectively. Hence we take $\eta = (1.037)^{20} - 1$ and $\kappa = (1.052)^{20} - 1$ as exogenous productivity growth rates (innovation rates) in the two sectors, and apply them to all model periods since AD1860.

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Table 1

Benchmark parameter and initial values, France, AD1400-AD2100

	Interpretation	Value
Parameters		
φ	Wife's time cost per child	0.289
γ^1	Wife's preference for number of children	3
γ^2	Husband's preference for number of children	3.4
μ	Agricultural production function parameter	2.68
ε	Diminishing returns to agricultural learning-by-doing	0.296
α	Diminishing returns to labor hours in agricultural sector	0.85
δ	Manufacturing production function parameter	1.192
ϕ	Diminishing returns to manufacturing learning-by-doing	0.23
T	Total amount of land	1
Initial values		
L_1^1	Initial population of women	0.007
L_1^2	Initial population of men	0.007
A_1	Initial agricultural productivity level	0.01
M_1	Initial manufacturing productivity level	10

Table 2

French development patterns to be matched

- Industrial Revolution in AD1820 (criterion: annual per capita income growth rate > 0.55%)
- Demographic Revolution in AD1780 (criterion: fertility starts its long-run decline)
- Agricultural employment share was 61% in AD1760
- Relative food price was rising throughout AD1820-AD1920
- Female labor-force participation rate was 24% in AD1860

- The above are consistent with development patterns shown in Figures 1, 2, 5, 6, 7 in section 3
- Matlab generates real solution paths throughout the whole simulation time frame

Table 3

Comparison of AD1500 France and AD2000 Madagascar

	AD1500 France	AD2000 Madagascar
Per capita income (AD1990 international dollars)	727	695
Population (thousand)	15,000	15,742
AD2016 land area (sq. km)	549,970	581,540

Source: Maddison (2008), Central Intelligence Agency for land area, accessed 1 April 2016.

Table 4

Policy effects on Madagascar's development process, AD1900-AD2600

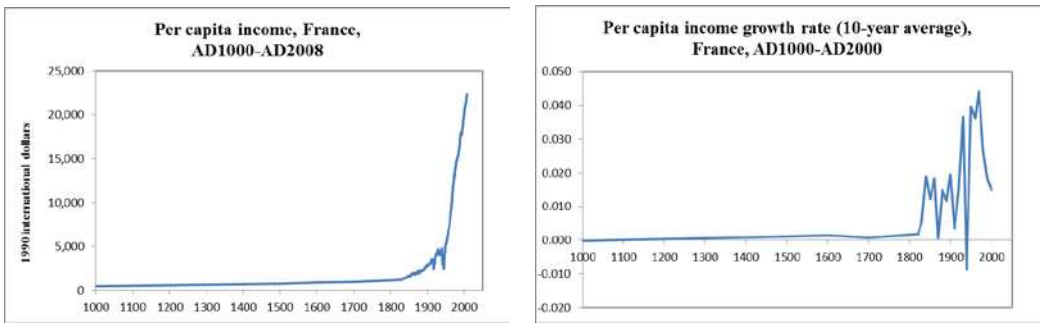
Policy since AD2000	*Modeling*	*Effects (relative to baseline case)*	
		*Accelerate/Decelerate economic development?**	*Gender equality?***
1. Preferential treatment	Exog. ↑ female bargaining power by 10%	Accelerate at first, decelerate later	Improve
2. Reducing child-rearing cost	Exog. ↓ time cost per child by 10%	Accelerate	Improve
3. Promoting agri. innovation	Permanently ↑ agricultural productivity growth rate by 10%	Decelerate at first, accelerate later	Worsen at first, improve later
4. Promoting manf. innovation	Permanently ↑ manufacturing productivity growth rate by 10%	Accelerate at first, decelerate later	Improve at first, worsen later

* Economic development is represented by per capita income evolution (y_t).

** Gender equality is represented by women's power (λ_t).

Figure 1

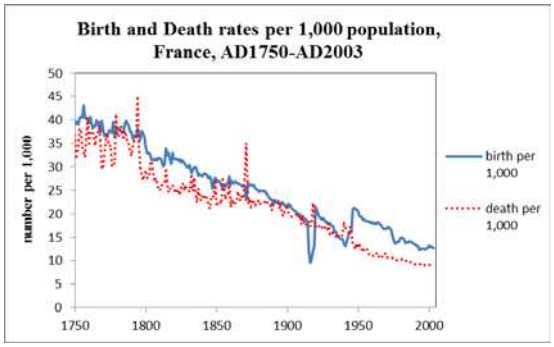
Per capita income (in AD1990 international dollars) and its 10-year average growth rate, France, AD1000-AD2008



Source: Maddison (2008).

Figure 2

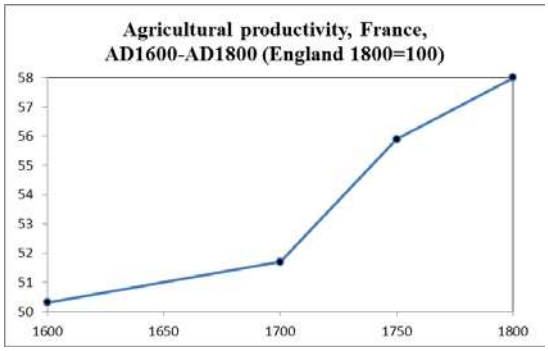
Birth and Death rates per 1,000 population, France, AD1750-AD2003



Source: Chesnais (1992) Table A1.1 and Table A3.1 for AD1750-AD1800 data. Mitchell (2007) Table A6 for AD1801-AD2003 data.

Figure 3

Agricultural productivity, France, AD1600-AD1800



Source: Dennison and Simpson (2010) Table 6.2.

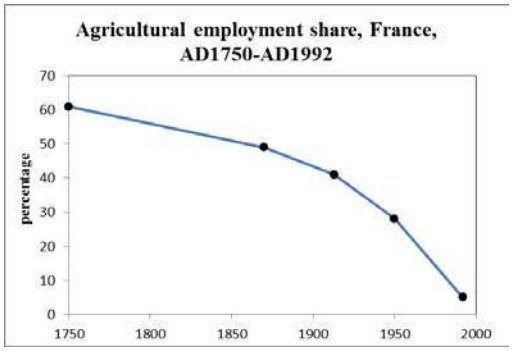
Figure 4

Real money wages in Industry, France, AD1840-AD1913

Source: Mitchell (2007) Table B4A for nominal money wages in Industry, Table H2 for consumer price index.

Figure 5

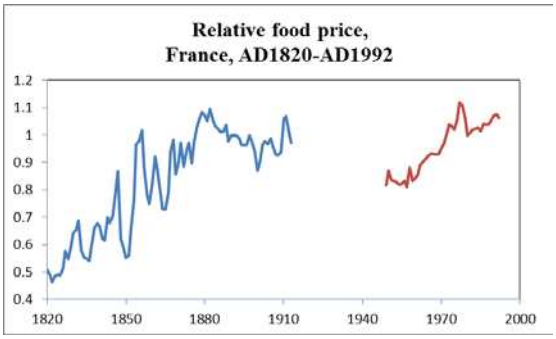
Agricultural employment share, France, AD1750-AD1992



Source: Mathias and Todorov (2005) Table 12, Allen (2000) for AD1750 data.

Figure 6

Relative food price, France, AD1820-AD1992



Source: Lévy-Leboyer and Bourguignon (1985) Tableaux A-IV for AD1820-AD1913 data. INSEE (2016), Food products price over Manufacturing products price with 1980 bases, viewed 1 April 2016, for AD1949-AD1992 data.

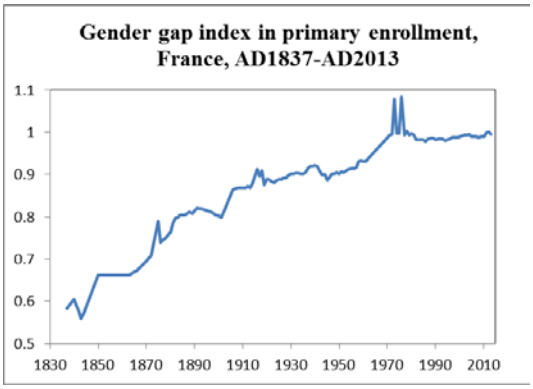
Figure 7

Female labor-force participation rate, France, AD1856-AD2012

Source: Deldycke et al. (1969, 29-30) for AD1856-AD1965 data. The Federal Reserve Bank of St. Louis (2016), Labor Force Participation Rate for Women in France (DISCONTINUED), viewed 1 April 2016, for AD1970-AD2012 data.

Figure 8

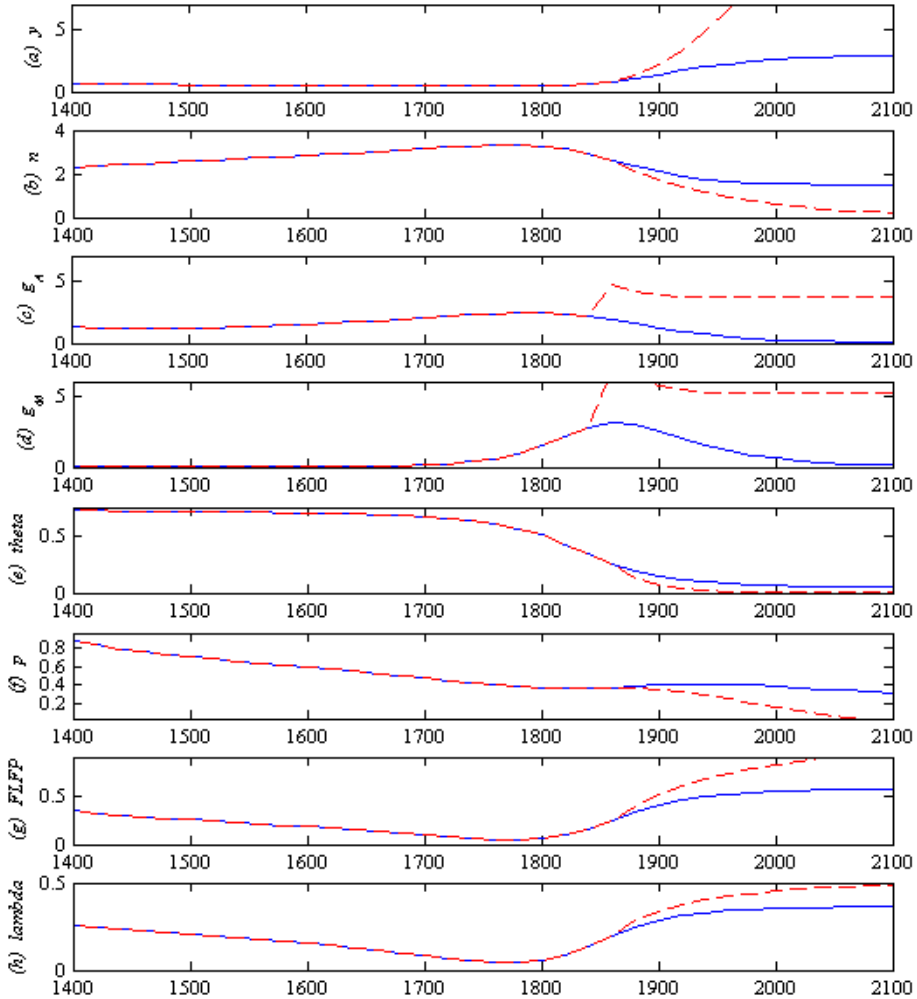
Gender gap index, France, AD1837-AD2013



Source: Diebolt and Perrin (2013a) for AD1837-AD1961 estimates. World Bank (2016), Gross enrolment ratio, primary, gender parity index (GPI), viewed 1 April 2016, for AD1971-AD2013 data.

Figure 9

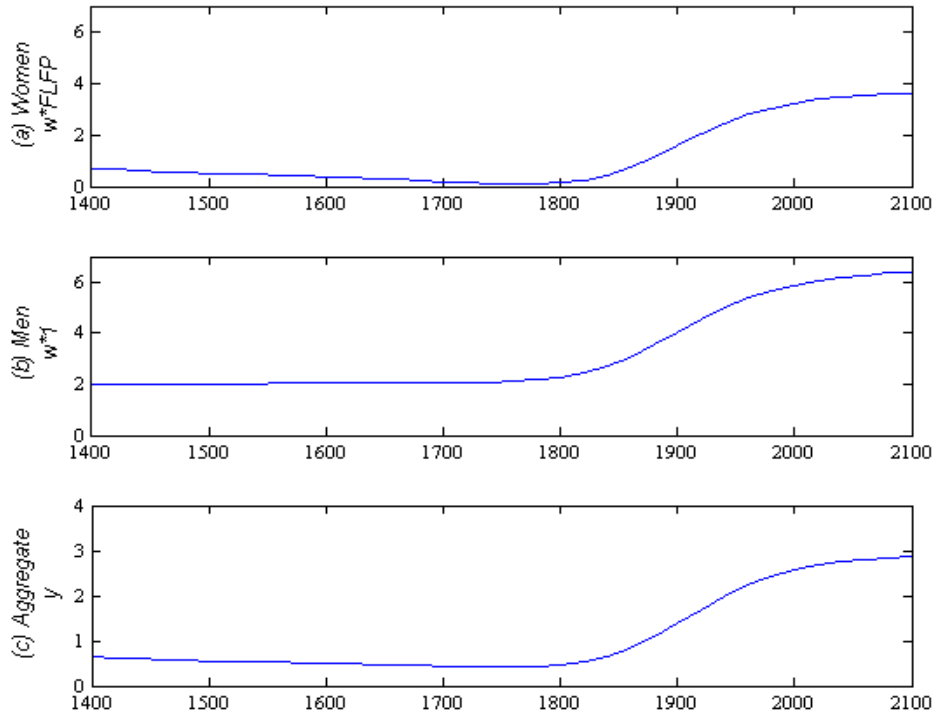
Simulated development paths, France, AD1400-AD2100



Note: Solid (blue) lines: benchmark model without innovation. Dashed (red) lines: extended model with innovation. Panels show (a) per capita income, (b) fertility, (c) agricultural productivity growth rate, (d) manufacturing productivity growth rate, (e) agricultural employment share, (f) relative food price, (g) female labor-force participation rate, and (h) women's power from AD1400 to AD2100.

Figure 10

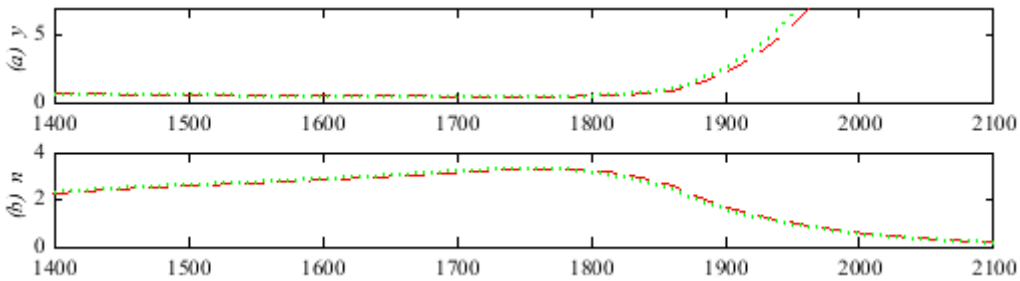
Simulated women's income versus men's income, France, AD1400-AD2100



Note: Panels show (a) women's income $w_t \cdot FLFP_t$, (b) men's income $w_t \cdot 1$, (c) per capita income y_t from AD1400 to AD2100.

Figure 11

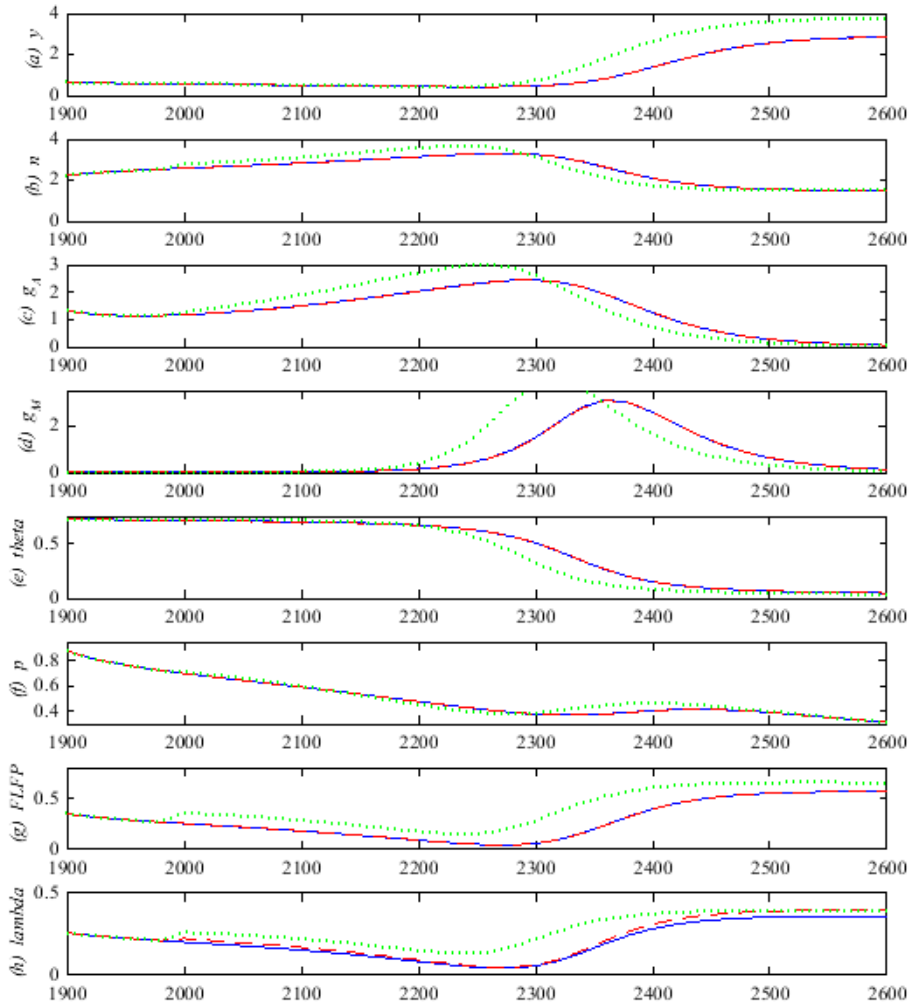
Simulated development paths, patriarchy France, AD1400-AD2100



Note: Dashed (red) lines: France with innovation, benchmark parameters from Table 1. Dotted (green) lines: patriarchy France with innovation, $\gamma^1 = 3.4$, otherwise benchmark parameters from Table 1. Panels show (a) per capita income, (b) fertility from AD1400 to AD2100.

Figure 12A

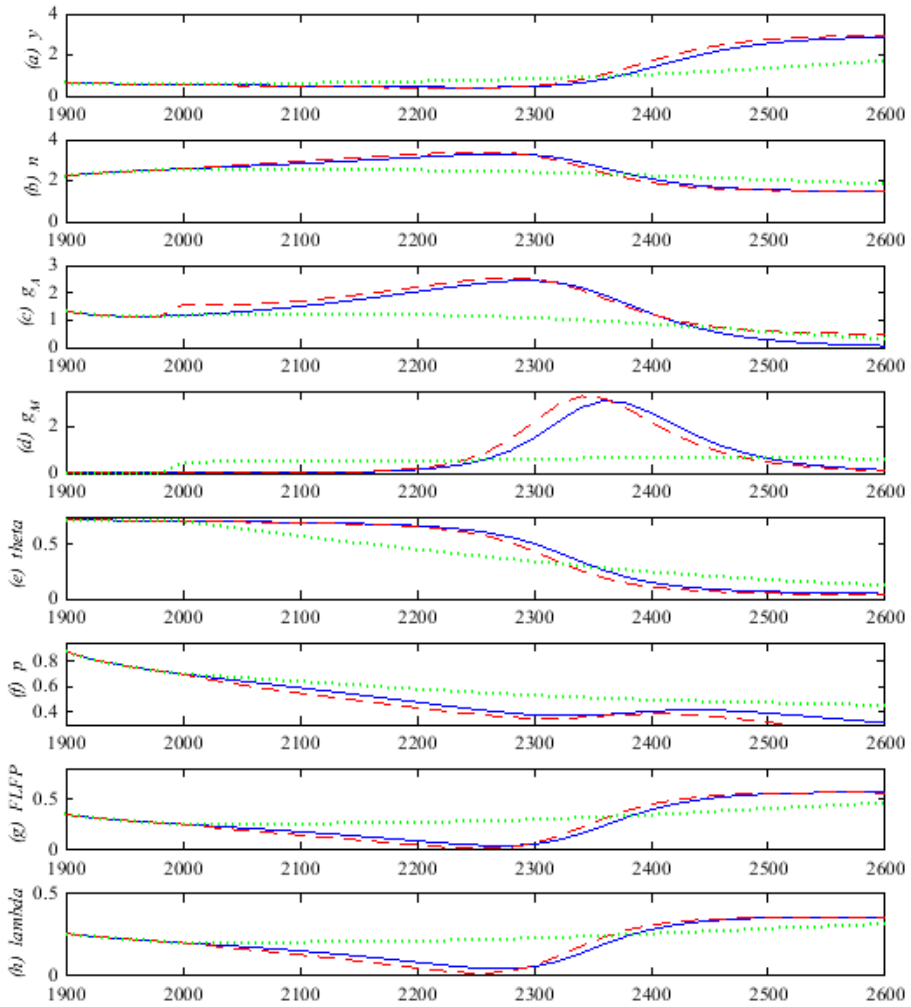
Policy effects on Madagascar development process: policies 1 and 2, AD1900-AD2600



Note: Solid (blue) lines: the baseline economy. Dashed (red) lines: Economy with policy 1 – preferential treatment. Dotted (green) lines: Economy with policy 2 – reducing child-rearing cost. Panels show (a) per capita income, (b) fertility, (c) agricultural productivity growth rate, (d) manufacturing productivity growth rate, (e) agricultural employment share, (f) relative food price, (g) female labor-force participation rate, and (h) women's power from AD1900 to AD2600.

Figure 12B

Policy effects on Madagascar development process: policies 3 and 4, AD1900-AD2600



Note: Solid (blue) lines: the baseline economy. Dashed (red) lines: Economy with policy 3 – promoting agricultural innovation. Dotted (green) lines: Economy with policy 4 – promoting manufacturing innovation. Panels show (a) per capita income, (b) fertility, (c) agricultural productivity growth rate, (d) manufacturing productivity growth rate, (e) agricultural employment share, (f) relative food price, (g) female labor-force participation rate, and (h) women's power from AD1900 to AD2600.