Childlessness and Development *

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Abstract

This paper leverages harmonized micro-data consisting of 82 million females from 164 household surveys covering 78 unique countries from all income levels to investigate the relationship between childlessness and development. Empirically, I find that childlessness rates display a U-shaped pattern with development at country, subgroups and individual levels, which contribute to 1/3 of heterogeneity of aggregate fertility across countries. Moreover, females in richer countries and those are more educated delay their fertility, suggested by the life-cycle childlessness rates. Combining these novel empirical findings, I construct a two-period model under a parsimonious set of assumptions to speak to the empirical finding: when the wage growth effect dominates the wage level effect, females choose to delay fertility; childlessness is driven by natural sterilization and different preference for number of children.

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1 Introduction

Helen Keller, born in 1880, was famous for her autobiography *Three days to See*. However, it is less well-known that a large majority of females in that era can only choose either career or family. For well-educated females like her graduated from Harvard University, about half of them choose career over family. Some of them have no children throughout their life. Barbara McClintock, born in 1902, was the recipient of the Nobel Prize for Physiology or Medicine for her contribution of mobile genetic elements, the first woman to win that prize unshared. For most of women highly educated as her at that time, they can only sequentially chose career or family. Barbara chose to start her career and then switched to her family. Such story is not anecdotal, on the contrary, is quite universal in the history. During the process of economic development, decision on career and having children evolved. Such observation in the United States is referred as *Passing the Batons* by Goldin (2021). However, this great transition from a cross-country perspective is less visited. In particular, how does the career cost from labor market affect the timing of fertility for different countries? Does such trade-off have economy-wide impact on fertility, especially for the childlessness rates?

This paper tries to answer these questions empirically, theoretically and quantitatively. My analysis starts by leveraging Integrated Public Use Microdata Series (IPUMS), which is the world largest individual level population database. Such rich survey data is national representative, and the variables are cross-country comparable. It covers a wide range of countries from all income level, which is particularly helpful to scrutinize the understudied childlessness rates in the low-income economy. In Section 2, I document a novel U-shaped relationship between childlessness rate for prime-aged female and logged GDP per capita. In particular, both lower and higher income countries have higher childlessness rates relative to the middle income countries. This pattern is robust on the aggregate level, within different demographic subgroups and on the individual level, and, in some degrees, is consistent with the time series data. On top of that, I conduct a simple decomposition exercise in Section 2.3, showing that the extensive margin of fertility is quantitatively significant across countries, which accounts for about 34% of cross-country variation of aggregate fertility rate. To understand the sources of childlessness heterogeneity across countries, I conduct a Kitagawa-Blinder-Oaxaca decomposition exercise and find the country effect is more significant than the composition effect. Within in the composition effect, education, living in the urban and employment accounts more on childlessness heterogeneity.

Section 3 investigates another understudied topic of fertility, which is the timing of fertility across different countries. I compute average childlessness rates for female at different ages for countries in three income groups, namely, high-income, middle-income and low-income. The average childlessness rates in poorer countries are systematically higher before age 40, but such rates are almost the same for female above 45. This observation suggests that females in higher income countries are more likely to postpone the timing of having child. Dividing females by different demographic subgroups, I discover that females with higher education and living in the urban are more likely to postpone their timing for fertility. Single and married mothers are different in the level of childlessness rates but are similar in terms of the timing for giving birth. There is no significant difference between employed and unemployed mother. These evidence suggests that difference in human capital might play a crucial role in age at first birth within a country.

Section 4 provides a simple two-period model under a parsimonious set of assumptions to speak to these novel empirical findings. In particular, this simple model relies the empirical evidence of heterogeneous life-cycle growth across countries and demographic subgroup. The model features endogenous fertility decision on the extensive margin and its timing and the exogenous wage growth associated with wage level w. Female faces the trade-off between the cost and benefit of having a child. The cost of having a kid is manifolds, in terms of an expenditure cost, a time cost in raising the kid, and the opportunity cost for wage growth. However, female also gains utility on having kid á la Becker and Tomes (1976). Firstly, I argue there are two counterbalancing force affects the fertility timing, which I call *wage level effect* and *wage growth effect* in Section **??**. A higher wage level decreases the relative expenditure cost and thus encouraging early fertility, while a higher wage growth encourages delayed fertility since it slacken the life-time budget constraint. If the latter dominates, the model can speak to the fact that females in higher income countries and those are more educated within a country postpone to have kid. Second, there are two reasons for childlessness, demonstrated in 4.2.2. The first one is *natural sterilization*, which is driven by the expenditure cost. For female in extreme poverty, having a kid pushes the consumption level to zero due to this expenditure cost, which is not optimal. The other one is *preference-driven childlessness* due to females have different taste for number of children q. Combining these two ingredients of fertility decision, I can identify the fertility decision based on the type of agent (w, q). This exercise bridges the micro-level individual decision to the macro-level childlessness rate. I theoretically prove that the childlessness rates is weakly decreasing up to some wage level w, which coincides with the left-half of the U-shaped childlessness rate and development relationship in the empirical evidence.

The contribution of this paper is manifolds. Firstly, my paper enriches the insights of fertility decision by distinguishing the extensive margin and the intensive one. A large strand of literature highlights the declining fertility along the stage of development, for OECD countries Doepke and Tertilt (2016) and **?** for sub-Saharan Africa countries, as well as over time Greenwood, Guner and Marto (2021), which only focuses on the aggregate level of fertility. However, the pattern for these two margins are not necessarily the same (Aaronson et al., 2014), even goes to the opposite direction during the demographical transition (Gobbi and Goñi, 2020). At the same time, Momota (2016) highlights that distinguishing the intensive and extensive margin is particularly crucial for understanding human capital accumulation and welfare in the long run. However, previous research seldom visits these two margins. An exceptional research highlights the importance of extensive margin of fertility is Baudin et al. (2015), which documents a U-shaped relationship between childlessness and education level in US. Similar patterns in other countries are also identified in Baudin et al. (2020). Another research by Kim et al. (2021) touches upon the relationship between childlessness and income in Korea motivated by status externality, i.e., parents care about the relative quality of children instead of absolute quality of children. These two papers highlight an essential mechanism of childlessness for the poor. In Baudin et al. (2015), for female having child there is a minimum requirement for consumption must be reached, and thus poor female is constrained and become naturally sterile. While in Kim et al. (2021), a soaring education cost for children prevents poor female to have kids since she feels better off by having no kid instead of having poorly-educated kid. In this paper, a fixed cost of having a kid is modelled so that female in lower income countries will become childless. Moreover, this model extends the Baudin et al. (2015) in a two-period setting with income growth, and highlights that females in wealthier countries find childlessness optimal since the high opportunity cost of having children in terms of life-cycle income growth.

On one hand, a growing literature suggests a negative impact of giving birth. Hyland, Djankov and Goldberg (2020) argue that from a global perspective, the most severe penalties for female when it comes to laws related with having children and getting paid. The differential impact of having children for male and female is called the child penalty, supported by intensive empirical evidence (Miller, 2009; Kleven et al., 2019; Kim and Moser, 2021) and scrutinized from a theoretical perspective (Goldin and Katz, 2002; Caucutt et al., 2002; Iyigun, 2000; Adda et al., 2017; Xiao, 2021; Jiang et al., 2019). While, on the other hand, a large bulk of literature highlight the heterogeneity of labor market across countries: including labor market transition (Donovan et al., 2020) and life-cycle income growth comparison (Lagakos et al., 2018; Islam et al., 2018; Fang and Qiu, 2021). For the latter strand of literature, numerous reasons of this life-cycle income growth heterogeneity are brought into discussion (Ma et al., 2021), but the consequence of this heterogeneity is seldom visited. This paper unites these two bodies of work by evaluating the difference of life-cycle income profile affects female the timing of fertility decision during the process of economic development. In particular, I evaluate the sources of cost of having children across-countries, enriching the child penalty literature from a global perspective. I also show the consequence of labor market outcome across the globe in terms of different fertility decisions.

This paper closely relates to a growing bulk of literature, which investigates the patterns in family economics from the perspective of development, which includes, to name a few, Greenwood, Guner and Marto (2021) about technological transition on fertility, Feng and Ren (2021a) about economic development on desired fertility and marriage, Tertilt (2005) about polygamy on fertility, De Silva and Tenreyro (2020) about social norm on falling fertility, Bau and Fernández (2021) about culture on the family institutes across countries, Delventhal, Fernández-Villaverde and Guner (2021) about demographical transition on both time and spatial horizon, Doepke et al. (2021) about the close connection between female labor force participation and fertility. Meanwhile, other previous research document the change of childbearing age for females and provide the mechanism behind. Empirically, numerous papers indicate the effect of pills (Goldin and Katz, 2002; Bailey, 2006); while, theoretically, Wolpin (1984) provides a dynamic programming framework that can account for the number and timing of fertility. A fertility delay in recent decades is documented and explained by Jiang (2018). De la Croix and Pommeret (2021) view having kids as a risky investment and its option value affects the timing of fertility. More specifically, childbearing results in an increase of income growth uncertainty. Such increase is stronger for those more educated, which explains that the age at first birth and the childlessness rate both increase with education. An earlier work by Ward and Butz (1980) argues that couples avoid to time their fertility when female wage are expected to be high. My paper combines these two strands of literature by extending the insight of Ward and Butz (1980) from the angle of development and evaluate how the cross-country career cost contribute to this fertility timing pattern from the cross-country view.

2 Childlessness and Development

2.1 Data and Measurement

The data I use to calculate the childlessness rate is extracted by IPUMS-I (2020), a harmonized cross-country comparable dataset covering countries from all income levels. In particular, the data consists of 164 country-year samples with 72 unique countries after 1990. I choose this time window because my focus is cross-sectional evidence instead of time-series fluctuations. IPUMS-I reports the number of children ever born to each woman of whom the question was asked, denoted by the variable (`CHBORN`). In most samples, women were to report all live births by all fathers, whether the child was still living. To include more country-year samples in my analysis, I define a baseline country-year sample, in which number of children and female age are not missing. I also define a restricted sample so that each females have non-missing characteristics on employment status, education level, marital status and urban/rural residency. To make the population cross-country comparable, I restrict my observations as those female aged between 15 to 44. Childlessness is defined as no live births for a woman, which sheds lights on the extensive margin of fertility. Childlessness rate in a cross-section is defined as the proportion of female with no kids ever born. Table 6 provides a list of samples in the baseline analysis. For GDP data, I use Penn World Table 10.0 (Feenstra, Inklaar and Timmer, 2015).

2.2 U-shaped Relationship

2.2.1 Country Level

Figure 1 shows stylized facts about fertility across countries. Each smaller and more transparent dot represent a cross-section (country-year pair). And the larger, darker, diamond-shaped dots are for the country average. The solid and dashed line are quadratic fitted lines for the country average and country-year samples, respectively.

The first panel documents a negative correlation between average number of children ever-born for female aged from 15 to 54 and logged GDP per capita. This negative gradient is documented extensively in the literature, to name a few, Jones, Schoonbroodt and Tertilt (2008), Manuelli and Seshadri (2009), Doepke and Tertilt (2016), and Greenwood, Guner and Marto (2021). The second panel shows how the average number of children per mother varies over income level. Combining the first two panels, I document the novel empirical pattern for this paper that the childlessness-development relationship is not monotonic. The last panel highlights a *U-shaped* relationship between childlessness rate and development, which indicates that middle-income countries have a lower childlessness rate compared with poorer and richer countries. In other words, mothers in lower income countries have substantially more kids. This cross-sectional U-shaped childlessness-income relationship echos that finding within a specific country, for example, as Kim, Tertilt and Yum (2021), the bottom- and top-income quantile have higher childlessness rates in Korea.

I follow up with a battery of robustness check for the U-shaped relationship between childlessness rates and development. In the baseline result shown in Figure 1, I focus on females aged from 15 to 44. Firstly, I vary the age bin, and reproduce this stylized fact for female population over 15, over 18, over 22, and prime-age (from 15 to 54) as in other literature (Zipfel, 1950; Feng and Ren, 2021a). Second, I exclude potential outlier for observations with childlessness rates smaller than 20%. Third, I make the female population more comparable across countries, ruling out the female with missing information on education, employment status, marital status or urban/ rural residency. Due to the lack of information in some of the country-year survey, this robustness check cut my country-year observation to with unique countries. Fourth, I expand my baseline samples by including an auxiliary data from IPUMS-DHS, which has higher weights for surveys in lower and middle-income countries. Including IPUMS-DHS ends up with 375 country-year observations with 92 unique countries. For the overlapping country-year observations, I cross-check the childlessness rates from different sources as a test for data-quality control. There are 4 duplication from two data sources but the childlessness rates are very close to each other. I keep the data from IPUMS-I if duplication occurs. Fifth, I narrow down the time horizons into 15 years (1990-2004 and 2005-2020), which serves a good exercise for controlling social norms changes (De La Croix and Doepke, 2003). Sixth, I change my measurement for development by replacing logged GDP per capita by logged GNP per capita, which is obtained by World Bank. Lastly, I change the baseline regression using population weight of each country.

For all of the aforementioned robustness check, I regress both on country-year observations and on country-average. The regression results and the corresponding axis of symmetry, measured as $-\widehat{\beta}_1/(2 \times \widehat{\beta}_2)$ are summarized in Table 1. As a comparison, the first row indicates the regression results corresponds with Figure 1. The results of these 22 robustness checks reinforce the U-shaped relationship between childlessness and development. The axis of symmetry shows the logged GDP per capita for the lowest childlessness rates. Almost all coefficients are statistically significant at 99% level.

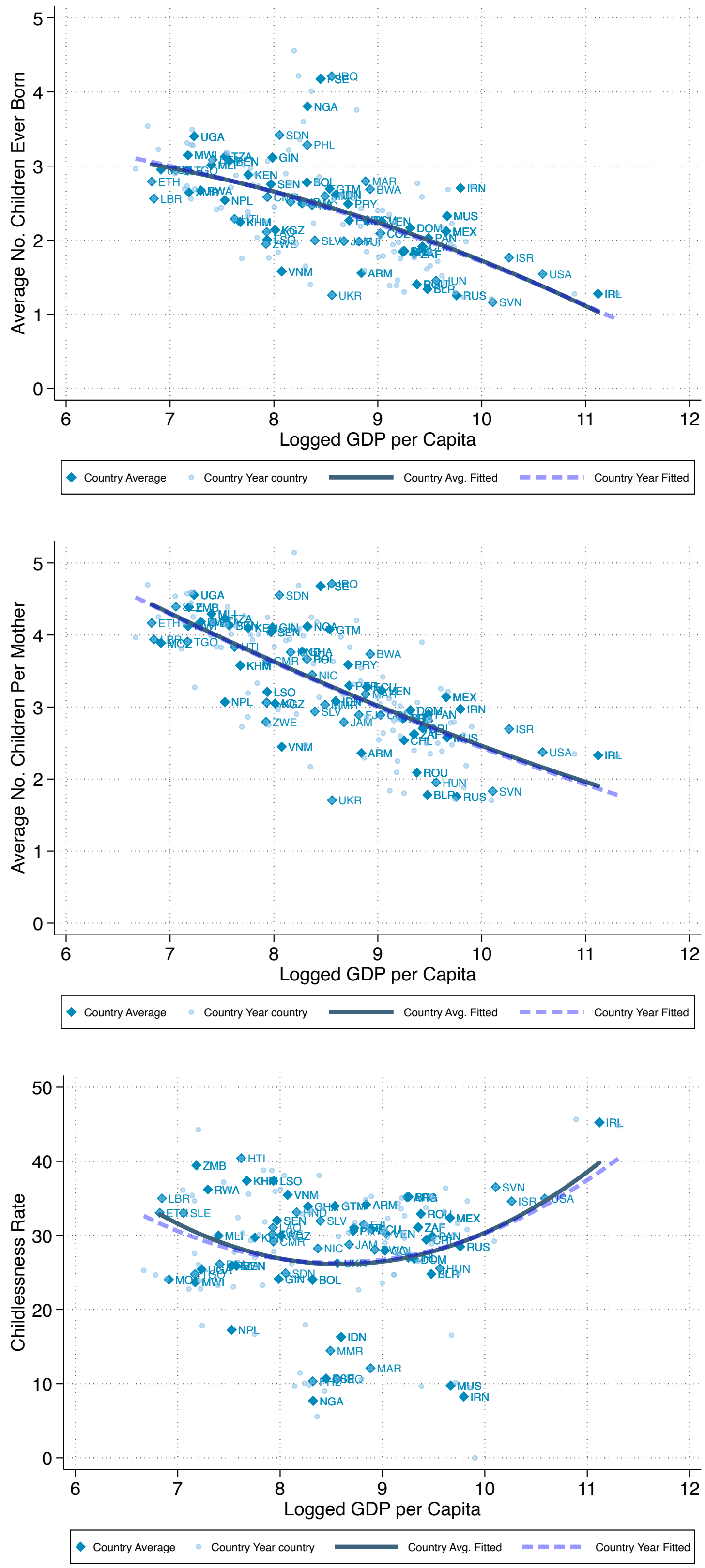
2.2.2 Demographic Subgroup Level

To show the robustness of this pattern, I calculate the childlessness rates by different demographic subgroups, for example, education, urban/rural residence, employment status, marital status etc. In particular. I follow the regression specification

$$\text{Childless\%}_{c,g,t} = \beta_0 + \beta_1 \log(\text{GDP per Capita})_{c,t} + \beta_2 \log(\text{GDP per Capita})^2_{c,t} + \epsilon_{c,g,t} \tag{1}$$

where the dependent variable is the childlessness rate in subgroup g country c. Table **??** reports coefficient of β_1 and β_2, respectively, along with the p-value. A robust pattern of negative β_1 and positive β_2 indicates a U-shaped relationship both using country-year sample and country average sample. The axis of symmetry, calculated by

Figure 1: Childlessness Rate and Fertility Across Countries



Note: This figure shows the relationship between childlessness rate and fertility (measured by average children ever born per female and average number of children per mother) with logged GDP per capita. Childlessness and fertility data is from IPUMS-I. Childlessness is defined as the share of childless female between age 15 and 44. Data about GDP per capita is extracted from Penn World Table 10.0. Each smaller and more transparent dot represent a cross-section (country-year pair). And the larger, darker, diamond-shaped dots are for the country average. The solid and dashed line are quadratic fitted lines for the country average and country-year samples, respectively.

Table 1: Robustness Check of U-shaped Relation Between Childlessness Rates and Development

	Country Year							Country Average						
	β_1	p val.	β_2	p val.	Obs.	R-Sq.	Ax. Sym	β_1	p val.	β_2	p val.	Obs.	R-Sq.	Ax. Sym.
(0) Baseline	-50.46	0.00	3.06	0.00	164	0.18	8.24	-54.19	0.00	3.26	0.00	78	0.24	8.24
(1) Age 15-54	-43.01	0.00	2.56	0.00	164	0.14	8.40	-48.10	0.00	2.84	0.00	78	0.20	8.40
(2) Over 15	-43.01	0.00	2.56	0.00	164	0.14	8.40	-48.10	0.00	2.84	0.00	78	0.20	8.40
(3) Over 18	-35.53	0.00	2.20	0.00	164	0.24	8.06	-40.22	0.00	2.46	0.00	78	0.32	8.06
(4) Over 22	-33.17	0.00	2.12	0.00	164	0.44	7.82	-37.14	0.00	2.34	0.00	78	0.52	7.82
(5) Drop below 20%	-24.81	0.00	1.61	0.00	138	0.36	7.70	-24.54	0.00	1.60	0.00	68	0.44	7.66
(6) Comparable	-22.14	0.10	1.34	0.08	162	0.03	8.24	-36.79	0.06	2.15	0.05	72	0.05	8.54
(7) Include IPUMS-DHS	-29.53	0.00	1.87	0.00	375	0.08	7.92	-36.93	0.03	2.27	0.02	92	0.11	8.13
(8) Year 1990-2004	-57.31	0.00	3.48	0.00	96	0.19	8.22	-51.33	0.00	3.15	0.00	67	0.22	8.14
(9) Year 2005-2020	-45.19	0.02	2.73	0.01	68	0.16	8.29	-40.78	0.04	2.49	0.03	58	0.16	8.20
(10) GNI	-43.25	0.00	2.69	0.00	126	0.24	8.04	-42.38	0.01	2.62	0.00	64	0.29	8.09
(11) Pop. Weight	-53.79	0.00	3.27	0.00	161	0.17	8.22	-57.55	0.00	3.46	0.00	76	0.22	8.32

Note: This table demonstrates the robustness check of U-shaped relationship between childlessness rates and development following the specification

$$\text{Childless\%}_{c,t} = \beta_0 + \beta_1 \log(\text{GDP per Capita})_{c,t} + \beta_2 \log(\text{GDP per Capita})^2_{c,t} + \epsilon_{c,t}$$

The left columns shows the regression result using country-year observation, while the right ones using country-average (average childlessness rates and logged average GDP per capita over years). Row (0) shows the regression result in the baseline exercise, corresponding to the fitted line in Panel C of Figure 1. Row (1) to (4) vary the age bin, and reproduce this stylized fact for female population over 15, over 18, over 22, and prime-age (from 15 to 54). Row (5) excludes potential outlier for observations with childlessness rates smaller than 20%. Row (6) uses more comparable samples for female population without missing information on education, employment status, marital status and urban/ rural residency. Row (7) expands baseline samples by including an auxiliary data from IPUMS-DHS, which has higher weights for surveys in lower and middle-income countries. Row (8) and (9) narrow down the time horizons into 15 years (1990-2004 and 2005-2020). Row (10) changes the measurement for development by replacing logged GDP per capita by logged GNP per capita, which is obtained by World Bank. Row (11) changes the baseline regression using population weight of each country. In each regression, estimated β_1 and β_2 and associated p-value are reported. Number of observations, R-squared are also reported. Axis of symmetry is calculated by $-\beta_1/(2 \times \beta_2)$.

$-\beta_1/(2 \times \beta_2)$ answers the level of income for countries with the childlessness rate, which is the logged GDP level at the bottom fitted U-shaped curve. Strikingly, the result is almost the same across different subgroups, mostly lies in the range of 8.5 to 9.5. It implies that, fixing the demographic subgroups, the childlessness rates are lowest for countries in this particular range of income.

2.2.3 Individual Level

I proceed this analysis into individual level by combining the country-year sample in IPUMS-I, which allows me to identify about females. I use the following specification

$$\mathbf{1}\{\text{Childless}\}_{i,c,t} = \beta_0 + \beta_1 \log(\text{GDP per Capita})_{c,t} + \beta_2 \log(\text{GDP per Capita})^2_{c,t} + \Lambda_i + \epsilon_{i,c,t} \tag{2}$$

where the dependent variable is an indicator for female with no child in year t, Λ_i captures a wide range of individual characteristics. Table 3 reports individual regression result. The coefficients of interest are β_1 and β_2 and the axis of symmetry. All columns suggest a U-shaped relationship between childlessness dummy and logged GDP per capita. In particular, the axis of symmetry is very close to the results using country and subgroup level regression. Column 2 suggests that older female are less likely to be childless. Column 3 suggests marriage discourages childlessness. Also, more educated female are more likely to having no kids. Childlessness rates is higher for urban residents, which is indicated by Column 5.

2.2.4 Comparing with Time Series Evidence

So far, I establish a U-shaped pattern of childlessness rates and development using cross-sectional data. But does the time-series pattern coincide with the cross-sectional pattern? To answer this question, I conduct the following two exercises.

Table 2: Coefficients: of Childlessness Rates by Subgroups

	Country Year					Country Average				
	β_1	p val.	β_2	p val.	Ax. Sym.	β_1	p val.	β_2	p val.	Ax. Sym.
					Panel A: Urban/Rural Status					
Rural	-35.83	0.00	2.14	0.00	8.36	-48.07	0.00	2.78	0.00	8.64
Urban	-46.52	0.00	2.66	0.00	8.75	-48.07	0.00	2.78	0.00	8.64
					Panel B: Education Attainment					
Less Than Primary	-22.56	0.41	1.21	0.46	9.33	-37.44	0.08	2.02	0.11	9.28
Primary Completed	-58.53	0.01	3.33	0.01	8.79	-58.45	0.00	3.30	0.00	8.85
Secondary Completed	-38.03	0.03	2.01	0.04	9.44	-58.45	0.00	3.30	0.00	8.85
University Completed	-48.20	0.02	2.80	0.02	8.61	-58.27	0.00	3.33	0.00	8.74
					Panel C: Marital Status					
Never-Married	-6.78	0.71	0.32	0.76	10.65	-18.15	0.07	1.01	0.07	8.96
Ever-Married	-20.77	0.00	1.19	0.00	8.71	-45.26	0.02	2.52	0.02	8.98
					Panel D: Employment Status					
Employed	-23.49	0.07	1.52	0.04	7.71	-44.10	0.00	2.55	0.00	8.65
Unemployed	-19.52	0.35	1.02	0.40	9.59	-33.81	0.02	1.96	0.02	8.64
Inactive	-63.51	0.00	3.62	0.00	8.77	-44.10	0.00	2.55	0.00	8.65

I start my analysis using U.S. data, which are national representative data dating back to 1900 from IPUMS-USA (Ruggles et al., 2021) and IPUMS-CPS (Flood et al., 2021). Such micro level data is very similar with census or household survey data from IPUMS-I, which are used in demonstrating cross-sectional pattern. For GDP per capita data before 1950, I fall back to Madison Historical Data (MHD) by Bolt, Inklaar, De Jong and Van Zanden (2018). To make the logged GDP per capita comparable, I adjust the Madison data, which is based on PPP, using the overlapping period after 1950 between MHD and PWT. The sample selection for IPUMS-USA and IPUMS-CPS are left in Appendix Table 7. Despite the long time window of USA household data, it only covers the stage of development corresponding to the right half of U-shaped curve. The time series data matches right-half of the fitted cross-sectional curve, especially after 1940. The huge change of childlessness rates in 1900 and 1910 may be due to the data quality or the World War I. Moreover, the time series data from IPUMS-USA fits those from CPS very well, and the data almost connect each other head-and-tail, which implies data from different sources speak to a consistent transition within the US.

My second exercise tries to include time series evidence from a larger sample of countries, with the cost of significantly shorter time window. The goal is to compare the time series slope of childlessness with respect to logged GDP per capita and that of the cross-sectional slope from the U-shaped curve. To obtain the time-series slope of childlessness and development, I regress childlessness rate and logged GDP per capita for each countries with more than 3 country-year sample, i.e.

$$\text{Childless\%}_{ct} = \gamma_0 + \gamma_1 \log(\text{GDP per Capita})_{c,t} + \epsilon_{ct} \tag{3}$$

where γ_1 is the desired time-series slope, which is country-specific. The cross-sectional slope is given by

$$\frac{\partial \widehat{\text{Childless\%}}_{ct}}{\partial \text{logged GDP per capita}_{c,t}} = \widehat{\beta_1} + 2 \times \widehat{\beta_2} \log(\text{GDP per Capita})_{c,t},$$

where $\widehat{\beta_1}$ and $\widehat{\beta_2}$ are from country-level baseline regression. In the right panel of Figure 2, I plot these two slopes corresponding time span, in the spirit of Baudin et al. (2015) and Feng and Ren (2021a). If the time series pattern is congruent with cross-sectional pattern, one should expect a negative coefficient γ_1 for countries with lower

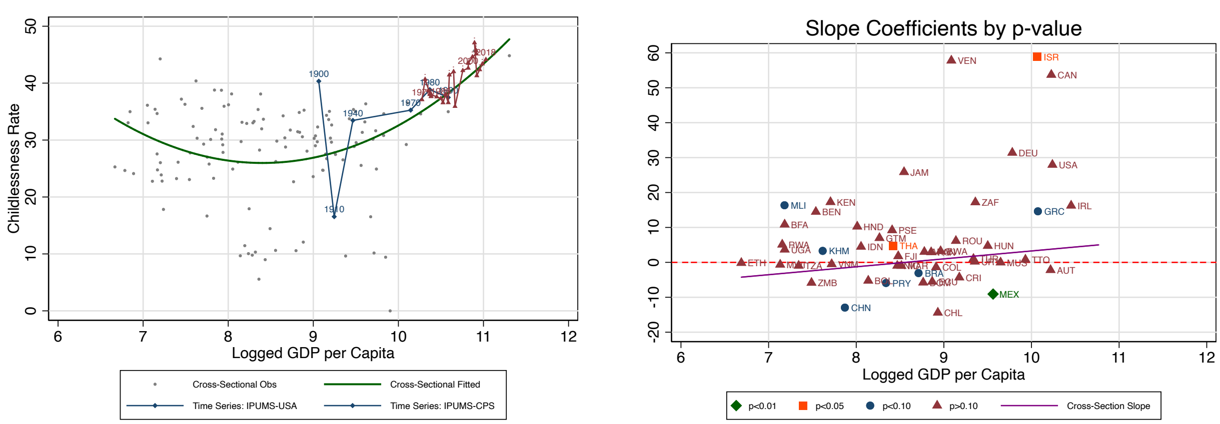
Table 3: Childlessness and Development: Individual Level

	1{Childlessness}								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
log(GDP Per Capita)	-0.220***	-0.132***	-0.096***	-0.268***	-0.284***	-0.293***	-0.021***	-0.019***	-0.031***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
log(GDP Per Capita)^2	0.014***	0.010***	0.005***	0.015***	0.017***	0.018***	0.001***	0.001***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age		-0.021***					-0.016***	-0.015***	-0.015***
		(0.000)					(0.000)	(0.000)	(0.000)
Married			-0.522***				-0.410***	-0.413***	-0.413***
			(0.000)				(0.000)	(0.000)	(0.000)
Primary				0.146***			0.007***	0.003***	0.004***
				(0.000)			(0.000)	(0.000)	(0.000)
Secondary				0.164***			0.056***	0.047***	0.049***
				(0.000)			(0.000)	(0.000)	(0.000)
University				0.183***			0.143***	0.141***	0.143***
				(0.000)			(0.000)	(0.000)	(0.000)
Urban					0.076***		0.013***	0.007***	0.007***
					(0.000)		(0.000)	(0.000)	(0.000)
Employed						-0.047***	-0.021***	0.021***	0.034***
						(0.000)	(0.000)	(0.000)	(0.000)
Unemployed						0.046***	-0.055***	-0.056***	-0.056***
						(0.000)	(0.000)	(0.000)	(0.000)
Axis. Symmetry	7.99	6.44	9.02	9.13	8.57	8.23	7.55	7.67	8.13
Industry FE	Yes	No	No	No	No	No	No	No	Yes
Occupation FE	No	No	No	No	No	No	No	Yes	Yes
R Squared	0.003	0.259	0.303	0.024	0.009	0.007	0.433	0.427	0.427
Observations	82244396	82244396	82244396	82244396	82244396	82244396	82244396	63634122	62296614

* p<0.10, ** p<0.05, *** p<0.010

GDP per capita and a positive one for those with higher GDP per capita. The time-series result the cross-sectional pattern in richer economy pretty well. But it does not fit the story for those in lower-income perfectly. Overall, the time series slope coefficients is positively related with logged GDP per capita.

Figure 2: Comparison of Time Series and Cross-Sectional Childlessness Rates



Note: This figure makes a comparison of time-series and cross-sectional childlessness-development relationship. The left displays the evolution of childlessness rates in the US from 1900 to 2019. Data are extracted from IPUMS-USA and IPUMS-CPS. The gray dots are country-year observation, which are the same as the right panel of Figure 1. The green line is the fitted line for cross-sectional data. The right panel shows the relationship between the slope coefficients γ_1 in specification 3 with average logged GDP per capita within a country. The purple line is the slope coefficient of fitted curve in the right panel of 1 with functional form $y = 2 \times \beta_2 \times \log(\text{GDP per Capita}) + \beta_1$, where β_1 and β_2 are estimated from 2 and group g represents the entire country.

2.3 Connecting Extensive Margin of Fertility to Aggregate Fertility

After documenting a robust U-shaped childlessness-development relationship, a natural question is how the extensive margin of fertility contribute to aggregate fertility? Consider the following exercise to decompose $f = mk$, where f is aggregate level fertility, i.e., average number of children ever born per prime-aged female, m is the motherhood rate, which equals $1 - c$, where c is childlessness rate and k is the number of kids ever-born for prime-aged mother.

$$\frac{f_i - \bar{f}}{\bar{f}} = \frac{f_i}{\bar{f}} - 1 = \left(\frac{m_i - \bar{m}}{\bar{m}} + 1\right)\left(\frac{k_i - \bar{k}}{\bar{k}} + 1\right) - 1 \tag{4}$$

$$= \underbrace{\frac{m_i - \bar{m}}{\bar{m}}}_{\text{extensive}=34\%} + \underbrace{\frac{k_i - \bar{k}}{\bar{k}}}_{\text{intensive}=74\%} + \underbrace{\frac{m_i - \bar{m}}{\bar{m}} \times \frac{k_i - \bar{k}}{\bar{k}}}_{\text{interaction}=-8\%}, \tag{5}$$

where $\bar{x}$ represents the mean of x for all country-year observation. Equation 4 decomposes the deviation of fertility rate of a specific country c from the world average including three effects: an extensive margin component $(m_i - \bar{m})/\bar{m}$, , an intensive margin component, $(k_i - \bar{k})/\bar{k}$, and an interaction term, which is the multiplication of extensive and intensive margin. I summarize the decomposition result in Equation 4 by taking the mean contribution of extensive margin, intensive margin and interaction margin, respectively. One can find the extensive margin childlessness rate contribute 34% to aggregate fertility across countries, on average, while the intensive margin accounts for 74%.

2.4 Selection Into Childlessness

What are the demographic characteristics of childless females? Are childless females in different countries have different demographic characteristics?

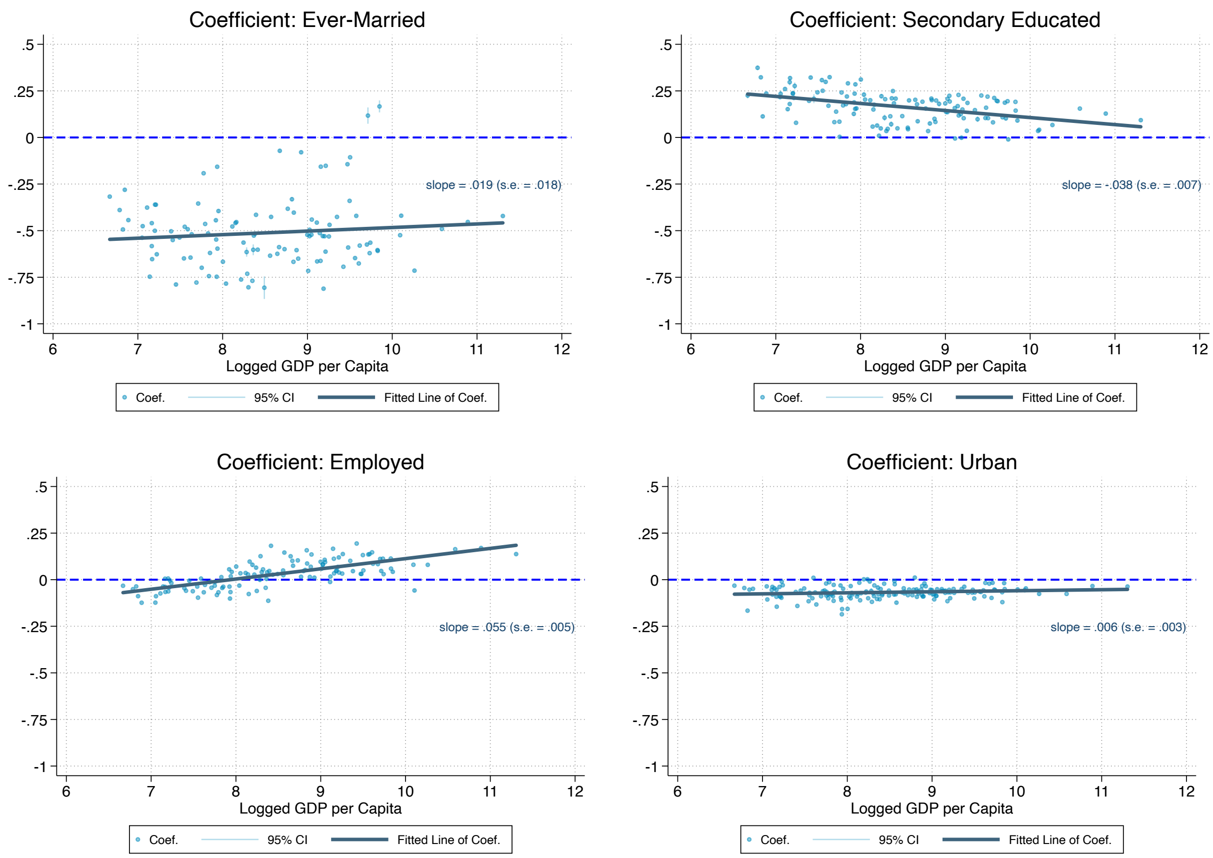
To answer this question, I follow Feng and Ren (2021b), by firstly regressing the childlessness dummy on dummies of individual characteristics (ever-married, secondary educated and above, urban resident, and employed), respectively, controlling for the age in each cross-section. I gather the regression coefficient attached with characteristic dummies and plot it against logged GDP per capita in Figure 3.

Firstly, each dot with 95% confident interval represents the estimated coefficient of regression in a specific cross-section. If the estimated coefficient is positive, females with certain demographic characteristic in that cross-section are more likely to become childless. Figure 3 indicates that ever-married females are less likely to be childless, while females in urban are less likely to be childless, though the magnitude of selection is small. Females complete secondary education are more likely to be childless. Secondly, by comparing the magnitude of the coefficient, one can see the different magnitude of selection over the level of development. There is no significant heterogeneity of ever-married female or urban female selected into childlessness over the level of development. However, the selection magnitude of educated and employed females into childlessness are quite different. Female with higher education is poorer countries are significantly more likely to be childless. Moreover, employed females are positively selected into childlessness in more developed economies but are negatively selected into childlessness in less-developed ones.

2.5 The Sources of Childlessness Rates Heterogeneity

From the previous decomposition exercise in Section 2.3, I find the great contribution of childlessness to cross-country fertility differences in fertility. A natural follow-up question is how the heterogeneous demographical composition explain the childlessness rate across countries. In poorer countries, the population has higher proportion of younger and less-educated individual. I explore the extent of this composition effect driving the cross-sectional childlessness rates. Specifically, I conduct a Kitagawa–Blinder–Oaxaca decomposition (Kitagawa, 1955; Blinder, 1973; Oaxaca, 1973) in a flavor of Donovan et al. (2020) to answer this question. The decomposition

Figure 3: Selection Into Childlessness Across Countries



follows in three steps. Firstly, I do the following regression for individual i in country c at time t

$$\mathbf{1}\{\text{Childless}\}_{ict} = \Lambda_{ict}\beta_c + \epsilon_{ict} \tag{6}$$

where the dependent variable is an indicator for childlessness. On the right hand side, I include a vector of observable individual characteristic $\Lambda_{i,c,t}$ for the full interaction of age (9 five-year age bin), education (4 groups including less than primary completed, primary complete, secondary completed and university completed), residence (urban or rural), marital status (married or not), employment status (employed, unemployed and inactive).

The second step disentangle the difference of childlessness rate in a country-year pair (c, t) with that in the reference country, denoted as r into three components. Denote individuals as i in country-year pair (c, t) and as j in reference country r. To be more specific, consider

$$\text{Mean}_i\left(\text{Childless}_{i,c,t}\right) - \text{Mean}_j\left(\text{Childless}_{j,r}\right) = \left\{\begin{array}{ll} \left[\text{Mean}_i\left(\Lambda_{i,c,t}\right) - \text{Mean}_j\left(\Lambda_{j,r}\right)\right]\widehat{\beta}_r & \text{composition} \\ +\text{Mean}_j\left(\Lambda_{j,r}\right)\left[\widehat{\beta}_c - \widehat{\beta}_r\right] & \text{country} \\ +\left[\text{Mean}_i\left(\Lambda_{i,c,t}\right) - \left(\Lambda_{j,r}\right)\right]\left(\widehat{\beta}_c - \widehat{\beta}_r\right) & \text{interaction} \end{array}\right\} \tag{7}$$

The composition effects measures how the demographic composition heterogeneity contributes to the childlessness rates. For example, poorer countries have substantially younger population. Even if the childlessness rates within a particular age group is the same between two countries, different weights on demographic groups result in different childlessness rates. The country effect highlights that individual with identical demographic characteristics have different probability of being childless across countries. This probability difference is measured by $\widehat{\beta}_c - \widehat{\beta}_r$. In the last step, I take the average of these three effects over the country list.

The first row of Table 4 reports the results, where I use the United States 1990 sample as the reference. If I start with all country are identical and vary the demographic composition only, the childlessness rates will on average decrease 4.94% relative to the reference country. Furthermore, if adding the heterogeneity of childlessness rates associated with demographic characteristic, the country effect will further enlarge the childlessness heterogeneity by 7.62%. Finally, by adding the interaction components, the childlessness rates go back to the data in reality, which means that the childlessness rates in all other samples is 6.95% lower than the reference one. Moreover, this exercise indicates that the country effect is the driving force of heterogeneous childlessness rates across countries.

Table 4: The Sources of Childlessness Rates Heterogeneity

	Composition		Country		Interaction		Overall	
	Diff. (1)	Ratio (2)=(1)/(7)	Diff. (3)	Ratio (4)=(3)/(7)	Diff. (5)	Ratio (6)=(5)/(7)	Diff. (7)=(1)+(3)+(5)	Ratio (8)=(2)+(4)+(6)
All Interaction	-4.94	71.07	-7.62	109.54	5.61	-80.61	-6.95	100.00
Only Age	6.81	-97.90	-13.42	193.04	-0.34	4.86	-6.95	100.00
Only Education	-2.75	39.56	1.59	-22.89	-5.80	83.33	-6.95	100.00
Only Marital	-1.00	14.43	-8.50	122.27	2.55	-36.70	-6.95	100.00
Only Urban	-2.19	31.52	-5.33	76.64	0.57	-8.16	-6.95	100.00
Only Employment	-2.16	31.13	-5.73	82.36	0.94	-13.49	-6.95	100.00

Despite the country effect is dominant force for the cross-country heterogeneity, the composition effect also accounts for a substantial amount of heterogeneity. To uncover what socio-economic characteristic contributes to the composition effect, I follow up the similar decomposition exercise as 7 but controlling only one dimension of characteristic each time. Comparing the result in Column (1) under different decomposition exercises allows me running a horse race between these important characteristics and ascertain which one(s) among them has greater power in explaining the observed composition effect. Starting with all countries with same demographic distribution and within-subgroup childlessness rates, one adds the demographic distribution of education, marital status, urban residency, and employment status decreases the childlessness rates in other country relative to the reference country by 2.75%, 1.00%, 2.19% and 2.16%, respectively. It implies the heterogeneity of education, urban residency and employment status composition is crucial factor affects cross-country childlessness rates. However, if one control for the age distribution, the childlessness rates goes to the opposite direction.

3 Life-Cycle Childlessness Rate

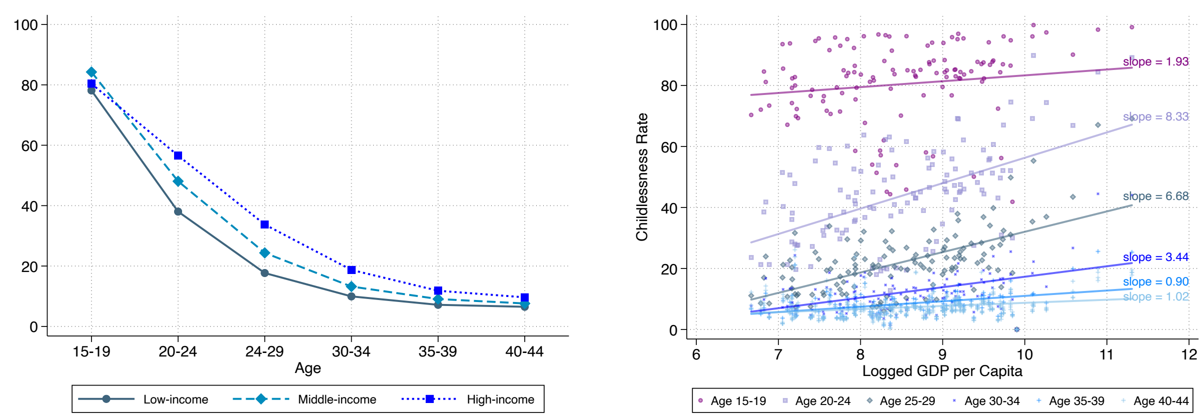
In this section, I explore the life cycle of childlessness rate by different income level and different demographic subgroups. Understanding this pattern helps us demystify the timing of motherhood across countries.

3.1 Overview

The left panel of Figure 4 illustrates the life cycle pattern of childlessness rate across income group. Nearly 85 percents of female are childless at their age of 15-19 across all income group. Childlessness rate declines sharply until 35 years old, and remains constant about 10% afterwards for each income group. This suggests 90% of female will have kids after all, but the timing is different. Women in high income countries tend to postpone their motherhood, or, in other words, wait longer for having kids. For example, there are 38% of female aged 20 to 24 remain childless in low-income countries. Such ratio is 48% and 57% in middle-income and high-income countries, despite the childlessness rate is similar for women aged 35 to 39 across income group.

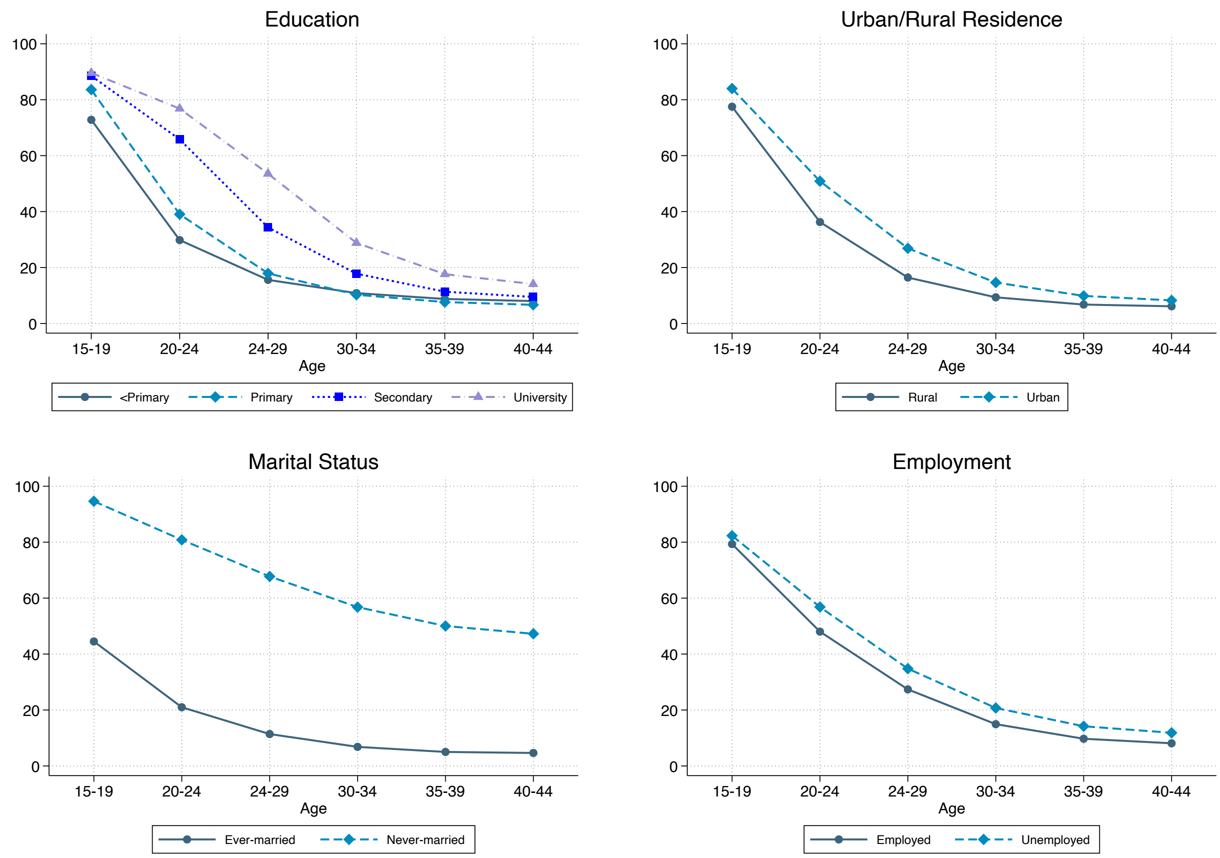
An alternative way to illustrate the delay of fertility in more developed countries is to plot the childlessness rates within each age group against with Logged GDP per capita, which is depicted in the right panel of Figure 4. If the fitted lines are with slope zero and and parallel with each other, then there is no timing difference for fertility across countries. Similar with the above analysis, there is no huge different for childlessness rates in the age groups of 15-19 and of 40 to 54. But the all other fitted lines are upward sloping, and the slope of fitted line become less steeper when we move to older age groups. This observation implies that female in more developed countries postpone their timing for fertility.

Figure 4: Childlessness Rate Over Life Cycle by Income



Note: This figure plots the life-cycle childlessness rate over ages (5-year age bin) across income groups. Childlessness rate is calculated from IPUMS-I, focusing on female aged from 15 to 54 and GDP per capita is extracted from Penn World Table 10.0. The threshold is $5,500, and $15,200.

Figure 5: Childlessness Rate Over Life Cycle by Demographic and Socio-economic Subgroup



Note: This figure plots the life cycle childlessness rate over ages (5-year age bin) across income groups by different demographic and socioeconomic subgroups: education, urban/rural residence/ marital status and employment. Childlessness rate is calculated from IPUMS-I, focusing on female aged from 15 to 54 and GDP per capita is extracted from Penn World Table 10.0. The threshold is \$5,500, and \$15,200. Education has four subgroups: less than primary, primary completed, secondary completed and university completed. Marital status is divided as ever-married (married, divorced, widowed) and never-married.

3.2 Heterogeneity Over Demographic Subgroups

What is the driving force of this delay of having children in richer countries? To understand this question, I further investigate the life-cycle childlessness rate across different demographic subgroups, which includes education, urban-rural residence, marital status, and employment status, which is highlighted in Figure 4 is very robust in different subgroups: a sharp decline before age 35 and constant afterwards. Second, there is a relative delay of having kids for more educated groups and urban residence. In particular, for female aged 20 to 24 with education less than primary school, only 30% of them are childless. However, such percentage increases to 39%, 65%, and 77% for primary-completed, secondary-completed, and university-completed, respectively. While 36% of rural female is childless between age 20 to 24, 51% of urban female in the same age bin is childless. Third, the childlessness rate is systematically higher for the never-married subgroup. Strikingly, for female ever-married during age 15 to 19, about 55% of them have given birth. Childlessness rate gradually declines to 5% after age 35 for ever-married female, and for those never-married, half of them have kids by age 35. The life cycle childlessness profile is more flattened since the ever-married rate increases sharply from 15 to 39, suggested by Feng and Ren (2021a). Lastly, the childlessness pattern seems similar for female employed and unemployed.

Next, I investigate the life cycle childlessness pattern for female and male. Because there is no direct information of number of children for male across a wide range of countries, I instead restrict the population to the married cohorts. By matching the spouse location and person number within a household, I can get the information of number of children for a married male. This life cycle comparison across genders sheds lights on timing of motherhood and fatherhood, in some extent. Figure 11 shows that the childlessness rate is similar across gender at age 15 and above age 40. The main difference is a delay of fatherhood compared with motherhood: at age 20 to 24, 30 percent of married male are childless while 21 percent of married female are childless. The childlessness rate gender gap shrinks gradually to 6% at age 25 to 29, and to 3% at age 30 to 34. To further investigate the cross-country heterogeneity, I reproduce Figure 11 by country income groups in Figure 12. There are two main observations. First, the life cycle childlessness profile is relatively steeper in lower income countries. Second, the childlessness rate gap between male and female is narrower in higher income countries, which might be a result of narrower within marriage age gap in richer countries, as indicated by Feng and Ren (2021c).

3.3 Cohorts Effects and Year Effects

4 An Intuitive Model

I provide a simple model in this section to illustrate the main mechanisms of fertility delay and childlessness, combining the insights from career cost of having kids. Under some special conditions, my model can speak to the empirical evidence shown in Section 2 and 3. The insights from this section will be the key ingredients for the quantitative analysis in Section 5. Calculations and proofs are left in the Appendix.

4.1 Set Up

I consider a simple model with a generic female parent who lives for two periods and has at most 1 kid. This set up rules out marriage, focuses on the extensive margin of fertility, and its timing.

In the first period, the female earns the wage rate w drawn from the distribution $\mathcal{W}(w)$ with support $[\underline{w}, \overline{w}]$ with $\underline{w} > 0$. In each period, she chooses the consumption level and decides to have a kid or not $n \in \{0, 1\}$. If she does not have kid for the first period, she will gain a higher level of wage $(1+g)w$. Otherwise, there is no wage growth. This captures the empirical evidence of life-cycle income growth through on-the-job learning (Ma et al., 2021) and the evidence of the child penalties (Kleven et al., 2019). I assume that g is strictly positive, strictly increasing with w, strictly concave with $g'(w) = 0$ as $w \to \infty$, and bounded above.

The cost of raising children is three-folds. First, there is a direct time cost devoted to rearing the child at the rate of ϕ, which dwindles the labor market participation and thus lower the income at that period. Second, there is an expenditure cost $\gamma > 0$, for example for food and clothes, tuition and so on. Lastly, there is an opportunity cost for having kid in the first period, since female has to give the wage growth in the second period. However, female gains utility from number of kid ever-born and level of consumption each period. The utility from having children is $q(n)$, which is strictly increasing with n. I assume in this model that once the child is born in that period, the child leaves home at the end of this period. In other word, for female with one kid, she only needs to pay for the expenditure and time cost of raising the child only in that period. This assumption mitigates the effect that female choose to delay simply due to early fertility requires to pay expenditure cost in each period.

The utility is time-separable. And there is no discounting between two periods, which is similar with Doepke et al. (2021). Female solves the following maximization problem

$$V(n_1, n_2) \equiv \tilde{V}(n_1, n_2, c_1, c_2) = [u(c_1) + q(n_1)] + [u(c_2) + q(n_2 + n_1)] \tag{8}$$

subject to

$$c_1 = w(1 - \phi n_1) - \gamma n_1, \quad c_2 = w(1 + g\mathbf{1}\{n_1 = 0\})(1 - \phi n_2) - \gamma n_2, \quad 0 \le n_1 + n_2 \le 1 \tag{9}$$

where the utility function u is strictly increasing, strictly concave and satisfies Inada condition. Here my analysis focueses on the case with logarithm utility. In the Appendix, I derive results for more general CRRA utility. The utility from number of kid enters in each time period, which is a simple way to include the potential differential fertility timing preference.

4.2 Discussion

My discussion are divided into the following three steps, which helps to understand the economic force contributes to these choices. First of all, I simply consider the fertility timing decision conditional on female with one kid. This allows me to answer the following question in Section **??**: if given the opportunity of having one kid, for female with type (w, q), does she prefer fertility delay? Based on the answer of this question, I follow up with whether having child is possible for this female and whether this female prefers to do so, which is elaborated in Section 4.2.2. Finally, I unify these two results and summarizes in Proposition **??**, which facilitates the key ingredients to plot fertility choice on (w, q) plane. It can be served as a bridge between individual fertility problem and aggregate childlessness rate.

4.2.1 Fertility Timing

In this section, I investigate the mechanism for fertility timing decision and try to connect this model to the empirical evidence in Section 3. The wage rate w can be regarded as comparing the females in different countries with same demographic subgroup, echoing the empirical evidence in Panel A Figure 5 that female with higher education delay their fertility. Alternatively, different wage rates can be interpreted as female from countries in different income level, which corresponds to Figure **??** that females in developed countries delay their fertility. Back to the model, I try to ask under what conditions I obtain the following property

$$\frac{\partial V(0,1) - V(1,0)}{\partial w} > 0, \tag{10}$$

In other word, conditional on having 1 kid, do female with higher wage choose to have kid in the second period? Also, I ask, under what condition, females with different fertility timing coexist in the equilibrium.

Proposition 1 (**Wage Growth Motive of Fertility Delay).** *Conditional on having 1 child, there is a wage level effect discourages the delay of fertility, i.e., $\mathcal{W}(w; \phi, \gamma, \sigma) < 0$ and a wage growth effect encourages delay of fertility, i.e., $\mathcal{G}(w; \phi, \gamma, \sigma) > 0$:*

$$\mathrm{d}V(0,1) - V(1,0) = \mathcal{W}(w; \phi, \gamma, \sigma)\mathrm{d}w + \mathcal{G}(w; \phi, \gamma, \sigma)\mathrm{d}g(w) \qquad \text{(Wage Growth Motive of Fertility Delay)}$$

Proposition 1 shows the motives of fertility timing decision under a general setting. Two counterbalancing effects contribute to the fertility timing decision. First, a growth in wage expands the life-time budget constraint, and motivates female to delay their fertility, which I call it *wage growth effect*. While, an increase in wage also pushes down the relative expenditure cost γ/w. And in this way, a higher wage discourages female to delay their timing for having kid. The fertility timing for females with different wage level is ambiguous since female with higher wage level also enjoys a more steeper life-cycle wage profile.

To see this, the Lemma 1 shows that for female with given wage level, if I increase her wage growth, she will be more willing to delaying fertility. And when there is no expenditure cost, wage growth rate is the only channel left.

Lemma 1 (Special Cases for Fertility Delays)**.** *Conditional on having 1 child, if g is constant over w, or if $\gamma = 0$, then for given wage rate w,*

$$\frac{\partial V(0,1) - V(1,0)}{\partial g} > 0, \tag{11}$$

Motivated by Proposition **??**, the empirical evidence that female with higher wages postpone the child born implies a strong wage growth effect that can overpower the wage level effect. In the appendix, I provide a specification of wage growth $g(w)$, a sufficient condition to match the aforementioned empirical results, even for more general cases of CRRA utility.

4.2.2 Childlessness

I distinguish two types of childlessness: the first one purely rises from non-negative consumption, which is called natural sterilization (NS); the second one shows up when the preference for fertility cannot overpower the preference from consumption.

Proposition 2 (**Natural Sterilization**)**.** *Female with $w \leq \underline{w}$ where $(1-\phi)[1+g(\underline{w})]\underline{w} = \gamma$*

In the case of NS, an expenditure cost for raising kid is so high that cannot be covered by some extremely poor females, which is in line of Baudin et al. (2015). In their discussion, they assume a consumption floor for female in raising children. The expenditure cost setting is very similar with their practice.

From the discussion of Section 4.2.1 and 4.2.2, I figure out the conditions for fertility timing, conditional on female having one kid. The next step of the analysis is to compare whether childlessness is preferred for these two groups of females if such option is offered.

Proposition 3 (**Preference Driven Sterilization**)**.** *Conditional on having no kid*

1. *or delay fertility, female with $q < q^{CD}(w)$ prefers childlessness.*
2. *or early fertility, female with $q < q^{CE}(w)$ prefers childlessness.*

4.2.3 Interactions

It is worth mentioning that the interaction between the extensive margin of fertility and its timing can act as an additional mechanism of fertility delay. Consider females with $(1-\phi)w < \gamma$. Even if they have extremely strong preference of having a kid for the first period, they are not optimal do so due to non-negative constraint on consumption. They are forced to wait for another period. And for some of them who does not suffer from NS may have a kid in the second period. I call this a *dynamic motive of fertility delay*. A higher wage growth also makes this particular group of females more likely to delay fertility. But the underlying mechanism is slightly different from NS from Proposition 1. The former group of female are among the poorest, who would have negative consumption if raising child in the first period, which implies the wage growth alleviates their situation in the second period by shielding them from a binding non-negative consumption constraint; while, for the female

To better understand the interaction of these two, I illustrate the joint decision of extensive margin of fertility and its timing by resorting the indifference curves which segment the (w,q) plane. For example, by setting $V(0,1) = V(1,0)$, I identify a set of agents indifferent in fertility timing, denoted by $q = q^{DE}(w)$. Similarly, I define $q^{CD}(w)$ and $q^{CE}(w)$.

Proposition 4 (Properties of Indifference Curves)**.** *If the wage growth effect is strong enough such that $g(w) > \widehat{g}(w)$, then*

1. *$q^{DE}(w)$ is increasing with w;*

2. *$q^{CD}(w)$ is decreasing with w;*

3. *$q^{CE}(w)$ is increasing with w, if $g(w) > \widetilde{g}(w)$; $q^{CE}(w)$ is decreasing with w, if otherwise.*

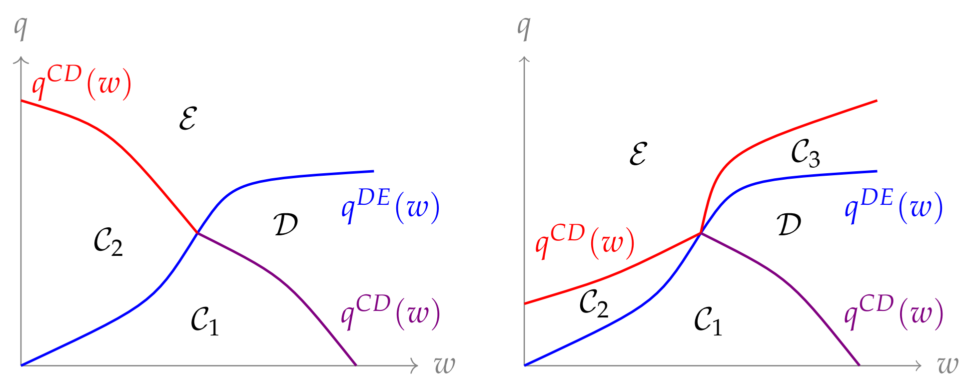
4. *If two of the above indifference curve intersect with each other, these three will jointly intersect at the same point, denoted by (w^*, q^*).*

This proposition helps me to distinguish the fertility decision for agent with type (w, q). Since I did not specify the functional form of $g(w)$, I provide some possible outcomes in Figure 6. The indifference curves segment the plane into several pieces, where $\mathcal{C}$ is for childlessness, $\mathcal{D}$ is for delayed fertility, and $\mathcal{E}$ is for early fertility. Subscription is for illustrative purpose only.

The left panel plots the case when $g(w) > \widetilde{g}(w)$. Female in the southwest corner of the plane choose to be have no kid. For other female, those with relatively higher q will choose early fertility, enjoying two periods flow of utility from having a kid. This case is particular interesting for its aggregate implication. If the conditional PDF of q is the same across w, the childlessness rate is declining from lower wage to higher wage. Despite it cannot replicate the U-shaped childlessness relationship, it is illuminating how *wage growth effect* can generate the left-side of the U-shaped curve, a mechanism that is distinct from Baudin et al. (2015).

The right panel plots one case for $widetildeg(w) < g(w) < \widetilde{g}(w)$. Notice that $q^{CE}(w)$ and $q^{DE}(w)$ are upward sloping. I cannot compare the level of these two curves, which implies area $\mathcal{C}_2$ and $\mathcal{C}_3$ may not show up on the plane. In this case, childlessness may rise for those with relative high income at region $\mathcal{C}_3$. This time, I cannot conjecture how aggregate childlessness rate varies across wage level.

Figure 6: Possible Outcomes of Indifference Curves on (w, q) Plane



The aforementioned cases point out some key ingredients about how individual level fertility decision aggregates up to economy-wide childlessness rates. First, the magnitude of wage growth effect affecs the shapes of indifference curves. Second, the correlation between w and q alters the distribution of agent type. If I assume a the condition PDF of q is the same over w, then it will be very hard to generate an empirically U-shaped childlessness rates.

5 Quantitative Model

In this section, I bring a formal model that embeds the insights from Section 4. On one hand, I bring this model to US and Mexico data to explain the childlessness and fertility pattern within a country. On the other hand, I carry forward this model into US state level data to explore how fertility decision and its timing vary over state with different level of GDP per capita (stage of development).

5.1 Model

In this section, I construct a partial equilibrium life cycle model to connect the timing of fertility with the career cost of having children from life-cycle wage growth. There are two features in this model: a human capital accumulation channel due to on-the-job learning and an endogenous fertility decision.

Time is discrete. The economy is populated by J overlapping generations of females, who discount time at the rate of β. At the start of each period, agent is characterized by the tuple (h, y, o, j), where h is the level of human capital, y is the number of young children at home, o is the number of old children that have left home, e is the experience at work, j is her age. The total number of children is $n = y + o$, which is bounded by $\overline{n}$. Each period, agent makes fertility decision for new-born $b \in B \equiv \{0, 1, 2, 3, \cdot, \overline{b}\}$ and consumption decision c. Staring from a deterministic age $J_{\text{infertile}}$, female become infertile and no longer capable to having new-born.

The budget constraint depends on the fertility status, level of human capital and education attainment, which admits the following form

$$c(y, b, h) = [1 - \phi(y + b)]wh - \gamma(y + b), \tag{12}$$

where ψ measures the time cost of having a kid and γ is the average cost of raising a child at home. Similar as Baudin et al. (2015), I assume the following function form of utility

$$U^i(h, y, o, b) = \log[c^i(y, b, h)] + \theta^i \log\left(y^i + o^i + \zeta\right) \tag{13}$$

where a positive ψ allows childlessness. The evolution of human capital follows $h' = (1 + \mathbf{1}\{b = 0\}g_j)h$ ($h' = (1 - \mathbf{1}\{b > 0\}\psi)(1 + g_j)h$). If female have new-born in a certain period, there is no increment in human capital.

Moreover, in each period, the kid moves out from the home with probability λ for each period. I fact, I restrict that, there is at most 1 kid leaving in each period. This setting rules out that early arrival of kid implies paying more periods of expenditure cost. Additionally, it keeps the model tractable because I do not need to trace the entire history of each children. The Bellman equation for the parent is given by

$$V^i(h, y, o, j) = \max_{c, b \in B, h'} U^i(h, y, o, b) + \beta \left[\underbrace{(1 - \lambda)V\left(h', y + b, o, j + 1\right)}_{\text{stay}} + \underbrace{\lambda V\left(h', y^{\text{sep.}}, y + o + b - y^{\text{sep.}}, j + 1\right)}_{\text{separation}} \right] \tag{14}$$

where $y^{\text{sep.}} = (y + b - 1)^+$, is the number of young children at home after the separation.

5.2 Calibration [Under Construction]

I follow a two step calibration strategy: first, calibrating the model to match the US economy data in 1990, which serves as an ideal baseline result; second, I calibrate the model to 10 representative economy with different income levels to understand how childlessness rates and fertility time changes over the development.

5.2.1 Calibration to the US Data

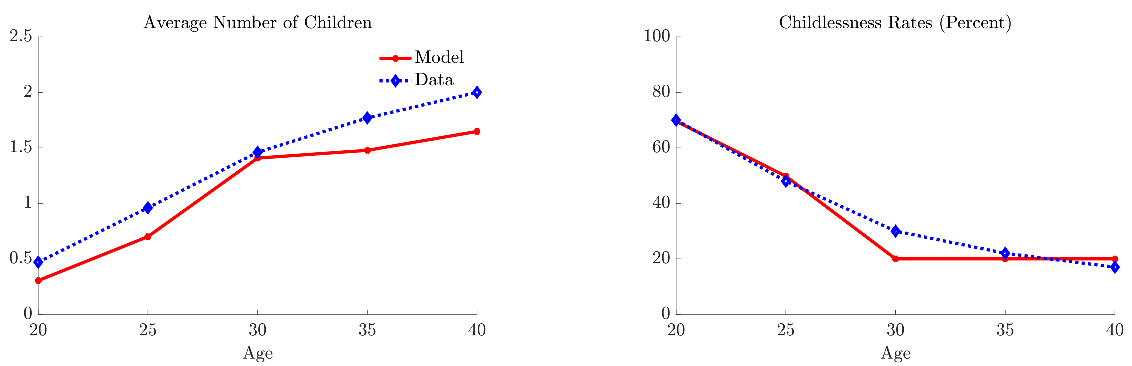
To begin with, I pre-assign the following data moments from direct evidence. The life cycle income growth g_1 to g_J is from Lagakos et al. (2018). The fertility related parameter ζ is assigned to 9.362 and the time cost for having kid is 0.205, following Baudin et al. (2015). The move-out probability per period is set at 0.250, which match the average age of moving out is 19 in US (I.S. Bureau of Labor Statistics). The wage distribution is extracted from IPUMS-I USA 1990 data. I choose this data source since it contains both the income and child born information. The income distribution is log normal with normalized mean of 1 and std of 0.1 to match the coefficient variation of logged income for female in the age group 20-24. The calibration to the US 1990 is summarized in Table 5.

Table 5: Calibration to US 1990

Parameter	Interpretation	Value	Evidence
		Panel A: Pre-assigned Parameters	
$(g_1, ..., g_J)$	life-cycle income growth	/	Lagakos et al. (2018)
ζ	fertility pref. related with childlessness	9.362	Baudin et al. (2015)
ϕ	time cost for having kid	0.205	Baudin et al. (2015)
λ	move-out probability per period	0.250	Average age of move-out is 19
(μ, σ)	log wage distribution for age 20-24	$(1, 0.1)$	IPUMS-I USA 1990
		Panel B: Internally-calibrated Parameters	
$(\theta^H, \theta^L, \pi^H)$	types of fertility preference	(5,2,0.35)	Life-cycle average number of children
γ	expenditure cost	0.7	Life-cycle childlessness rates

Figure 7 shows the goodness of fitness of this model.

Figure 7: Goodness of Fitness: US 1990



Note: This figure compares the life-cycle fertility on both the average number of children and the childlessness rates.

6 Concluding Remarks

In this paper, I study the relation between childlessness, the extensive margin of fertility, and development. I highlight that in low- and high-income countries, childlessness rates are higher, which is distinct with the negative fertility-development gradient in the previous research. Comparing the life-cycle childlessness rate, I find female in richer income countries are more likely to postpone their fertility.

Motivated by these empirical evidence, I illustrate the key ingredients of fertility decision in a two-period illustrative model. Following the approach from micro-to-macro, I first illuminate the mechanisms for different fertility decisions. Delayed fertility is desirable for females with higher wage due to a dominant wage growth effect. There are two reasons for having no child: natural sterilization and preference-driven childlessness. Based on this individual decisions, I articulate the possible equilibrium outcome for the coexistence of different fertility scheme by utilizing indifference curve and consumption constraint to separate agents with different types. My model theoretically speaks to the weakly decreasing childlessness rates up to some wage level, which simultaneously matches the previous empirical results. This pattern is hardly to match using canonical model in the previous literature.

I bring the insight of this illustrative example into a formal quantitative model and replicate the result that holding all others fixed, a higher income growth profile corresponds to a delay of fertility. This exercise speaks to the data that life-cycle income growth is higher in developed countries and for those more educated female. Meanwhile, my empirical finding also suggests a delay of fertility for female in richer countries and highly educated.

I will conduct following analysis to enrich this paper. A good follow-up exercise is to calibrate the quantitative model to the data. This can be served as the starting point to understand the composition of cost of fertility across countries. In particular, a comparison of career cost generated in the model with preliminary estimation result from Kleven and Leite-Mariante (2022) is very promising [1]. Also, it is useful to understand to what extent the career cost contribute to the fertility timing difference across countries.

[1] The preliminary estimation results are subject to changes.

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A Data

A.1 Details on Cross-Sectional Data

A.2 Details on US Time Series Data

To extend the time window for comparable childlessness rates data, I gather data from different sources. All of these US data is national representative.

Table 6: Sample Selection

Country	Country Code	No. Sample	Time Span		Childless%		Agg. Fertility		GDP p.c. range	
			start	end	start	end	start	end	min	max
Argentina	ARG	3	1980	2001	35	35	1.8	1.8	4500	13500
Armenia	ARM	2	2001	2011	33	35	1.6	1.5	4000	10000
Belarus	BLR	2	1999	2009	25	25	1.4	1.3	9000	17000
Benin	BEN	3	1992	2013	23	32	3.3	2.7	1500	2500
Bolivia	BOL	4	1976	2012	32	23	3.1	2.6	2500	6500
Botswana	BWA	1	1991	1991	28	28	2.7	2.7	7500	7500
Brazil	BRA	6	1960	2010	40	36	3.0	1.5	2500	15000
Burkina Faso	BFA	1	2006	2006	26	26	3.1	3.1	1500	1500
Cambodia	KHM	4	1998	2013	35	38	2.7	1.8	1500	3000
Cameroon	CMR	1	2005	2005	29	29	2.6	2.6	3000	3000
Canada	CAN	1	1971	1971	16	16	2.5	2.5	22000	22000
Chile	CHL	5	1960	2002	40	27	2.3	1.8	5000	11500
Colombia	COL	4	1973	2005	29	32	3.4	1.8	6000	8500
Costa Rica	CRI	4	1973	2011	38	31	3.0	1.7	7500	14500
Dominican Republic	DOM	3	1970	2010	38	29	3.1	2.0	3000	13000
Ecuador	ECU	3	1990	2010	32	30	2.6	2.0	6000	10000
El Salvador	SLV	1	2007	2007	32	32	2.0	2.0	4500	4500
Ethiopia	ETH	1	2007	2007	33	33	2.8	2.8	1000	1000
Fiji	FJI	1	2007	2007	32	32	2.0	2.0	6500	6500
Ghana	GHA	2	2000	2010	30	38	2.8	2.2	3500	4500
Guatemala	GTM	5	1964	2002	31	34	2.9	2.6	2500	5500
Guinea	GIN	2	1996	2014	18	30	3.4	2.9	2000	4000
Haiti	HTI	1	2003	2003	40	40	2.3	2.3	2000	2000
Honduras	HND	3	1974	2001	30	33	3.5	2.5	2500	3500
Hungary	HUN	1	1990	1990	26	26	1.5	1.5	14000	14000
Indonesia	IDN	6	1971	2010	10	30	3.9	1.8	1500	8000
Iran	IRN	2	2006	2011	17	0	2.7	2.7	16000	20000
Iraq	IRQ	1	1997	1997	11	11	4.2	4.2	5000	5000
Ireland	IRL	2	2011	2016	46	45	1.3	1.3	53500	81000
Israel	ISR	1	1995	1995	35	35	1.8	1.8	28500	28500
Jamaica	JAM	1	2001	2001	29	29	2.0	2.0	6000	6000
Kenya	KEN	3	1989	2009	22	30	3.8	2.8	2000	2500
Kyrgyzstan	KGZ	2	1999	2009	27	33	2.3	1.9	2500	3500
Lao People's DR	LAO	1	2005	2005	31	31	2.1	2.1	3000	3000
Lesotho	LSO	2	1996	2006	39	36	2.2	1.8	3000	3000
Liberia	LBR	1	2008	2008	35	35	2.6	2.6	1000	1000
Malawi	MWI	3	1987	2008	20	23	3.8	3.1	1000	1500
Malaysia	MYS	2	1970	1980	6	7	4.4	3.9	4000	7500
Mali	MLI	2	1998	2009	28	32	3.3	2.7	1500	2000
Mauritius	MUS	3	1990	2011	10	9	2.8	2.0	12000	19000
Mexico	MEX	5	1970	2015	37	31	3.3	1.8	9000	18500
Morocco	MAR	1	2014	2014	12	12	2.8	2.8	7000	7000
Mozambique	MOZ	2	1997	2007	25	23	3.0	2.9	1000	1000
Myanmar	MMR	1	2014	2014	14	14	2.6	2.6	5000	5000
Nepal	NPL	2	2001	2011	18	17	2.7	2.4	1500	2500
Nicaragua	NIC	1	2005	2005	28	28	2.5	2.5	4500	4500
Nigeria	NGA	2	2006	2007	10	6	3.6	4.0	4000	4500
Pakistan	PAK	1	1973	1973	15	15	3.7	3.7	2000	2000
Panama	PAN	4	1970	2010	32	30	2.9	1.9	5500	16500
Paraguay	PRY	5	1962	2002	37	31	2.6	2.4	2500	7000
Peru	PER	2	1993	2007	33	29	2.5	2.0	4000	8500
Philippines	PHL	1	1990	1990	10	10	3.3	3.3	4000	4000
Romania	ROU	3	1992	2011	31	35	1.6	1.2	7000	18500
Russian Federation	RUS	2	2002	2010	28	29	1.3	1.2	10500	24000
Rwanda	RWA	2	2002	2012	36	36	2.9	2.4	1000	2000
Senegal	SEN	2	2002	2013	28	36	3.1	2.4	3000	3000
Sierra Leone	SLE	1	2004	2004	33	33	2.9	2.9	1000	1000
Slovenia	SVN	1	2002	2002	37	37	1.2	1.2	24500	24500
South Africa	ZAF	4	1996	2011	27	30	2.2	1.7	9500	13500
Spain	ESP	1	1981	1981	9	9	2.4	2.4	15000	15000
State of Palestine	PSE	3	1997	2017	12	11	4.6	3.8	3500	6500
Sudan	SDN	1	2008	2008	25	25	3.4	3.4	3000	3000
Togo	TGO	1	2010	2010	25	25	2.9	2.9	1500	1500
U.R. of Tanzania	TZA	2	2002	2012	26	26	3.3	3.0	1500	2500
Uganda	UGA	3	1991	2014	25	28	3.5	3.2	1000	2000
Ukraine	UKR	1	2001	2001	26	26	1.3	1.3	5000	5000
United States	USA	2	1960	1990	16	35	2.3	1.5	19000	39500
Uruguay	URY	2	1975	1985	36	34	1.8	1.8	8000	8500
Venezuela	VEN	2	1990	2001	30	31	2.4	2.1	8500	8500
Viet Nam	VNM	3	1989	2009	36	35	2.1	1.4	1000	4000
Zambia	ZMB	2	1990	2000	44	35	2.6	2.7	1500	1500
Zimbabwe	ZWE	1	2012	2012	30	30	2.0	2.0	3000	3000

Table 7: Data Sources: USA Time Series

Year	Name	Source	Variable	Universe
1900	1900 5 percent/ 1900 100 percent	IPUMS-USA	CHBORN	
1910	1910 1 percent/ 1910 100 percent	IPUMS-USA	CHBORN	
1940	1940 1 percent/ 1940 100 percent	IPUMS-USA	CHBORN	
1970	1970 1 neighborhood	IPUMS-USA	CHBORN	
1976	June 1976	IPUMS-CPS	FREVER	
1977	June 1977	IPUMS-CPS	FREVER	
1979	June 1979	IPUMS-CPS	FREVER	
1980	June 1980	IPUMS-CPS	FREVER	
1980	1980 5 percent state	IPUMS-USA	CHBORN	
1981	June 1981	IPUMS-CPS	FREVER	
1982	June 1982	IPUMS-CPS	FREVER	
1983	June 1983	IPUMS-CPS	FREVER	
1984	June 1984	IPUMS-CPS	FREVER	
1986	June 1986	IPUMS-CPS	FREVER	
1987	June 1988	IPUMS-CPS	FREVER	
1987	June 1988	IPUMS-CPS	FREVER	
1990	1990 5 percent state	IPUMS-USA	CHBORN	
1992	June 1992	IPUMS-CPS	FREVER	
1994	June 1994	IPUMS-CPS	FREVER	
1995	June 1995	IPUMS-CPS	FREVER	
2000	June 2000	IPUMS-CPS	FREVER	
2002	June 2002	IPUMS-CPS	FREVER	
2004	June 2004	IPUMS-CPS	FREVER	
2006	June 2006	IPUMS-CPS	FREVER	
2008	June 2008	IPUMS-CPS	FREVER	
2010	June 2010	IPUMS-CPS	FREVER	
2012	June 2012	IPUMS-CPS	FREVER	
2014	June 2014	IPUMS-CPS	FREVER	
2016	June 2016	IPUMS-CPS	FREVER	
2018	June 2018	IPUMS-CPS	FREVER	
2020	June 2020	IPUMS-CPS	FREVER	

A.3 Details on UNSD Data

- Female population by age, number of children ever born and urban/rural residence is available http://data.un.org/Data.aspx?d=POP&f=tableCode%3a40
- Live births by age of mother and sex of child is available http://data.un.org/Data.aspx?d=POP&f=tableCode%3a260
- Maternity leave benefits is available http://data.un.org/DocumentData.aspx?id=344

A.4 Sample Selections

A.4.1 Individual Level Income and Childlessness Data

Table 8: Sample Selection: Individual Level Income and Childlessness

Country Name	Year
Brazil	1970, 1980, 1991, 2000, 2010
Canada	1971, 1981, 1991
Colombia	1973
Dominican Republic	1981, 2002
Mauritius	2000
Mexico	1970, 2000
Panama	1980, 1990, 2010
Puerto Rico	1970, 1980, 1990
South Africa	1996, 2001, 2007, 2011
Trinidad and Tobago	1970, 2000
United States	1960, 1970, 1980, 1990
Venezuela	2001
No. Country: 12	No. Sample: 31; Time Span: 1970 - 2011

General amounts are expressed as they were reported at the time of the census in the currency of the respective country. Figures are not adjusted for inflation or devaluation. Figures for some samples represent the midpoints of intervals and are not exact currency amounts.

The time window for the data differs:

1. Previous calendar year: Canada, Puerto Rico 1970-2000, United States 1960-2000

2. Previous twelve months: Puerto Rico 2005-2010, South Africa, United States 2005-2015

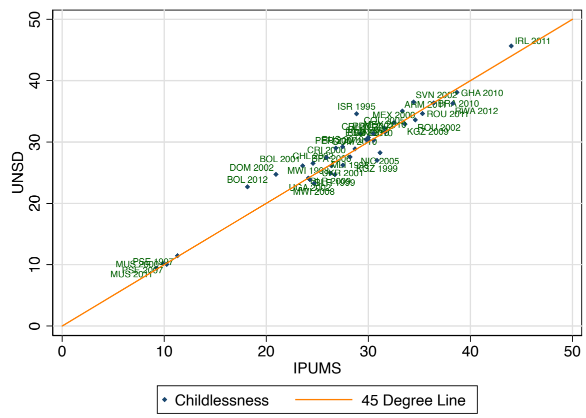
3. Previous month: Brazil, Colombia, Dominican Republic, Indonesia, Mauritius, Mexico, Panama, Trinidad and Tobago 2000, Venezuela

4. The universe for 1981 Dominican Republic includes only people who ever worked, which is more restrictive than other samples.

B Figures

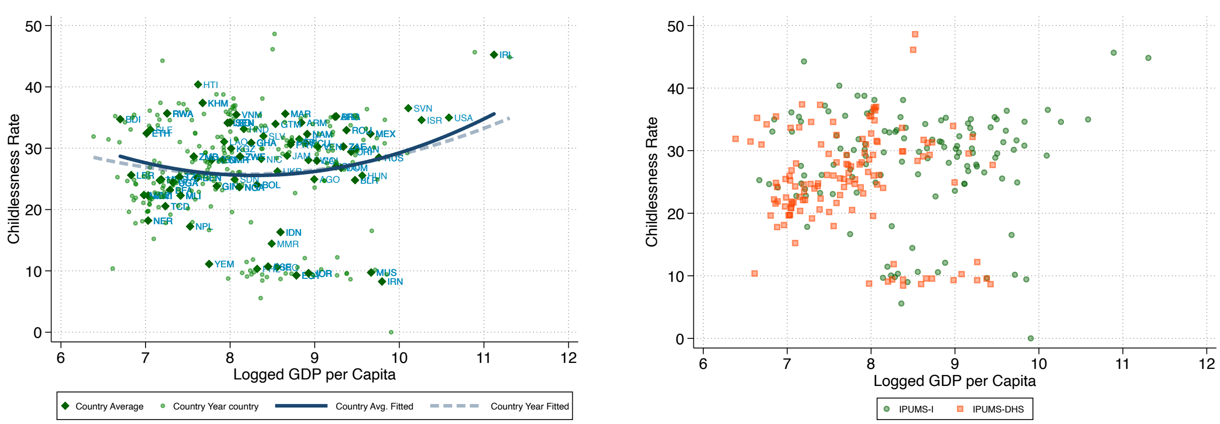
B.1 Childlessness Rates Comparison From Different Data Sources

Figure 8: Childlessness Rates Comparison: IPUMS and UNSD



B.2 Robustness Check of U-Shaped Pattern

Figure 9: Robustness Check: Childlessness Rates Across Countries

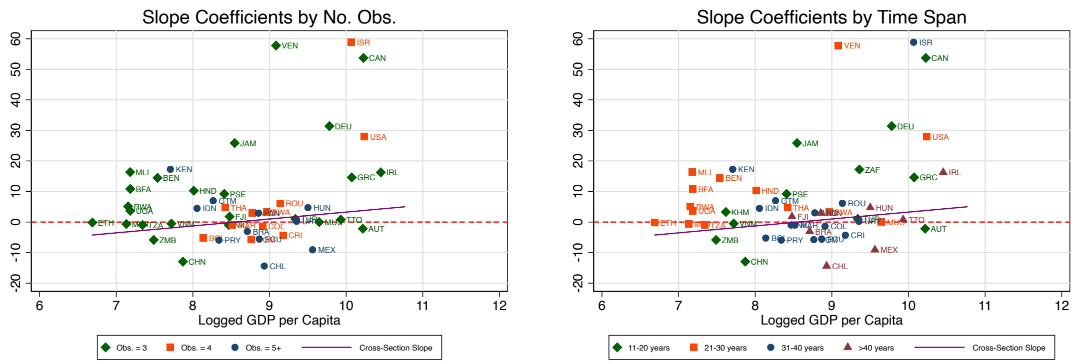


Note: This figure shows the relationship between childlessness rate and fertility (measured by average children ever born) with logged GDP per capita using all country-year sample available from IPUMS-I and IPUMS-DHS, focusing on female aged from 15 to 54. GDP per capita is extracted from Penn World Table 10.0. The left panel shows the U-shaped pattern is well-preserved. The right panel compares data from two sources.

B.3 Comparing Slope Coefficients between Time Series and Cross-Sectional Data

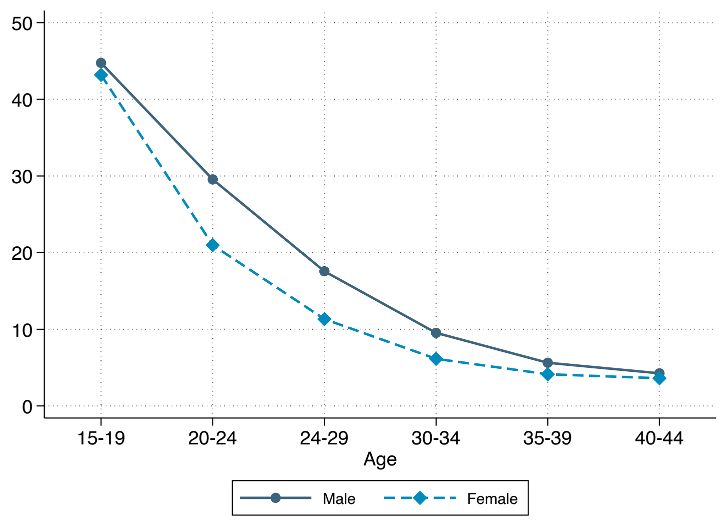
B.4 Life-Cycle Childlessness Rates by Gender and Income Levels

Figure 10: Comparison of Time Series and Cross-Sectional Slope Coefficients



Note: This two panels replicating the right panel of Figure 2. Each dot represents a time-series coefficient for a country. Dots are colored by number of observations available (left panel) and time span of data available for a country (right panel).

Figure 11: Childlessness Rate Over Life Cycle for Married Male and Female



Note: This figure plots the life cycle childlessness rate over ages (5-year age bin) across income groups. Childlessness rate is calculated from IPUMS-I, focusing on female aged from 15 to 54 and GDP per capita is extracted from Penn World Table 10.0.

C Theory

C.1 Premise

Notice that $q(0)$ is normalized as 0 and $q(1) = q$, the utility for different fertility schemes is given by

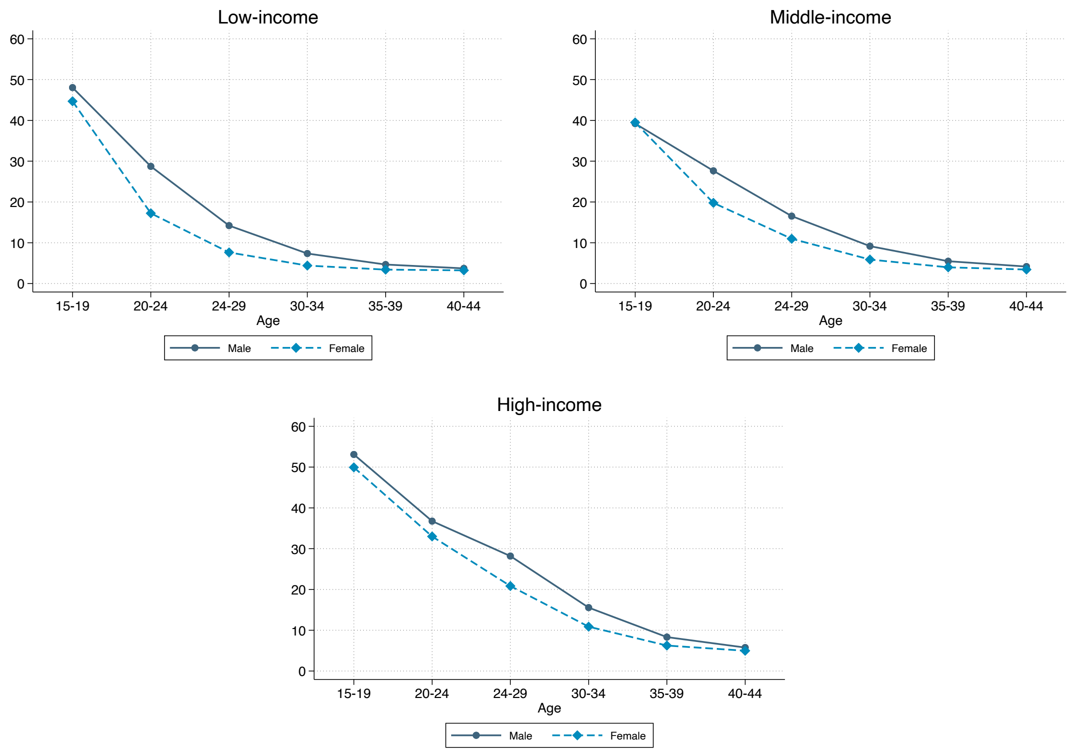
$$V(1,0) = u(w(1-\phi) - \gamma) + u(w) + 2q \qquad \text{(Early Fertility (E))}$$

$$V(0,1) = u(w) + u(w(1+g)(1-\phi) - \gamma) + q \qquad \text{(Delay Fertility (D))}$$

$$V(0,0) = u(w) + u(w(1+g)) \qquad \text{(Childlessness (C))}$$

I consider logarithm utility in the following analysis by default. The pairwise differentials in utility are given

Figure 12: Childlessness Rate Over Life Cycle for Married Male and Female by Income Group



Note: This figure plots the life cycle childlessness rate over ages (5-year age bin) across income groups. Childlessness rate is calculated from IPUMS-I, focusing on female aged from 15 to 54 and GDP per capita is extracted from Penn World Table 10.0. The threshold is \$5,500, and \$15,200.

by

$$V(0,1) - V(1,0) = \log\left(\frac{w(1+g(w))(1-\phi)-\gamma}{w(1-\phi)-\gamma}\right) - q \tag{DE}$$

$$V(0,0) - V(0,1) = -\log\left((1-\phi) - \frac{\gamma}{w(1+g(w))}\right) - q \tag{CD}$$

$$V(0,0) - V(1,0) = \log\left(\frac{w(1+g(w))}{w(1-\phi)-\gamma}\right) - 2q \tag{CE}$$

C.2 Proof of Proposition 1

Taking derivative with respect to w in (DE) leads to

$$\frac{\mathrm{d}V(0,1)-V(1,0)}{\mathrm{d}w} = \frac{(1-\phi)[1+g+wg'(w)]}{w(1+g(w))(1-\phi)-\gamma} - \frac{1-\phi}{w(1-\phi)-\gamma} \tag{15}$$

$$= \underbrace{\frac{1-\phi}{w(1-\phi)-\frac{\gamma}{1+g}} - \frac{1-\phi}{w(1-\phi)-\gamma}}_{\mathcal{W}(w;\phi,\gamma,\sigma)<0} + \underbrace{\frac{w}{w(1+g(w))(1-\phi)-\gamma}}_{\mathcal{G}(w;\phi,\gamma,\sigma)>0} g'(w) \tag{16}$$

The first inequality utilizes $g > 0$. This result immediately gives us Lemma 1.

Now I consider a more general case for CRRA utility function with parameter σ.

$$V(0,1) - V(1,0) = u[w(1+g(w))(1-\phi)-\gamma] - u(w(1-\phi)-\gamma) - q \tag{17}$$

Taking the derivative with respect to w

$$\frac{\partial V(0,1)-V(1,0)}{\partial w} = \underbrace{(1-\phi)[(1+g(w))u'[w(1+g(w))(1-\phi)-\gamma]-u'(w(1-\phi)-\gamma)]}_{\text{wage level effect (+/-)}} \tag{18}$$

$$+\underbrace{w(1-\phi)u'(w(1+g(w))(1-\phi)-\gamma)\frac{\mathrm{d}g(w)}{\mathrm{d}w}}_{\text{wage growth effect(+)}} \tag{19}$$

Taking the derivative with respect to ϕ

$$\frac{\partial V(0,1)-V(1,0)}{\partial \phi} = -w\left\{(1+g(w))u'[w(1+g(w))(1-\phi)-\gamma]-u'(w(1-\phi)-\gamma)\right\} \tag{20}$$

Proof. Comparing the utility for early and delayed fertility $V(1,0)$ and $V(0,1)$

$$V(0,1)-V(1,0) = u[w(1+g(w))(1-\phi)-\gamma]-u(w(1-\phi)-\gamma)-q \tag{21}$$

1. Let $\gamma = 0$,

$$V(0,1)-V(1,0) = \log[1+g(w)]-q, \tag{22}$$

which is increasing in w. The cutoff is $\hat{w}(q) = g^{-1}[\exp(q)-1]$, where g^{-1} denotes the inverse function of g.

2. Taking the derivation with respect to w

$$\frac{\partial V(0,1)-V(1,0)}{\partial w} = \underbrace{(1-\phi)[(1+g(w))u'[w(1+g(w))(1-\phi)-\gamma]-u'(w(1-\phi)-\gamma)]}_{\text{wage level effect (+/-)}} \tag{23}$$

$$+\underbrace{w(1-\phi)u'(w(1+g(w))(1-\phi)-\gamma)\frac{\mathrm{d}g(w)}{\mathrm{d}w}}_{\text{wage growth effect(+)}} \tag{24}$$

The first term is the wage level effect, which is undetermined so far. The second term captures the wage growth effect, because $g(w) > 0$ for all w by Assumption which is strictly positive. **??**. Under CRRA utility, the sign function for the wage level effect

$$\begin{aligned}\text{sgn[wage level effect]} &= \text{sgn}\{(1+g(w))[w(1+g(w))(1-\phi)-\gamma]^{-\sigma}-[w(1-\phi)-\gamma]^{-\sigma}\} \\ &= \text{sgn}\left\{\left[\frac{w(1+g(w)(1-\phi)-\gamma)}{w(1-\phi)-\gamma}\right]^{-\sigma}-\frac{1}{1+g}\right\} \\ &= \text{sgn}\left[(1+g)^{\frac{1}{\sigma}}-\left(1+\underbrace{\frac{w(1-\phi)}{w(1-\phi)-\gamma}}_{>1}g\right)\right]\end{aligned}$$

which implies that a higher level of σ (a lower level of intertemporal elasticity of substitution) results in a more negative wage effect. It is easy to find when $\sigma = 1$, the wage level effect is also negative. Thus for all $\sigma \geq 1$, I have a negative wage effect.

Now I derive the sufficient condition when the wage growth effect is strong enough. Here I am back to logarithm utility and solve the following ordinary difference equation

$$\frac{\mathrm{d}g(w)}{\mathrm{d}w} = \frac{g(w)\gamma}{(1-\phi)w^2 - \gamma w} \tag{25}$$

which is obtained by setting Equation 24 to zero. Setting the initial condition of ODE with $g(\underline{w}) = \underline{g}$. After some simple algebra, I obtain

$$\frac{1}{g(w)}\mathrm{d}g(w) = \frac{\gamma}{(1-\phi)w^2 - \gamma w}\mathrm{d}w \tag{26}$$

$$= \frac{1-\phi}{(1-\phi)w - \gamma} - \frac{1}{w}\mathrm{d}w \tag{27}$$

Integrating both sides and using the initial condition $g(\underline{w}) = \underline{g}$, I obtain

$$g(w) > \widehat{g}(w) \equiv \omega(w;\gamma,\phi)\underline{g}, \quad \text{where} \quad \omega(w;\gamma,\phi) \equiv \frac{1-\phi-\frac{\gamma}{w}}{1-\phi-\frac{\gamma}{\underline{w}}}$$

which utilizes one-dimensional comparison theorem.

■

C.3 Proof of Proposition 2 and 3

Proposition 2 is obtained by non-negative consumption and $g'(w) > 0$. This ensures a unique a wage threshold. Proposition 3 follows from (CD) and (CE) immediately.

C.4 Proof of Proposition 4

Taking derivatives with respect to w and q for (DE) and (**??**), I have

$$\frac{\partial V(0,0) - V(0,1)}{\partial w} < 0, \quad \frac{\partial V(0,0) - V(0,1)}{\partial q} < 0 \tag{28}$$

By assuming a strong enough wage growth effect, I obtain

$$\frac{\partial V(0,1) - V(1,0)}{\partial w} > 0, \quad \frac{\partial V(0,0) - V(0,1)}{\partial q} < 0 \tag{29}$$

The remaining piece is that

$$\frac{\partial V(0,0) - V(1,0)}{\partial w} ?0, \quad \frac{\partial V(0,0) - V(1,0)}{\partial q} < 0 \tag{30}$$

First, consider the case that

$$\frac{\partial V(0,0) - V(1,0)}{\partial w} > 0 \tag{31}$$

It requires

$$\frac{g'(w)}{1+g(w)} > \frac{1}{w - \frac{\gamma}{1-\phi}} - \frac{1}{w}, \tag{32}$$

where the left hand side equals to $\frac{\mathrm{d}\log(1+g(w))}{\mathrm{d}w}$. After some algebra, I arrive at

$$\log(1+g(w)) = \log\left(w - \frac{\gamma}{1-\phi}\right) - \log w + \log C. \tag{33}$$

To pin down the constant C, I substitute the initial value of $g(\underline{w}) = \underline{g}$,

$$C = \frac{1+\underline{g(w)}}{1 - \frac{\gamma}{\underline{w}(1-\phi)}}. \tag{34}$$

Substitute back, I obtain

$$g(w) > \widetilde{g}(w) \equiv \omega(w;\gamma,\phi)(1+\underline{g}) - 1, \text{where} \quad \omega(w;\gamma,\phi) \equiv \frac{1-\phi-\frac{\gamma}{w}}{1-\phi-\frac{\gamma}{\underline{w}}} \tag{35}$$

The last step is to apply implicit function theorem to obtain parts 1 to 3.

If there is an intersection between two of these indifference curves, the third one will definitely pass through the intersection by definition. For example, $V(0,1) - V(1,0) = 0$ and $V(0,1) - V(0,0) = 0$ imply $V(1,0) - V(1,0) = 0$.

C.5 Special cases for Indifference Curves on (w, q) Plane

Taking derivative with respect to ϕ, I get

$$\frac{\mathrm{d}V(0,1) - V(1,0)}{\mathrm{d}\phi} = w\left[\frac{1}{w(1-\phi)-\gamma} - \frac{1}{w(1-\phi) - \frac{\gamma}{1+g}}\right] > 0 \tag{36}$$

$$\frac{\mathrm{d}V(0,0) - V(0,1)}{\mathrm{d}\phi} > 0 \tag{37}$$

$$\frac{\mathrm{d}V(0,0) - V(1,0)}{\mathrm{d}\phi} > 0 \tag{38}$$