The Emergence of Procyclical Fertility:
The Role of Gender Differences in Employment Risk

Sena Coskun [1]
Husnu Dalgic [2]

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[1] University of Mannheim. Email: sena.coskun@uni-mannheim.de
[2] University of Mannheim. Email: dalgic@uni-mannheim.de

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Sena Coskun[†]and Husnu Dalgic[‡]

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Abstract

Fertility in the US has exhibited a procyclical pattern since the 1970s. We argue that gender differences in employment risk leads to procyclical fertility: men tend to work in volatile and procyclical industries, while women are more likely to work in relatively stable and countercyclical industries. The relative gender employment gap is countercyclical as women become breadwinners in recessions, producing an insurance effect of female income. Our quantitative framework features a general equilibrium OLG model with endogenous fertility and human capital choice and shows that the current gender industry composition in the US data fully accounts for the procyclicality observed. We can also generate countercyclical fertility, as observed in the 1960s, either when the female income share is low or procyclical. Finally, we argue that the insurance effect of female income in bad times tilts the quality-quantity trade-off towards quality.

Key words: fertility, fertility cyclicality, industry cyclicality, gender asymmetric employment, gender income gap, quality-quantity trade-off

JEL Codes: E24, E32, J11, J13, J16, J21, J24

1 Introduction

Men and women tend to work in different types of industries, with men predominantly employed in procyclical industries while women are mostly employed in countercyclical industries. In this paper, we argue that incorporating gender differences in the labor market is essential to understanding the cyclicality of fertility. In a recession, a typical man loses his job while a typical woman becomes the breadwinner. Women who are breadwinners cannot afford to take time off to have children since they are the ones who bear the time cost of children. We argue that in a world in which men become nurses and women become construction workers, we would observe "countercyclical fertility" at the expense of lower human capital accumulation.
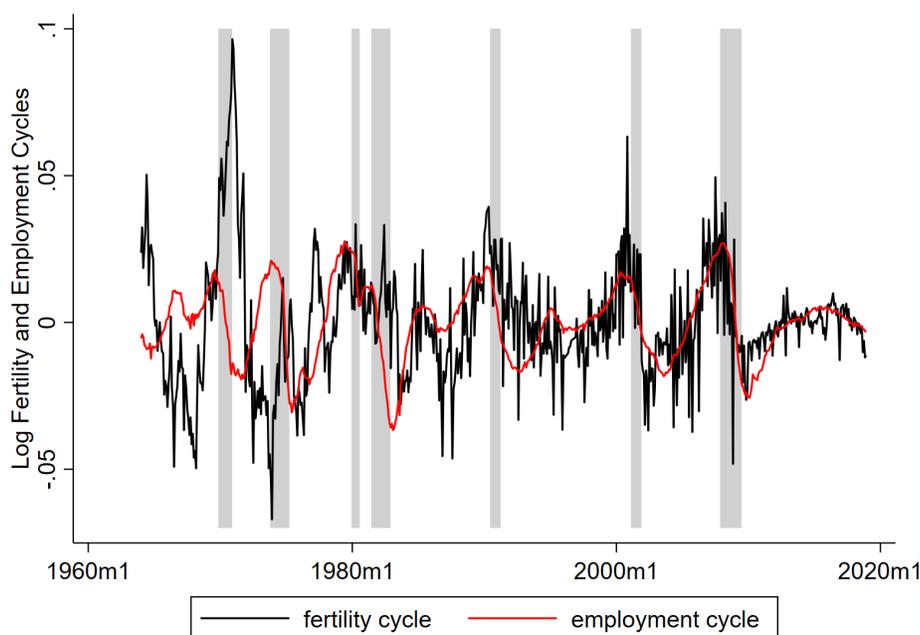

Figure 1: Fertility and Recessions

Note: Shaded areas indicate recessions. Recession dates are taken from NBER business cycles (from peak to through). The data sources are the birth records from the National Health Statistics and employment figures from the Bureau of Labor Statistics. The fertility figure used is the seasonally adjusted monthly fertility rate (number of births to women aged 15-44/population of women aged 15-44). To obtain the cyclical component, an HP filter with smoothing parameter $\lambda = 129600$ has been used. The seasonally adjusted total monthly employment series from BLS has been used with the same HP filter to obtain the cyclical component of aggregate employment.

There is no intrinsic reason for fertility to be procyclical. It is more straightforward to think about the income effect when considering the behavior of fertility around business cycles: in a recession, families observe their income falling and cannot afford more children. However, as seen in Butz and Ward [1979], fertility may also be countercyclical due to the substitution

effect brought about by a rapid increase in the female participation rate as seen in the 1960s. In a recession, the time cost of children falls and families thus have more children. In Figure 1, fertility moves countercyclically during the 1960s, as noted by Butz and Ward [1979] (the correlation between the two cycles is -0.47 for the period 1964-1974)[1]. However, we find that the fertility rate moves positively with the employment rate in all recession periods since 1975 (the correlation between the two cycles is 0.43 for the period 1975-2018). With female participation exceeding 50% after the 1980s, the importance of female income in the family increased. Therefore, in order to understand fertility dynamics, we explore male and female income patterns separately.

We document that around 70% of men work in highly procyclical industries such as construction, manufacturing, professional services and retail, while 40% of women work in countercyclical (education and health services and government) [2]. Accordingly, we show that female employment is much less volatile than male employment around business cycles (Hoynes et al. [2012], Doepke and Tertilt [2016], Alon et al. [2020]). The relative employment (income) gap between men and women is thus countercyclical around business cycles. Indeed, Albanesi and Sahin [2018] show that gender asymmetry in industries is the main driver of cyclicality in the gender unemployment gap. During economic downturns, men tend to lose their jobs at higher rates since they are employed in heavily procyclical industries, resulting in a negative impact on fertility because families cannot afford more children. On the other hand, female employment is either unaffected or affected positively due to the countercyclical properties of female-dominated industries. In turn, these better economic prospects for women reinforce the negative impact on fertility, since women who are breadwinners cannot afford to take time off and have children. Thus, the cyclicality of fertility depends on 1-) the differential impact of male and female income on fertility, 2-) different cyclicalities of male and female income which depend on 3-) gender asymmetry in industry employment and the cyclicality of individual industries. In other words, in a world where men are nurses and women are construction workers, fertility would be countercyclical.

In addition to documenting national gender-industry cyclicalities, we also provide evidence at the state level. In our state-level analysis, we show that the correlation between the relative gender employment gap and aggregate employment cycle is negative in a majority of states. Moreover, the countercyclical gender employment gap is correlated with procyclical fertility

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[1]The decline in fertility rate begins before the reported start date of the recession, which might imply that people experience job losses and update their expectations Buckles et al. [2020]

[2]We use industries where the correlation between industry-level employment and aggregate employment is above 90%. See Table 1

at the state level. In other words, in states where we observe a higher gap in female vs. male employment (stronger female breadwinner effect), fertility is more correlated with aggregate employment cycles (i.e., more procyclical) after controlling for some state characteristics.

The seminal work on the "added worker effect" by Lundberg [1985] argues that women whose husbands become unemployed in a recession are likely to enter the labor market, which temporarily increases female participation. According to Albanesi [2019], increases in female employment made the recovery much faster in previous recessions. In such recessions, she argues, jobless recoveries started once the female labor force participation rate reached a plateau. A more recent study by Guner et al. [2020] argues that the added worker effect makes female employment relatively more stable as those who lose their jobs in a recession are offset by additional women entering the labor market. Our framework is consistent with all of these findings. Whether due to the added worker effect or to industry cyclicality, we observe more stable female employment over business cycles and, as a result, the importance of female income increases during recessions as more women become the family breadwinner.

In order to explore fertility dynamics under different gender employment and cyclicality scenarios, we build a general equilibrium overlapping generations model in which families make fertility decisions and invest in their children's human capital. Our model captures several distinct features of fertility decisions by linking them in a unified framework. Key mechanisms of this framework include the quality-quantity trade-off, differential impact of male and female income, child penalties, and the interaction of these factors with business cycles. To the best of our knowledge, our effort marks the first exploration of how all these channels interact. In the model, parents care about their children's well-being (Becker and Barro [1988], Becker et al. [1990]) through investing in their human capital (De La Croix and Doepke [2003]). Our analysis treats male and female income separately and introduces "child penalties" for women. In the model, male and female income follow different income processes, which are calibrated from the data. The model features a quality-quantity trade-off à la Becker. The opportunity cost of having children is higher for women with high income due to child penalties, meaning that these women prefer having fewer children but investing more in their human capital. We introduce both short-term and long-term child penalties to be consistent with the findings of Kleven et al. [2019b,a]. Short-term child penalties reflect the fact that women must take time off when they have kids. Long-term penalties reflect related effects over longer time horizons that can result in permanent income losses for mothers, such as career breaks, depreciation of human capital and lower returns to experience etc..

The model is calibrated to match absolute levels (by age) as well as the volatility of fertility

in the US over the period 1975-2018. The observed volatility and cyclicality in male and female employment is fed into the model, and we find that male and female employment cyclicalities alone can explain procyclical fertility. The current employment structure in the US contributes to both the cyclicality as well as the absolute level of fertility. As a result of observed differences in the cyclicality of male and female employment, women's income tends to be higher than men's in bad times and lower in good times. The long-term child penalties faced by women create a dynamic trade-off in which families decrease fertility because they are afraid it will have a negative effect on women's future income, which will be valuable if there is a recession in the future. Instead, families spend more on their children's human capital, which tilts families toward quality in the quality-quantity trade-off. In other words, in the absence of long-term penalties, fertility might be procyclical or countercyclical depending on how male vs. female income changes around business cycles. However, long-term penalties affect families' choice ex-ante, as the reduction in female income leads families to respond by decreasing the level of fertility overall.

We show that if men work in countercyclical and women work in procyclical industries (men become nurses, women become construction workers), fertility is higher and countercyclical. However, the quality investment in children would be lower and more volatile. Specifically, in an economy where women work in countercyclical industries and men work in procyclical ones (the "women-nurse economy") we find that fertility is 0.17% lower than the benchmark and human capital is 0.26% higher. On the other hand, in an economy where men work in countercyclical industries and women work in procyclical ones ("men-nurse economy"), we find that fertility is 0.11% higher than the benchmark and human capital is 0.18% lower. In other words, we argue that in a world in which men are nurses and women are construction workers, we would observe countercyclical fertility at the expense of lower human capital accumulation.

Finally, we argue that we can explain the period of countercyclical fertility during the 1960s reported in Butz and Ward [1979] through the lower share of family incomes provided by women during that period. When the female income share is reduced to 29% of male income (as estimated for the period 1964-1974), the model generates countercyclical fertility. This is because when the relative income of women is lower, they no longer become breadwinners in recessions because of their lower share of family income.

Our framework is very similar to Jones and Schoonbroodt [2016], who find a pattern of procyclical fertility, though we argue that incorporating gender differences in the labor market is essential, since women are the ones who generally bear the time cost of children. When

the time cost applies to men as well and fixed costs are absent, fertility is countercyclical by nature because families have more children when it is less costly to do so, namely in a recession. Introducing fixed costs helps to explain procyclical fertility. In this sense, the framework in Jones and Schoonbroodt [2016] is consistent in explaining the first half of the 20th century. However, it remains silent in explaining the countercyclical fertility period during the 1960s as reported in Butz and Ward [1979]. The main contribution of our paper is to show that a gender perspective is essential to an explanation of the cyclical behavior of fertility in a world with quality-quantity trade-offs and time costs born mostly by women (which is empirically shown by Kleven et al. [2019b,a]). Moreover, our framework can generate both countercyclical (1960s), and procyclical periods (1970s onward) based solely on the female income share relative to male income (estimated separately for the periods of 1964-1974 and 1975-2018).

In the past century, the US fertility rate experienced large boom and bust periods (Figure 11). The Great Depression (1930s), post-war baby boom (1940s and 1950s) (Jones and Schoonbroodt [2016], Doepke et al. [2015]), women's influx into the labor market (60s), technological progress in the household sector (Greenwood et al. [2000]), and the pill revolution (1960s) (Goldin and Katz [2000]) were all major events that caused the total fertility rate to fluctuate between 2 and 3.6 children per women. Fertility reached a more stable level from 1975 onward (between 1.74 and 2.12 children per women), though fluctuations do still occur. We study the cyclical properties of fertility during this period of "stable fertility," from 1975-2018.

Several studies (Macunovich [1995, 1996], Mocan [1990];Schaller [2016];Ahn and Mira [2002];Sobotka et al. [2011];Jones and Schoonbroodt [2016]; Buckles et al. [2020]) examine the cyclicality of fertility and conclude that fertility is procyclical. We provide a novel explanation for the cyclical behavior of fertility based on gender differences in employment risk and argue that this has been a crucial mechanism in the second half of the 20th century. We borrow from the existing literature to complement our argument by using child penalties (Kleven et al. [2019b]) and the differential impact of male vs. female income shocks on fertility (Heckman and Walker [1990] ;Lindo [2010]; Amialchuk [2013];Schaller [2016]).

Despite changing time-use trends, such as a more balanced division of labor in child rearing, women continue to disproportionately bear the time cost of a child. Kleven et al. [2019b] find that women with children earn, on average, 20% less than women without children.[3] Thus,

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[3]This is the combined effect of mothers who work less, who stop working, who face discrimination, or who change occupations. Gallen [2018] argues that part of the pay gap can be explained by the fact that women have

much of the opportunity cost of having a child is comprised of women's foregone earnings. Heckman and Walker [1990] identify the effect of increased women's wages on fertility by analyzing Swedish panel data and find that higher female wages lead to delayed childbirth and, as a result, lower fertility. Women who give birth early in their careers suffer from child penalties that lead higher-earning women to postpone having children, while lower earners give birth earlier (Caucutt et al. [2002]). In order to identify the effect of male income on fertility, unexpected job displacement has been used as an exogenous shock. Both Lindo [2010] and Amialchuk [2013] find that an unexpected shock to male income (job displacement) decreases fertility. Schaller [2016] attempts to track both effects by using exogenous labor demand shocks and gender employment indices in different industries. Consistent with the literature, she finds that male wages are positively related to fertility, whilefemale wages negatively affect fertility. Dettling and Kearney [2014] also shows that house prices (which often move in parallel with business cycles) have a positive impact on fertility. Similarly, Schmitt [2011] and Özcan et al. [2010] find that male unemployment affects fertility negatively whereas female unemployment affects it positively. Following studies that examine occupation riskiness by looking at the wage and unemployment volatility (e.g., Saks and Shore [2005]), Sommer [2016] study the effect of unexpected earnings risk on fertility and finds that a higher earnings risk is associated with delayed and lower fertility. Guner et al. [2019] show that labor market frictions (uncertainty about employment, flexibility of work schedules) lowers fertility. A comprehensive study by Adda et al. [2017] endogenize all lifetime choices and argue that career choices are made alongside fertility choices, hence there is sorting in occupations according to lifetime fertility choices.

To the best of our knowledge, our study is the first to highlight a link between the cyclicality of male- and female-dominated industries and fertility dynamics, which have implications for population growth and human capital accumulation. The current structure of the labor market, with women and men sorting into different types of industries, creates an insurance mechanism that helps smooth income fluctuations, makes fertility procyclical and tilts the quality-quantity trade-off towards quality. In a world where female earnings are lower than male earnings (e.g., the 1960s) or in a world in which male and female industry allocations are reversed (e.g., men are nurses and women are construction workers), fertility would be countercyclical at the expense of lower human capital accumulation.

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lower productivity especially when they become mothers.

2 Data

The goals of our empirical study are twofold. First, we seek to explore how gender asymmetry in industry employment changes the patterns of male and female income across business cycles. Second, we aim to estimate the moments that will be used in the model. We use national-level targets in the calibration for the period of 1975-2018, and employ state-level evidence to understand how the countercyclical gender employment gap is correlated with procyclical fertility. Due to data availability, we focus on 1990-2018 for the state-level analysis.

We make use of publicly available data on fertility rates and employment numbers. The fertility data is given as births per woman aged 15-44 and is taken from National Health Statistics micro-data and merged with female population data from the Survey of Epidemiology and End Results (SEER) to calculate fertility rates for different age groups. We also obtained monthly fertility rates from the National Health Statistics database, which we digitized from monthly vital statistics reports. We take industry employment numbers at the state level as well as monthly female and male employment at the industry level from the Bureau of Labor Statistics database. Monthly data has been used to calculate the correlation between total employment changes and industry-level employment changes. Finally, basic monthly CPS is used to estimate the female share of the workforce at the state level and the gender income ratio at the national level.

3 Facts

3.1 The gender employment/income gap is countercyclical

Figure 2 shows that gender employment gap and the gender income gap (women/men) are countercyclical. In other words, female employment (income) relative to male employment (income) increases in recession times and decreases in boom times. The left panel shows the cyclical component of the difference of log monthly female vs. male employment and the cyclical component of aggregate employment from seasonally adjusted employment series between the years 1964 and 2018. The right panel shows the cyclical component of the difference in female vs. male income and annual aggregate employment. Both figures indicate that the correlation between the gender employment or income gaps and aggregate employment is highly negative.
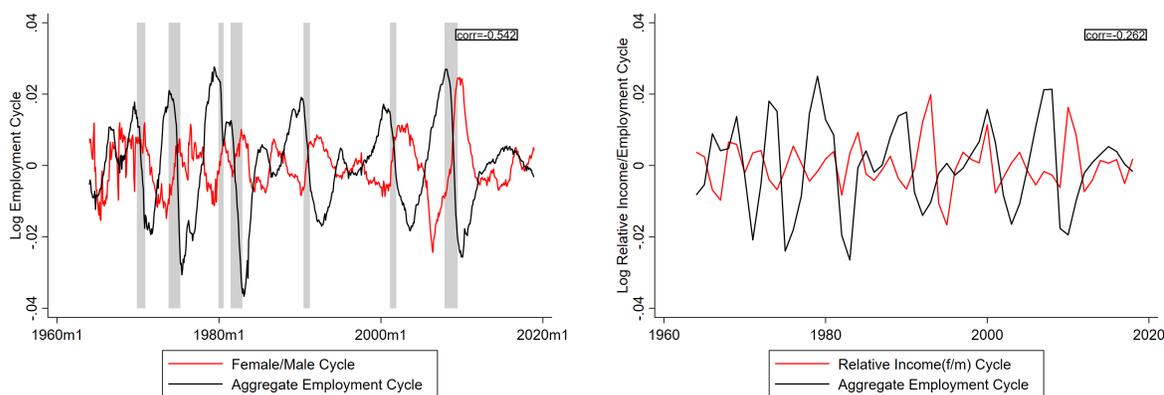
Figure 2: Countercyclical gender employment/income gap

Note: The left panel is a seasonally adjusted monthly employment series from BLS. HP filter with smoothing parameter = 129600 is applied. Shaded areas indicate NBER recessions. The right panel is IPUMS-CPS 1964-2018. Relative income is the ratio of female to male average labor income among people aged 18-65, including people who are not working. The employment cycle is from BLS annual series. HP filter with smoothing parameter = 6.25 is applied.

3.2 Industry employment by gender is asymmetric

To understand the source of the countercyclical gender employment gap, we document the cyclical properties of industries and their gender makeup. We show that different industries have different cyclical properties and gender employment compositions. We document cyclical properties in two ways: first, we document the volatility of employment by documenting the standard deviation of the cyclical component of industry employment. Second, we assess the degree of procyclicality in different industries by documenting the correlation between employment cyclicality in each industry and overall employment cyclicality. Table 1 shows that the correlation between industry-level employment changes to total employment changes ranges from -0.24 to 0.98. Industries with a countercyclical tendency are education, health services, and government, which together account for 40% of women's employment.[4] Meanwhile, the most procyclical industries are trade, transportation, utilities, professional services, construction, manufacturing, and leisure, which employ 68% of men. In addition to male-dominated industries being more pro-cyclical, their employment volatility is also very high.

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[4] Charles et al. [2018] find that college attendance decreases during boom times and increases during recessions. This finding can also be seen as a reason why education and health services are acyclical and even sometimes countercyclical.

Industry	Std. Dev	Correlation	Share within female employment	Share within male employment
Education and Health Services	0.004	-0.24	21%	6%
Government	0.006	-0.07	19%	14%
Mining, Logging	0.05	0.48	0%	1%
Other Services	0.007	0.65	4%	4%
Information	0.02	0.73	2%	2%
Financial Activities	0.011	0.75	7%	5%
Leisure	0.011	0.92	10%	9%
Manufacturing	0.022	0.95	7%	16%
Construction	0.038	0.96	1%	8%
Professional Services	0.02	0.96	12%	13%
Trade, Transportation, Utilities	0.014	0.98	16%	22%
Total	0.011	1	100%	100%

Table 1: Correlation of industry employment cycles and total employment cycles

Note: Monthly employment data (1990-2018) is taken from Bureau of Labor Statistics. The cyclical component of industry-level employment is calculated using an HP filter with smoothing parameter $\lambda = 129600$. The first column represents the standard deviation of the cyclical component and the second column represents the correlation of the cyclical component of each industry with aggregate changes in employment. The third and fourth columns represent women's and men's share of total employment in the corresponding industry.
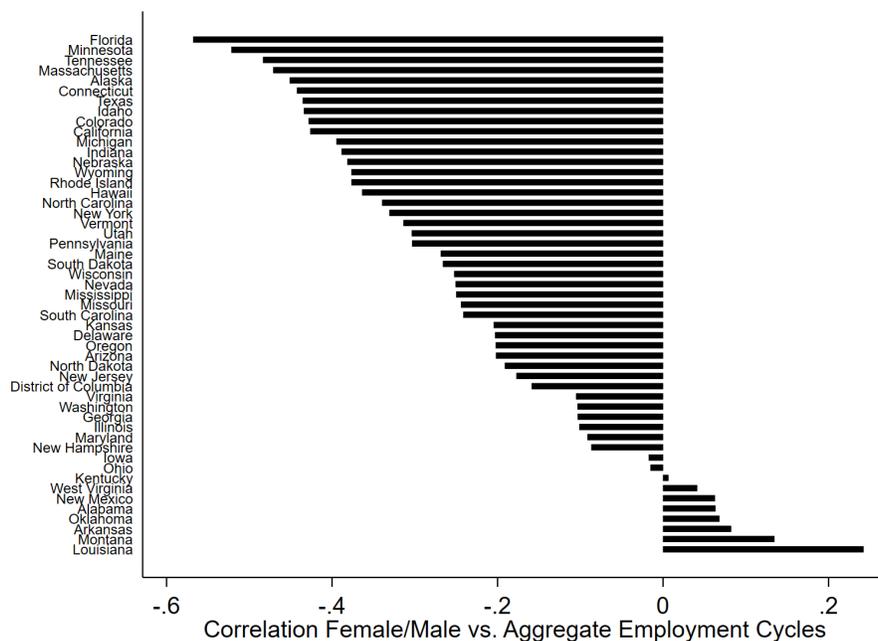
Figure 3: Correlation between female/male employment and aggregate employment cycles by state

Note: State-level employment figures for women and men are documented using Bureau of Labor Statistics state-level annual employment numbers and the estimated state-level gender makeup of the labor force from basic monthly CPS. An HP filter with smoothing parameter $\lambda = 6.25$ is used to determine the cyclical components and the state-level correlations are calculated for the years 1990-2018.

3.3 The employment cycles of men and women are negatively correlated at the state level

In Figure 3, we show that although a countercyclical gender employment gap exists in a majority of states, a great deal of heterogeneity exists in the cyclicality measure (correlation between female-male employment and aggregate employment cycle), which ranges from -0.6 to 0.2, with most larger states exhibiting higher countercyclicality.
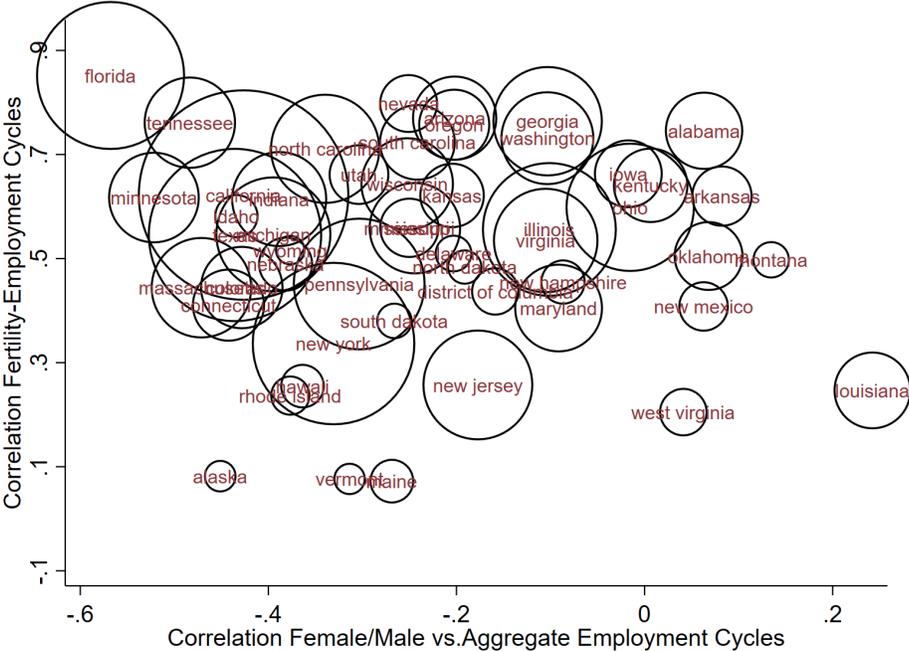

Figure 4: Fertility cyclicality and female/male employment vs. aggregate employment cycles by state

Note: State-level employment figures for women and men are documented using Bureau of Labor Statistics state-level annual employment numbers and the estimated state-level gender makeup of the labor force from basic monthly CPS. An HP filter with smoothing parameter $\lambda = 6.25$ is used to determine the cyclical components and the state-level correlations are calculated for the years 1990-2018.

3.4 A countercyclical gender employment gap is correlated with more procyclical fertility at the state level

In Figure 4, we document cyclicality in the state-level gender employment gap and fertility. Although both measures are quite heterogeneous, we can observe a negative correlation, which is especially pronounced in larger states. In order to assess this correlation, we document the results of the regression analysis in Table 2. In the first column, our baseline

regression of fertility cyclicality (comprised of a correlation between fertility and aggregate employment cycles) on gender employment cyclicality (the correlation of the gender employment gap and the aggregate employment cycle) does not show a significant coefficient as states differ in terms of income levels and female participation rates, which also have a direct impact on fertility dynamics. When we control for these, we find a significant negative coefficient. Thus, we observe more procyclical fertility trends in states with a more countercyclical gender employment gap.

Table 2: State Regression

	(1) Cyclicality of Fertility	(2) Cyclicality of Fertility	(3) Cyclicality of Fertility
Cyclicality of Gender Emp Gap	-0.156	-0.171	-0.172*
	(0.121)	(0.105)	(0.102)
Average Income		-0.980***	-1.226***
		(0.234)	(0.265)
Female Participation			1.204*
			(0.656)
Constant	0.522***	11.035***	12.978***
	(0.040)	(2.510)	(2.668)
N	51	51	51
R2	0.033	0.292	0.339

Standard errors in parentheses

* $p<0.1$, ** $p<0.05$, *** $p<0.01$

4 Model

Our model captures several distinct features of fertility decisions by linking them in a unified framework. The quality-quantity trade-off, differential impact of male and female income, and child penalties, as well as their interactions with business cycles are the key mechanisms in our framework. To the best of our knowledge, we are the first to explore the interaction of all these channels.

We build an overlapping generations model in which families make fertility choices and invest in their children's human capital, motivated by a quality-quantity trade off (De La Croix and Doepke [2003]) . Investment in human capital leads to higher productivity once the children enter the labor market. In the model, women are the main caregivers of children. They therefore face short- and long-term child penalties. People in the model live for 5

periods (child, young, middle, old and retired). Children live and consume with their parents. Young and middle households make fertility and quality decisions as well as choices relating to consumption and saving. Old households continue working but cannot have children. When retired, households consume the returns to their accumulated assets. Consumption goods in the model are produced using inputs from male- and female-dominated industries. In each industry, productivity follows an exogenous process that we estimate from the data. We run several counterfactual experiments to see how different gender income risk scenarios affect fertility and human capital.

4.1 Household Problem

Households (HHs) of young and middle generations are able to make decisions about fertility, labor supply, and consumption. Old households do not make fertility decisions, but they still supply labor, earn wages, and save for the retirement. Each member of the household is endowed with 1 unit of labor. Since households do not enjoy leisure, male members supply 1 unit of labor. However, as female members are the caregivers of children in the model, they supply child penalty adjusted labor (due to the time cost of children).

Young HHs

Young families make consumption, saving and fertility-quality decisions. Male members supply 1 unit of labor ($l_t^{m,y} = 1$), whereas female members need to spend time caring for children ($l_t^{f,y} = (1 - \tau n_t^y)$).

$$V_t^y = \max_{c_t^y, a_t^y, n_t^y, e_t^y, q_t^y} U^y(c_t^y, q_t^y, n_t^y) + \beta \mathbb{E} V_{t+1}^m(a_t^y, q_t^y, n_t^y)$$

$$s.t. \ c_t^y + a_t^y + \bar{w} e_t^y n_t^y = w_t^{m,y} + w_t^{f,y}(1 - \tau n_t^y)$$

where c_t^y is the joint consumption of the family, a_t^y is the assets they accumulate, n_t^y number of children they have and q_t^y is the human capital of their children. Similar to De La Croix and Doepke [2003], human capital is formed by investing $e_t^y \bar{w}$ per child, where $\bar{w}$ is the relative price of human capital investment,

$$q_t^y = (\theta + e_t^y)^\eta$$

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Males and females earn w_t^m and w_t^f respectively. Men spend one unit of labor, whereas women need to spend time raising their children (τn_t^y).

Middle HHs

Similar to young families, middle families make fertility-quality decisions. They have access to the returns on their assets accumulated when they were young. Male members supply 1 unit of labor ($l_t^{m,m} = 1$), whereas female members need to spend time caring for children ($l_t^{f,m} = (1 - \tau n_t^m)f(n_{t-1}^y, 0)$). In addition to the time cost, women who gave birth when they were young are subject to long-term child penalties (motivated by Kleven et al. [2019b]) through the function $f(n^y, n^m)$, where n^m is the number of children that a middle-age household has.

$$V_t^m(a_{t-1}^y, q_{t-1}^y, n_{t-1}^y) = \max_{c_t^m, a_t^m, n_t^m, e_t^m, q_t^m} U^m(c_t^m, q_{t-1}^y, n_{t-1}^y, q_t^m, n_t^m)$$
$$+ \beta \mathbb{E} V_{t+1}^o(a_t^m, q_{t-1}^y, n_{t-1}^y, q_t^m, n_t^m)$$
$$s.t. \ c_t^m + a_t^m + \bar{w} e_t^m n_t^m = w_t^{m,m} + w_t^{f,m} f(n_{t-1}^y, 0)(1 - \tau n_t^m) + a_{t-1}^y R_t$$

Old HHs

Old people continue working and only make consumption-saving decisions, though they do continue to derive utility from their children. Similarly, male members supply 1 unit of labor ($l_t^{m,o} = 1$), whereas female members still incur long-term child penalties ($l_t^{f,m} = f(n_{t-2}^y, n_{t-1}^m)$).

$$V_t^o(a_{t-1}^m, q_{t-2}^y, n_{t-2}^y, q_{t-1}^m, n_{t-1}^m) = \max_{c_t^o, a_t^o} U^o(c_t^o, q_{t-2}^y, n_{t-2}^y, q_{t-1}^m, n_{t-1}^m)$$
$$+ \beta \mathbb{E} V_{t+1}^r(a_t^o, q_{t-2}^y, n_{t-2}^y, q_{t-1}^m, n_{t-1}^m)$$
$$s.t. \ c_t^o + a_t^o = w_t^{m,o} + w_t^{f,o} f(n_{t-2}^y, n_{t-1}^m) + a_{t-1}^m R_t$$

Retired HHs

Retired people consume the returns of their accumulated assets.

$$V_t^r = \max_{c_t^r} U^r(c_t^r)$$

$$c_t^r = a_{t-1}^o R_t$$

4.2 Firm Problem

Consumption goods are produced using capital and labor,

$$Y_t = K_t^\alpha L_t^{1-\alpha}$$

Labor is composed of male and female labor

$$L_t = \left(z_t^m \left(L_t^m \right)^{1-\sigma} + z_t^f \left(L_t^f \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

where z_t^m and z_t^f are the productivity of male- and female-dominated industries, respectively. For simplicity, we assume complete segregation of genders; all men work in m industry and all women work in f industry.[5]

4.3 Demographics

Population Growth

We define the number of families in each generation i by N_t^i where $i \in \{y, m, o, r\}$. Young families at time t are born to young and middle parents at time $t-1$.

$$N_t^y = \frac{N_t^m}{2} n_{t-1}^y + \frac{N_t^o}{2} n_{t-1}^m$$

Each generation has an equal number of men and women so that $N_t^m n_{t-1}^y$ children are born to $\frac{N_t^m}{2} n_{t-1}^y$ families . Population growth across generations is defined as

$$(1 + n_t) = \frac{N_t^y}{N_t^m}$$

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[5]In our quantitative analysis, we are going to explore differnt levels of segregation when calibrating parameters.

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Fertility Rate

Define fertility rate as the total number of children born to young and middle-aged families divided by the total number of families.

$$\text{Fertility Rate}_t = \frac{n_t^y N_t^y + n_t^m N_t^m}{N_t^y + N_t^m}$$

If both the numerator and denominator are divided by N_t^m, by using the definition of population growth $(1+n_t) = \frac{N_t^y}{N_t^m}$, we get

$$\text{Fertility Rate}_t = \frac{n_t^y(1+n_t) + n_t^m}{2+n_t}$$

4.4   Equilibrium Conditions

Total Consumption

Total consumption is the sum of consumption by all generations:

$$C_t^y + C_t^m + C_t^o + C_t^r = C_t$$

Per-family consumption is therefore

$$N_t^y c_t^y + N_t^m c_t^m + N_t^o c_t^o + N_t^r c_t^r = C_t$$

Scaling by the number of retired families N_t^r, per-family consumption is c_t: $c_t = \frac{C_t}{N_t^r}$.

$$c_t^y(1+n_t)(1+n_{t-1})(1+n_{t-2}) + c_t^m(1+n_{t-1})(1+n_{t-2}) + c_t^o(1+n_{t-2}) + c_t^r = c_t$$

Capital accumulation

Total capital in the economy is the sum of accumulated assets.

$$A_{t-1}^y + A_{t-1}^m + A_{t-1}^o = K_t$$

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Similarly, per-family capital is:

$$a^y_{t-1}(1+n_t)(1+n_{t-1})(1+n_{t-2}) + a^m_{t-1}(1+n_{t-1})(1+n_{t-2}) + a^o_{t-1}(1+n_{t-2}) = k_t$$

Labor force

We assume that the effective labor force is determined by the human capital expenditure made for that generation.

$$q_t L^{m,y}_t + q_{t-1} L^{m,m}_t + q_{t-2} L^{m,o}_t = L^m_t$$

$$q_t L^{f,y}_t + q_{t-1} L^{f,m}_t + q_{t-2} L^{f,o}_t = L^f_t$$

where q_t is the human capital of the generation. We define generational human capital [6],

$$q_t = \frac{q^y_{t-1} n^y_{t-1}/2}{(1+n_t)} + \frac{q^m_{t-1} n^m_{t-1}/2}{(1+n_t)(1+n_{t-1})}$$

Similarly, we scale the labor force by the number of retired families.

$$q_t l^{m,y}_t(1+n_t)(1+n_{t-1})(1+n_{t-2}) + q_{t-1} l^{m,m}_t(1+n_{t-1})(1+n_{t-2}) + q_{t-2} l^{m,o}_t(1+n_{t-2}) = l^m_t$$

$$q_t l^{f,y}_t(1+n_t)(1+n_{t-1})(1+n_{t-2}) + q_{t-1} l^{f,m}_t(1+n_{t-1})(1+n_{t-2}) + q_{t-2} l^{f,o}_t(1+n_{t-2}) = l^f_t$$

Factor prices

Competitive firms set marginal returns to respective factor prices.

$$r_t = \alpha K^{\alpha-1}_t L^{1-\alpha}_t$$

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[6]See Appendix for the details.

Return on capital is defined as

$$R_t = 1 + r_t - \delta$$

where δ is the capital depreciation rate.

w_t^m and w_t^f are the wages per effective unit of labor earned by male and female workers.

$$w_t^m = z_t^m (1 - \alpha) K_t^\alpha L_t^{\sigma - \alpha} (L_t^m)^{-\sigma}$$

$$w_t^f = z_t^f (1 - \alpha) K_t^\alpha L_t^{\sigma - \alpha} (L_t^f)^{-\sigma}$$

However, each agent earns a wage rate that depends on the quality investment that has been made for their generation.

$w_t^{m,y} = w_t^m q_t$, $w_t^{m,m} = w_t^m q_{t-1}$, $w_t^{m,o} = w_t^m q_{t-2}$
$w_t^{f,y} = w_t^f q_t$, $w_t^{f,m} = w_t^f q_{t-1}$, $w_t^{f,o} = w_t^f q_{t-2}$

5   Calibration

We calibrate parameters to match the US fertility rate for young (15-30) and middle-aged (30-45) women as well as the volatility of fertility estimated from the data between 1975 and 2018. We estimate the productivity of male- and female-dominated industries from the data using industry employment as a proxy. We then feed these productivities into the model to see how well it is able to generate procyclical fertility.

Utility function

Young families derive utility from consumption and the children born to them:

$$U^y(c_t^y, q_t^y, n_t^y) = \frac{(c_t^y)^{1-\gamma}}{1-\gamma} + \xi \frac{(n_t^y q_t^y + \lambda)^{1-\sigma_n}}{1-\sigma_n}$$

where λ is the childlessness utility. For middle-aged and old families, the utility function takes the form

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$$U^m(c_t^m, q_{t-1}^y, n_{t-1}^y, q_t^m, n_t^m) = \frac{(c_t^m)^{1-\gamma}}{1-\gamma} + \xi \frac{(n_{t-1}^y q_{t-1}^y + n_t^m q_t^m)^{1-\sigma_n}}{1-\sigma_n}$$

$$U^o(c_t^o, q_{t-2}^y, n_{t-2}^y, q_{t-1}^m, n_{t-1}^m) = \frac{(c_t^o)^{1-\gamma}}{1-\gamma} + \xi \frac{(n_{t-2}^y q_{t-2}^y + n_{t-1}^m q_{t-1}^m)^{1-\sigma_n}}{1-\sigma_n}$$

And, for retired families,

$$U^r(c_t^r) = \frac{(c_t^r)^{1-\gamma}}{1-\gamma}$$

Parameters

The model is calibrated such that one period is 15 years. The discount rate is set as $\beta = 0.74$, which corresponds to a yearly steady-state interest rate of 2%. We assume standard parameters for capital share ($\alpha = 0.35$), risk aversion ($\gamma = 2$) and depreciation rate (annual depreciation rate of 10%). For the parameters of quality function, we use De La Croix and Doepke [2003]. We estimate the utility weight of children and the utility of childlessness (ξ, λ) from the data to match observed fertility rates in the US. Similarly, we estimate the elasticity of the utility of children to match the standard deviation of the total fertility rate. We set a linear child penalty function

$$f(n^y, n^m) = (1 - \tau_2 n^y - \tau_2 n^m)$$

We set $\tau_1 = \tau_2 = 0.15$ to be consistent with Kleven et al. [2019b]. Kleven et al. [2019b] show that the child penalty increases linearly with the number of children. In the long run, Danish mothers suffer earning losses of about 10% per child. Kleven et al. [2019a] demonstrate that US mothers, regardless of the number of children they have, suffer from an earning loss of around 30%. We extrapolate a linear child penalty feature along with an average fertility rate of 2 children per women for the US and assign $\tau_1 = \tau_2 = 0.15$ in our calibration.

We set $\bar{w}$ (relative price of human capital investment) equal to the average wage rate in the steady state $((w_m + w_f)q/2)$. We assume that industry productivities (z_t^m, z_t^f) follow 15-year AR(1) processes. Errors terms are jointly normally distributed.

$$\log(z_t^m) = \rho_m \log(z_{t-1}^m) + \varepsilon_t^m$$
$$\log(z_t^f) = \rho_f \log(z_{t-1}^f) + \varepsilon_t^f$$

$$\begin{bmatrix} \varepsilon_t^m \\ \varepsilon_t^f \end{bmatrix} \sim \mathcal{N} \left(\begin{bmatrix} \varepsilon_t^m \\ \varepsilon_t^f \end{bmatrix}, \begin{bmatrix} \sigma_m^2 & 0 \\ 0 & \sigma_f^2 \end{bmatrix} \right)$$

We use the cyclical components of male and female employment as proxies for productivities. We then estimate ρ_m, ρ_f, σ_m, σ_f from the annual data. By following the approach of Jones and Schoonbroodt [2016], we estimate 15-year frequency adjusted parameters for use in the model[7].

6 Results

We calibrate the model to match the level and volatility of the fertility rate observed in the data for the period of 1975-2018[8]. We then assess how well the model captures the procyclicality of fertility.

- We generate procyclical fertility: in our sample, the annual correlation between fertility and employment cycles between the years 1975 and 2018 is found to be 0.48. Our model predicts a correlation of 0.5 in our simulations. In Figure 5, we plot the employment-fertility cycles from the annual US data and an example simulation from the model.

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[7]See Appendix for the details.
[8]We use a third-order polynomial approximation around the deterministic steady state.
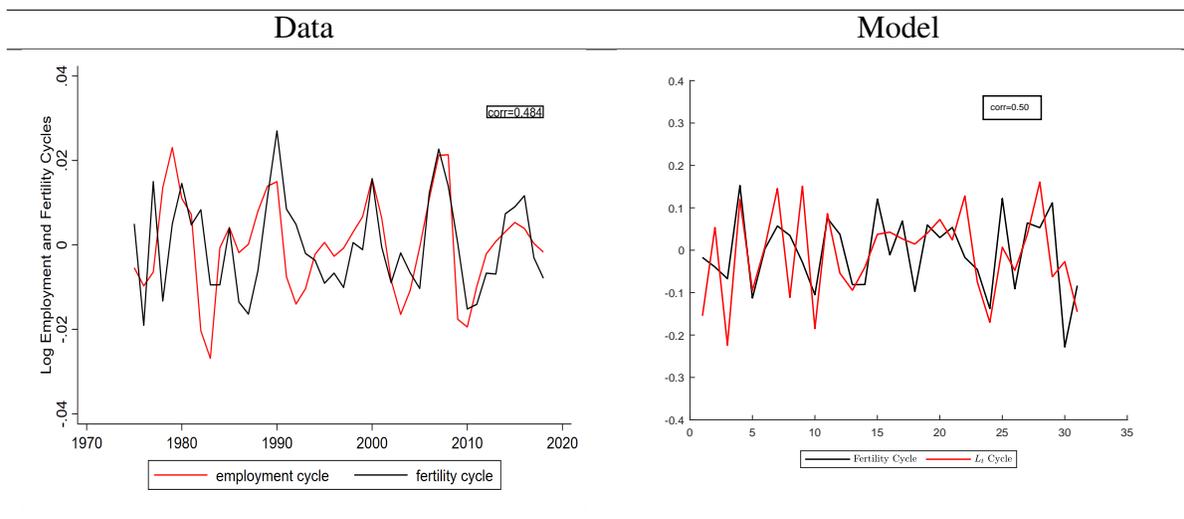
Figure 5: Procyclical fertility

Note: Data source is BLS for employment cycles, NHS for fertility cycles.

- We generate a countercyclical gender income gap. In the left panel of Figure 6, we plot employment vs. relative income cycles where the observations are all the years between 1975 and 2018. We observe a negative correlation between relative income cycles and employment cycles, which indicates that when the economy is in a downturn (i.e., lower overall employment), relative income is higher (i.e., relatively higher female income). A typical result of our model simulation is shown in the right panel of Figure 6; downturns are associated with a higher female income share.

- We can also generate the period of countercyclical fertility. A natural question is whether we can also explain the period of countercyclical fertility (60s-70s) as indicated in Butz and Ward [1979]. Our data focus on the period 1975-2018 because female participation is more stable and established in this period, while female income represents a significant share of family income. As estimated from the data, female income is 53% of male income in the 1975-2018 period (including extensive margin), while during the Butz and Ward [1979] period of 1964-1974, it is estimated as being 29%. By exogenously decreasing female income in our benchmark model, we can generate countercyclical fertility. Since female income is lower in the 1960s, it does not create a large income effect on fertility, but the substitution effect becomes stronger. Hence, fertility moves countercyclically.
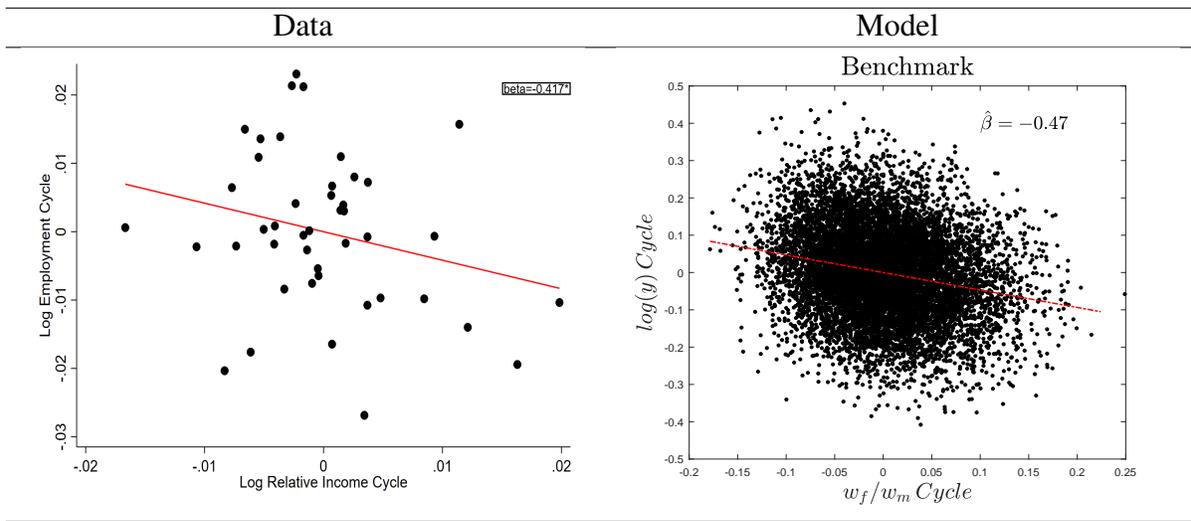
Figure 6: Cyclicality and gender income gap in the US

Note: IPUMS-CPS 1975-2018. Relative income represents, average labor income of female to male in the sample of 18-65, by including people who are not working as well.
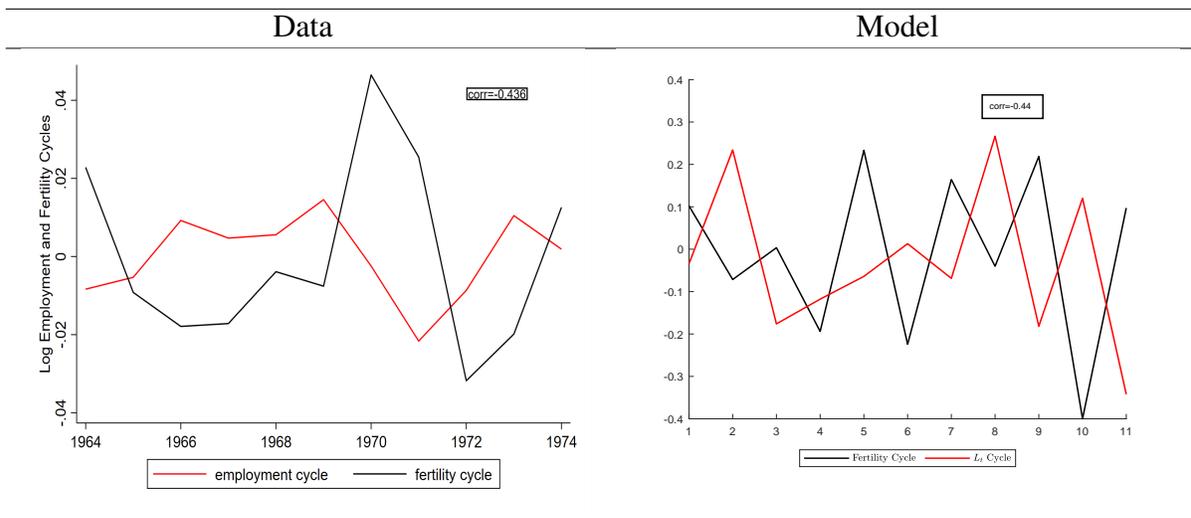

Figure 7: Countercyclical fertility

Note: Data source is BLS for employment cycles, NHS for fertility cycles.

- Cyclicality of the gender income gap is associated with the cyclicality of fertility. In order to see the effect of cyclicality of the gender income gap on fertility and human capital decisions, we consider three counterfactual economies as well as the benchmark economy. The differences in these economies stem from the volatility of male- and female-dominated industries. In our benchmark economy, the standard deviation of these industries are calibrated to match the standard deviations of male and female employment. In complete segregation (i.e., only women work in female-dominated industries and vice versa) and the current gender bias, or the "women-nurse economy", the standard deviations are estimated to match those of male- and female-dominated industries; i.e., education, health and government for women and construction and manufacturing for men. In the "women-nurse economy", male employment becomes much more volatile than female employment. The "men-nurse economy", which features complete segregation with the opposite gender bias, we assign the same calibrated parameters as in the "women-nurse economy" to the opposite gender. Thus, the "women-nurse economy" is a subset and extreme version of the current labor market, while the "men-nurse economy" is a counterfactual economy. Finally, we generate a "no gender asymmetry" economy by calibrating standard deviations to match that of overall employment. We find more procyclical fertility in the "women-nurse economy" and countercyclical fertility in the "men-nurse economy". In Table 3, we document steady states of these economies. Making gender asymmetry more extreme, i.e., moving from the benchmark to "women-nurse economy" makes fertility lower and more procyclical. The investment in human capital increases in the steady state. When male income is more volatile, women's income relative to men's becomes countercyclical (i.e., women are the breadwinners in a recession). This makes women's income more precious and, through the substitution effect, families have fewer children but invest more in their human capital. Conversely, fertility is countercyclical and higher in the "men-nurse economy" but at the expense of lower human capital in the steady state. Here, women's income relative to men's is procyclical, which makes women's income less valuable; as a result, women prefer having more children instead of investing in their children's human capital.

	$\rho(L,n)$ (Cyclicality)	$\sigma(fertility)$ (Volatility)	$\sigma(q)$	%ΔFertility from benchmark	%ΔQuality from benchmark
Benchmark					
$\sigma_m = 0.08$, $\sigma_f = 0.05$	0.5	0.08	0.03	-	-
Women-nurse					
$\sigma_m = 0.15$, $\sigma_f = 0.02$	0.57	0.14	0.05	-0.17%	0.26%
Men-nurse					
$\sigma_m = 0.02$, $\sigma_f = 0.15$	-0.1	0.08	0.06	0.11%	-0.18%
No gender asymmetry					
$\sigma_f = \sigma_m = 0.06$	0.42	0.07	0.03	0.03%	-0.04%

Table 3: Counterfactuals

Note: Standard deviations in complete segregation cases reflect those of the industries with the most extreme gender bias, i.e. construction and manufacturing for men and education and health services for women. We estimate the standard deviation of employment cycles of these industries in the same way we estimate male and female employment with AR processes.

- The counterfactual scenarios are associated with a greater countercyclical gender income gap in the "women-nurse" scenario and a greater procyclical income gap in the "men-nurse" scenario. In Figure 8, we simulate the model and plot income vs. relative wage for three different economies: benchmark, women-nurse, and men-nurse. When male industries are more volatile (as is the case in the benchmark and women nurses economies), the relative wage goes up in a recession; i.e., when output is low. In these economies, women become the family breadwinner in a recession. From the perspective of risk-averse agents, women are seen to earn more on average since women earn more in relative terms when marginal utility is high, making their income more precious. In the quality-quantity trade-off, the economy is pushed towards quality because the relative weight of women's income is higher as women bear the time cost of children. In the counterfactual "men-nurse economy", we observe high relative wages when the output is high. Women's income is therefore less precious, because it is high when the marginal utility of income is low. Hence, families in this economy are pushed towards quantity because the relative weight of women's income is low.
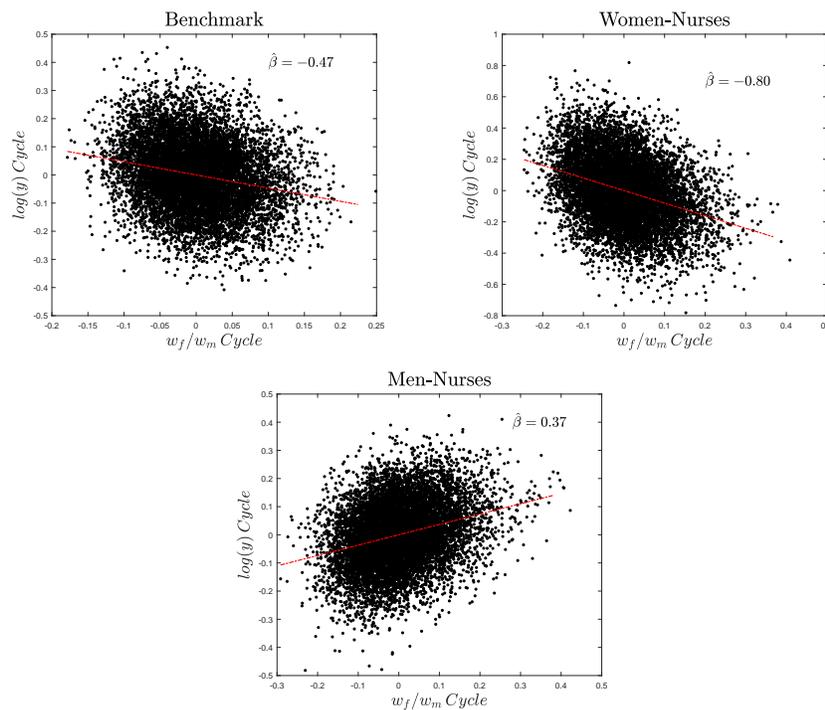

Figure 8: Cyclicality and gender income gap in the model

- We find that in the "women-nurse economy", fertility is less responsive to a recession shock, while quality is more responsive. Figure 9 shows fertility and human capital

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investment in response to a "recession shock." We assume a recession shock is a 1-std shock to both industries. In the "women-nurse economy", families have a better income insurance mechanism as women's income is more stable. However, due to the fact that the male income and the female substitution effects kick in at the same time, fertility becomes more volatile. On the other hand, stable female income during a recession period makes it possible to sustain high and smooth human capital. In the "men-nurse economy", female income falls substantially in a recession, hence a preference emerges for taking time off to have more children due to substitution effect that makes fertility countercyclical. It is not, however, possible to maintain high quality given that they have more children combined with a low income.
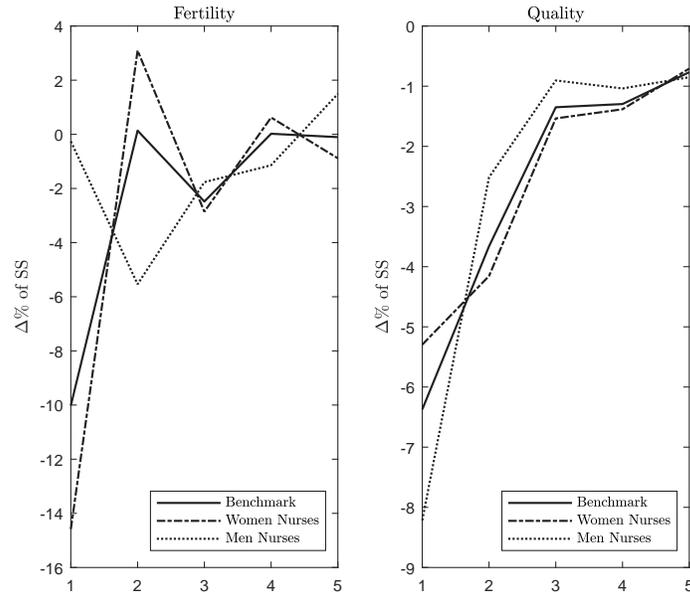

Figure 9: Impulse response to recession shock

7   Mechanism

Many studies confirm that women's role as the main caregiver leads them to take time off from the labor market and incur child penalties when they give birth. In our model, women incur short-term and long-term child penalties, which lead them to experience lower earnings when they have children. As a result, women's wages have a substitution effect, with

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higher female wages making children more costly to the family. In families in which the female wage is higher, couples have fewer children but they invest more in the children's human capital (quality-quantity trade-off) (Jones et al. [2010], Becker [1960], De La Croix and Doepke [2003]).

To show this channel in our model, we exogenously change the average productivity of z^f and z^m. We keep the average productivity constant while moving the ratio z^f/z^m when we simulate the model. In Figure 10, we plot average fertility and the quality and cyclicality of fertility with respect to the average relative wage (w_f/w_m) for every value of z^f/z^m. In addition to negative fertility-income and a positive quality-income relationship, we also highlight the procyclicality of fertility. When female wages are higher, the importance of female income in the family income becomes higher, resulting in fertility becoming even more related to business cycles and hence exhibiting a higher correlation with aggregate employment changes.
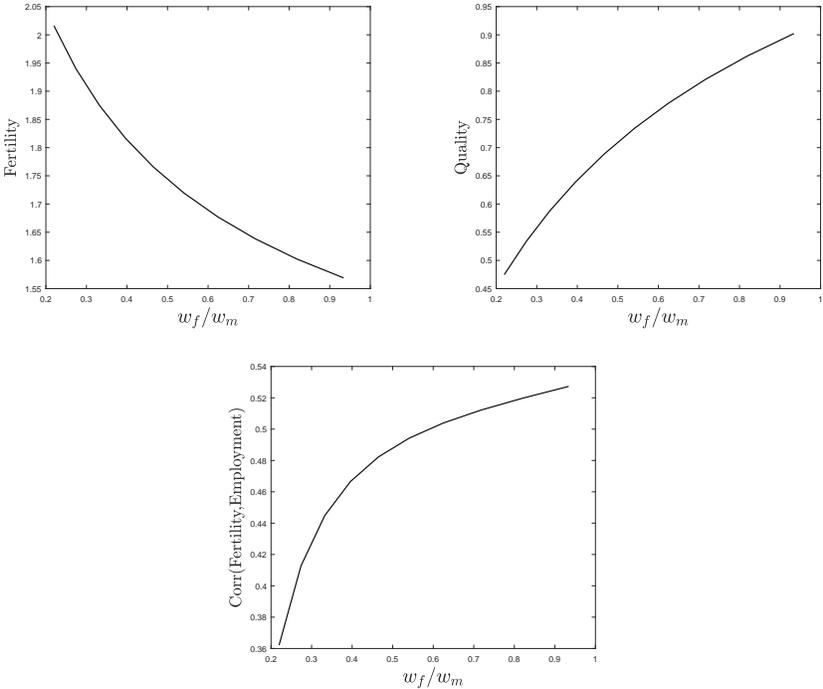

Figure 10: Quality-Quantity Trade-off and Procyclicality

Why does cyclicality matter for the quality-quantity trade-off?

To see this mechanism in our model, consider the fertility decision of a middle-aged household.

$$\overbrace{U_2^m(q_{t-1}^y, n_{t-1}^y, q_t^m, n_t^m) + \beta \mathbb{E}_t U_2^o(q_{t-1}^y, n_{t-1}^y, q_t^m, n_t^m)}^{\text{Marginal benefit of having children}} = \overbrace{U_1^m(c_t^m)\left(\bar{w}e_t^m + w_t^f \tau_1\right)}^{\text{Marginal current cost}}$$

$$+ \overbrace{\beta \mathbb{E}_t \left(U_1^o(c_{t+1}^o)w_{t+1}^f \tau_2\right)}^{\text{Marginal future cost}} \qquad (1)$$

where U_2 denotes the marginal utility of the household with respect to children while U_1 is the marginal utility of consumption. The left side of equation 1 is the current and expected future marginal utility of having a child. Similarly, the right-hand side is the current and expected future marginal cost of having a child. Marginal current cost is composed of marginal expenditure on a child's human capital ($\bar{w}e_t^m$) and the foregone earnings of the mother ($\tau_1 w_t^f$). The marginal current cost of having children determines the procyclicality of fertility. When the marginal utility and relative female income is high, having a child is more costly. The marginal future costs are the long-term child penalties ($w_{t+1}^f \tau_2$). Consider the marginal future cost of having children due to the long-term child penalty:

$$\mathbb{E}_t \left(U_1(c_{t+1}^o)w_{t+1}^f \tau_2\right) = \tau_2 \mathbb{E}_t \left(U_1(c_{t+1}^o)\right) \mathbb{E}_t \left(w_{t+1}^f\right) + \tau_2 cov\left[U_1(c_{t+1}^o), w_{t+1}^f\right] \qquad (2)$$

According to 2, covariance between marginal utility and female income matters for fertility decisions. When female/male income is countercyclical, covariance between the future marginal utility of consumption and female income is positive, which increases the expected cost of having a child.

To summarize, the cyclicality of women's relative income determines the procyclicality of fertility. At the same time, it interacts with the long-term child costs and affects the cost of having children independent of the current cycle. When the female/male income ratio is countercyclical, as observed in the data, the average cost of having children is higher. Families thus have fewer children and are able spend more on the human capital of each child.

8   Conclusion

In this paper, we establish a link between fertility and the macroeconomic dynamics of the labor market from a gender perspective. We argue that the procyclical trend in fertility depends on the cyclical features of the industries in which men and women work as well as women's share of household income. Men are predominantly employed in procyclical industries such as construction and manufacturing, while women disproportionately work in countercyclical industries such as education, health, and government. In a recession, a typical man loses his job and a typical woman becomes the breadwinner of the family. The gender income gap is thus typically countercyclical, which makes female income more precious due to its insurance effect. Women therefore decrease fertility in order to keep working when a recession hits, which creates procyclical fertility. Combined with the long-term child penalties that women experience, countercyclical female income increases the cost of having children and leads to lower fertility on average. Instead, families opt to invest more in the children they do have.

In our empirical analysis, we show that fertility has moved procyclically since the mid-1970s. We document gender-asymmetric industry characteristics and conclude that 70% of men work in highly procyclical industries and 40% of women work in countercyclical industries. As a result, men have higher employment volatility than women, and it is more procyclical. In our state-level analysis, we show that in the majority of states, relative gender employment cycles are negatively correlated with aggregate employment cycles, and the latter state-level relationship is negatively correlated with the cyclicality of fertility.

In order to quantify the effect of gender asymmetry on fertility and to incorporate the quality dimension of fertility choices, we build a general equilibrium overlapping generations model where families make decisions regarding fertility and the investment in their children's human capital. We find that the cyclicality of male and female employment alone can explain procyclical fertility. Gender asymmetry in industries and the countercyclicality of female-dominated fields makes women's income more valuable and pushes families towards quality in the quality-quantity trade-off via a substitution effect. If, however, men work in countercyclical industries and women in procyclical ones (e.g., more men become nurses and more women become construction workers), fertility is higher and countercyclical while the quality investment in children would be lower and more volatile. Moreover, our framework explains the "countercyclical fertility" period set forth in Butz and Ward [1979] as influenced by the lower female income share during that period.

We contribute to the literature by highlighting a link between the quality-quantity trade-off, the differential impact of male and female income, and child penalties, as well as the interaction of these factors with business cycles and fertility dynamics, with implications for population growth and human capital accumulation. The current labor market structure, in which women and men sort into different types of industries, creates an insurance mechanism that helps to smooth income fluctuations, making fertility procyclical and tilting the quality-quantity trade-off towards quality.

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A   Appendix
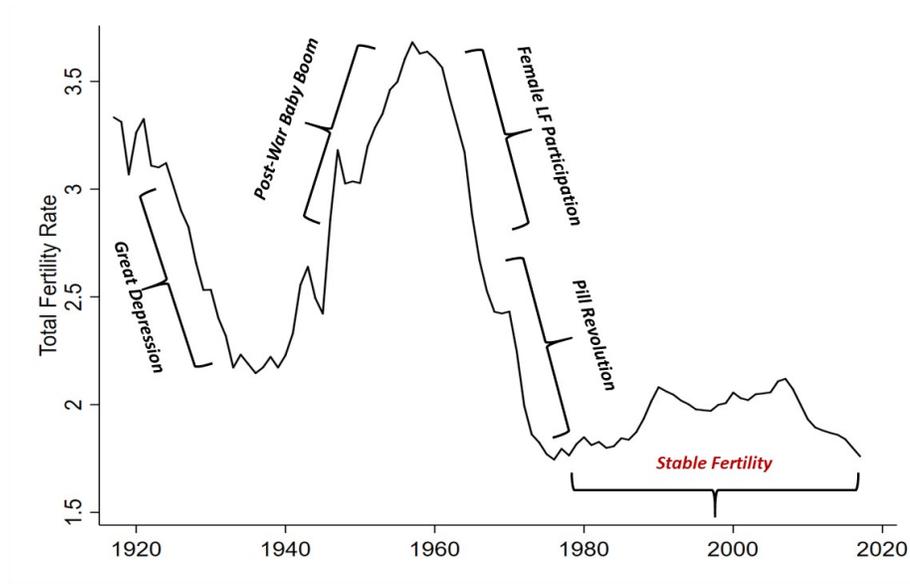
Figure 11: Total fertility rate in the last century (1917-2017)
Data source: National Health Statistics, Office of Population Research (Princeton University)
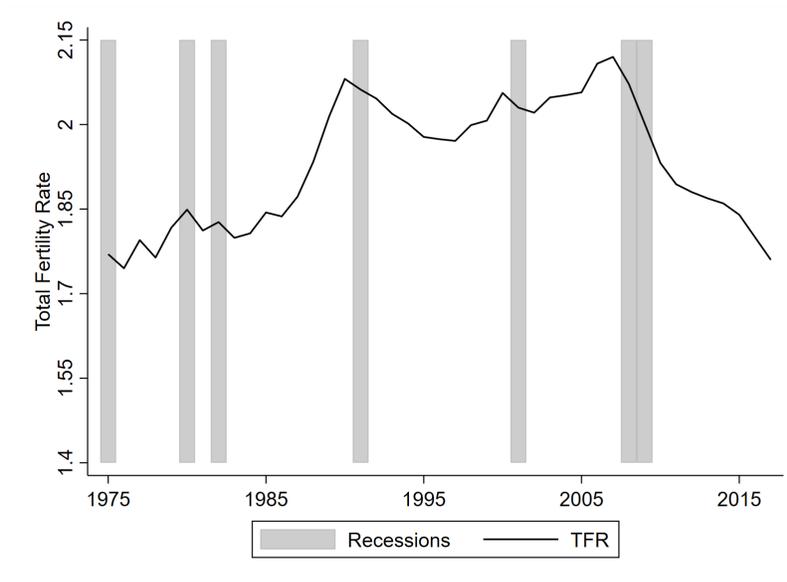

Figure 12: Fertility and recessions
Note: National Health Statistics, US total fertility rate between 1975-2018. Shaded areas indicate recession periods

Parameter	Description	Value	Source
Data Targets			
n^y	Number of children per women of age 15-29	0.65	National Health Statistics
n^m	Number of children per women of age 30-44	1.3	National Health Statistics
$\sigma(fertility\ rate)$	Annual standard deviation of fertility cycle	0.011	National Health Statistics
Model Free Parameters			
β	Discount rate	0.74	interest rate 2% per annum
α	Capital share	0.35	
δ	Depreciation	0.79	10% annual depreciation rate
γ	Risk aversion	2	
η	Curvature of quality function	0.63	De La Croix and Doepke [2003]
θ	Minimum quality expenditure	0.01	De La Croix and Doepke [2003]
σ	Elasticity of substitution (men vs women)	0.44	Ngai and Petrongolo [2017]
τ_1	Time cost of children	0.15	Kleven et al. [2019b,a]
τ_2	Child penalty	0.15	Kleven et al. [2019b,a]
σ_m	Standard deviation of male employment shock	0.09	BLS, Authors' calculation
σ_f	Standard deviation of female employment shock	0.06	BLS, Authors' calculation
Calibrated Parameters			
σ_n	Utility of children elasticity	1.74	Standard deviation of fertility rate
ξ	Utility of children weight	1.48	Number of children per young, middle (n^y, n^m)
λ	Childlessness utility	0.58	Number of children per young, middle (n^y, n^m)

Table 4: Parameters

Estimating Shock Processes

We use annual data on female and male employment from BLS. We first apply an HP filter to the data with $\lambda = 6.25$ to obtain the cyclical component. Then, we run the below regressions to the obtained cyclical components.

$$\log(v_t^m) = \delta_m \log(v_{t-1}^m) + e_t^m$$
$$\log(v_t^f) = \delta_f \log(v_{t-1}^f) + e_t^f$$

We find that $\hat{\delta}_m = 0.5$, $\hat{\delta}_f = 0.5$, $\sigma(\hat{e}_m) = 0.012$, $\sigma(\hat{e}_f) = 0.008$. We then simulate a long series of data and construct our productivity measure.

$$\log(z_t^m) = \sum_{j=0}^{14} \log(v_{t+j}^m)$$

$$\log(z_t^f) = \sum_{j=0}^{14} \log(v_{t+j}^f)$$

We then estimate

$$\log(z_t^m) = \rho_m \log(z_{t-1}^m) + \varepsilon_t^m$$
$$\log(z_t^f) = \rho_f \log(z_{t-1}^f) + \varepsilon_t^f$$

and find $\hat{\rho}_m = \hat{\rho}_f = 0.04$, $\sigma(\hat{\varepsilon}_m) = 0.16$, $\sigma(\hat{\varepsilon}_f) = 0.037$.

Generation Quality

Define $N_t^y(y)$ as the number of young families born to young parents at $t-1$. Similarly, $N_t^y(m)$ is defined as the number of young families born to middle parents at $t-1$.

Define q_t as the average human capital of young agents at time t.

$$N_t^y(y)q_{t-1}^y + N_t^y(m)q_{t-1}^m = N_t^y q_t$$

$$N_{t-1}^y(n_{t-1}^y/2)q_{t-1}^y + N_{t-1}^m(n_{t-1}^m/2)q_{t-1}^m = N_t^y q_t$$

$$N_t^m(n_{t-1}^y/2)q_{t-1}^y + N_t^o(n_{t-1}^m/2)q_{t-1}^m = N_t^y q_t$$

$$N_t^m/N_t^y(n_{t-1}^y/2)q_{t-1}^y + N_t^o/N_t^y(n_{t-1}^m/2)q_{t-1}^m = q_t$$

$$\frac{(n_{t-1}^y/2)q_{t-1}^y}{1+n_t} + \frac{(n_{t-1}^m/2)q_{t-1}^m}{(1+n_t)(1+n_{t-1})} = q_t$$