

Demographic Patterns and Household Saving in China[†]

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This paper studies how demographic variation affects the aggregate household saving rate. We focus on China because it is experiencing an historic demographic transition and has had a massive increase in household saving. We conduct a quantitative investigation using a structural overlapping generations model that incorporates parental care through support for dependent children and financial transfers to retirees. The saving decisions in the parameterized model mimic many of the features observed in the Chinese household saving rate time series from 1955 to 2009. Demographic change alone accounts for over half of the saving rate increase. (JEL D12, D91, E21, J11, O12, O16, P36)

This paper studies how demographic change affects the aggregate household saving rate. We focus on China because it has experienced large variations along both these dimensions. Moreover, China now plays a major role in the global economic system, and, during the last three decades, its economy has grown to become the world's second biggest in terms of aggregate GDP. China's saving rate also has grown and exceeds that of nearly every other country. The household component of Chinese saving, which in 2009 was 27 percent of income, contributes heavily to the country's investment led growth and helps to finance purchases of foreign currency denominated assets. The associated emergence of an external surplus has led to calls for "rebalancing" growth from investment to consumption (which necessarily means lowering the saving rate). We believe that the effective design of rebalancing policies requires an accurate understanding of the factors responsible for the high saving rate. This paper aims to contribute to such an understanding.

China's aggregate household saving rate has not always been high. From 1955 to 1977 the household saving rate fluctuated around an average of less than 5 percent. Then starting in 1978, the saving rate began to rise. The timing of this change in saving

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behavior coincides with the beginning of an equally dramatic demographic transition. The population began to shift from mostly young to predominantly middle-aged. At the peak of China's baby boom in the 1960s and 1970s, nearly half of the population was under 20. Then, largely as a result of the government's one-child policy, fertility rates plummeted. Today, less than 25 percent of the population is under 20, and the age distribution will continue to skew older for the foreseeable future.

We quantify the effects of China's demographic transition on its household saving rate by building a model of overlapping generations (OLG) of households that incorporates parental support for dependent children and transfers to retirees. In the model, individuals live for 85 years. From birth through age 19, individuals make no decisions and depend on their parents for consumption. At age 20, individuals begin making their own consumption and saving decisions. From 20 to 63 years old, they work and raise children. The number of dependent children and the wage depends on the individual's age. Dependent children's and parent's consumption both enter into parent's (household) utility with parents choosing the consumption of their young. Working age agents save for their own retirement and transfer a portion of their labor income to current retirees. The income transfer to retirees is split into a formal pension system and an informal family network of intergenerational transfers. Retirees (ages 64 and older) live off of accumulated assets, their pension, and family transfers from the currently working generations.

Our first set of model simulations isolate the effect of China's changing demographic structure. We present households in the parameterized model with a future time path for demographics and observe their saving decisions from 1955 to 2009, holding interest rates and labor income (by age) constant.¹ The simulated saving rate starts out low and rises at the same point observed in the data. The demographic changes alone generate over half of the observed increase in China's household saving rate. The large quantitative effect of China's demographic changes on the saving rate within this more or less standard life-cycle model is our main finding.

We emphasize three channels through which demographics affect the saving rate. The first channel is the dependent children effect, which refers to the decline in family size brought about by the one-child policy. All else equal, a household with relatively few children devotes a smaller share of household income to support dependents and therefore has more to save. When we hold the number of dependent children constant at the (relatively large) 1970 level, the household saving rate in 2009 is 7 percentage points smaller than in the simulation that allows family size to vary. The reduction in family size has a large impact on household saving.

The second demographic channel works through the composition effect. Most saving is created from unconsumed labor income earned by the working age population, and the prime working age group (20–63) increased from 46 percent of the

¹The model agents always believe that they possess perfect foresight, but the simulations contain a one time "surprise" change in the projected demographic structure due to the enactment of the one-child policy in 1979. Prior to 1979 agents correctly anticipate the demographic structure pre-1979, while their projections about the demographic structure post-1979 are wrong. In 1979 households learn that the one-child policy will curtail fertility going forward. After 1979, agents actually possess perfect foresight. In Section IVA, we show that the surprise nature of the one-child policy has little effect on the model simulated aggregate household saving rate. What matters more is that fertility rapidly declines, not whether the decline was fully anticipated.

population in 1970 to 65 percent in 2009. All else equal, the increased prevalence of this age group mechanically raises the aggregate saving rate.

The third channel operates through the intergenerational family transfers and the projected decline in workers per retiree. In the model, the amount of old age support per retiree depends on the relative size of the working age cohort. Since current workers in China have few children, the current working age population should save more aggressively because they will be supported in retirement by relatively few working people. In the model simulations, these latter two demographic channels matter for saving, but their impact is quantitatively smaller than the dependent children effect.

In addition to these three demographic channels, the model allows us to examine the effect of increasing lifespans on saving behavior. The relationship is straightforward within the model. Cohorts with longer lifespans spend more of their life in retirement, and must therefore save more during their working years. We also use the model to separately simulate urban and rural saving rates. Urban China has undergone a more dramatic decline in fertility, and urban retirees enjoy larger pensions. We find that these channels mostly offset each other and that both urban and rural households increase their saving rates over time.

We primarily focus on the demographic channels; however, China experienced many institutional and policy changes over the period of our study that also may have affected household saving. The most prominent of these include the Great Leap Forward from 1958 to 1961, the de-collectivization of agriculture in the 1980s, the reform of state-owned enterprises in the 1990s, and the on-going transition toward a free-market economy. Explicitly modeling all of these phenomena would be challenging, to say the least, and is not pursued in the paper. Instead, we try to incorporate these events by capturing their effect on wages and interest rates. Thus, we run several versions of the model that allow the interest rate and wages to vary over time as informed by the data. When households are presented the future time path of demographics, interest rates, and wages, the model can account for an even larger portion of the observed changes in the household saving rate from 1955 to 2009, including some of the short-run movements in saving.

Several theories have been put forth concerning Chinese household saving.² These include the precautionary saving motive in conjunction with relatively high-income risk and changes in the social safety net (Meng 2003; Chamon, Liu, and Prasad 2010; Chamon and Prasad 2010), unintended sex-ratio imbalances resulting from the one-child policy (Wei and Zhang 2011), and changes in the age-earnings profile (Song and Yang 2010). A few papers have also examined life-cycle considerations and demographic variation (Modigliani and Cao 2004; Horioka and Wan 2007; Horioka 2010; Banerjee, Meng, and Qian 2010); however, these studies deduce channels of influence from econometric specifications rather than from quantitative

²The literature has focused on Chinese household saving, while abstracting from corporate and government saving. Yang (2012) is an important exception dealing with China's external imbalance.

models.³ In all likelihood, these mechanisms are all contributing factors in determining the saving rate. In this paper, we focus on the demographic dimension.

The next section presents data on the unprecedented changes to China's age distribution and aggregate household saving rate. We also examine household survey data, which further motivates the connections between family size and saving decisions that we embed in the model. Section II presents the model of household saving, and Section III discusses our parameterization. Section IV reports the results of the quantitative analysis. Section V concludes.

I. China's Household Saving and Demographic Data

This section draws out connections in the data between demographics and the saving rate. Section IA documents the time-series comovement between China's demographic profile and aggregate household saving rate at the macro level. Section IB presents micro data evidence for a negative relationship between family size and household saving.

A. Macro Data

Figure 1 plots China's aggregate household saving rate (household saving divided by household income) from 1955 to 2009. The data comes from various issues of the China Statistical Yearbook. We use the available information as provided by these sources without modification.⁴ The saving rate is relatively low until 1978, after which it increases dramatically. At present, China saves at a rate that greatly exceeds every other large country.⁵ The evolution of China's saving rate has, however, been punctuated by sizable fluctuations. In a short six year span between 1978 and 1984 the saving rate increased by 15 percentage points. Then, saving fell to 10 percent in 1988, after which it resumed a general upward course.

Over this same time period, China experienced a considerable demographic transition. Using historical and projected estimates from the United Nations *World Population Prospects 2010*, Figure 2 displays the evolution of the age distribution from 1950 to 2050 by dividing the population into three age groups. The lower line

³Horioka and Terada-Hagiwara (2012) find that demographics help explain the evolution of saving rates in a panel of Asian countries, again using reduced form regressions. Recent work that employs the OLG framework outside of China to study saving includes Ferrero (2010), who finds an important role for demographics in explaining the long-run trend in US capital flows relative to other G6 countries. Krueger and Ludwig (2007) and Fehr, Jokisch, and Kotlikoff (2007) show the importance of demographic change in multi-country OLG models. Chen, İmrohoroğlu, and İmrohoroğlu (2007) argue that the decline in population growth has had only a small effect on the Japanese saving rate. Our approach differs from these in that we enter consumption by children directly into household utility as in Becker and Barro (1989). Our paper also makes contact with the broader literature on how demographic changes affect the macroeconomy. Shimer (2001) details how the age distribution impacts unemployment rates; Feyrer (2007) relates demographic change to productivity growth; and Jaimovich and Siu (2009) and Lugauer (2012) connect the age distribution to the magnitude of business cycles.

⁴Until 1978, the saving rate is computed using Modigliani and Cao's (2004) methodology. After 1978, the saving rate is disposable income less consumption from the *China Statistical Yearbook*. See Curtis and Mark (2011) for more about Chinese data and studying China using standard economic models. Ma and Yi (2010) also discuss the data and provide some empirical evidence suggesting that demographic change has helped increase the Chinese household saving rate.

⁵For example, the OECD reports 2007 household saving of 4.1 percent of GDP in the United States and 5.8 percent in Japan, compared to 22.2 percent in China.

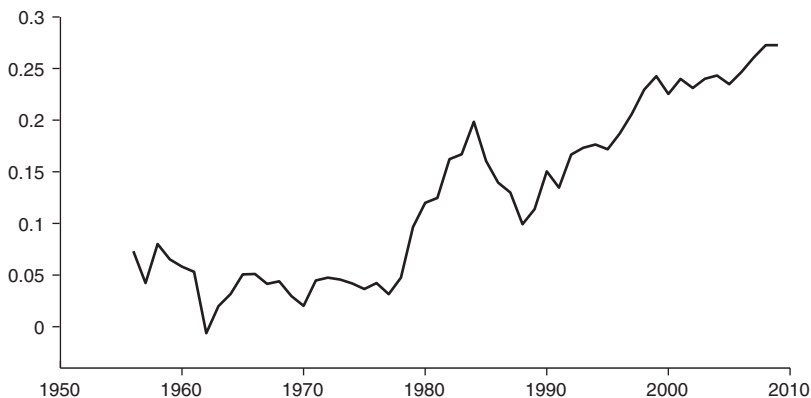


FIGURE 1. SAVING AS A SHARE OF HOUSEHOLD INCOME, 1955–2009

Source: Various issues of the *China Statistical Yearbook*

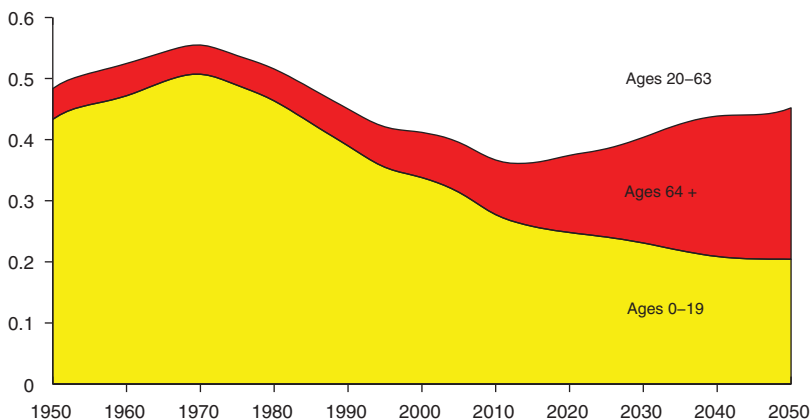


FIGURE 2. YOUTH (0–19), RETIREES (64+), AND WORKING AGE (20–63) AS A SHARE OF POPULATION, 1950–2050

Note: Sum of the three groups equals one but figure is truncated above at 0.60.

Source: *United Nations World Population Prospects 2010*

(bottom, light section) is the fraction of the population under 20, which we take as a coarse measure of the share of dependent children. The middle, dark area is the fraction of the population 63 and older and is an approximation for the number of retirees. The remaining share, ages 20 to 63, is a measure of the working age population. Beginning in 1970, the population has become increasingly older. The share of China's population over 63 is projected to surpass the fraction under 20 before 2035, an event not expected to occur in the United States until 2075.

We hypothesize three principal channels through which the demographic changes depicted in Figure 2 might affect household saving. The first is the dependent children effect which works through changes in family size. The dependent children share shrank from 49 percent of the population in 1970 to 25 percent in 2009. As family size declines, the saving rate should increase since having fewer children to support (all else constant) frees up household resources, which can be saved. As an indication of this channel at work, Figure 3 shows that the ratio of parents (ages

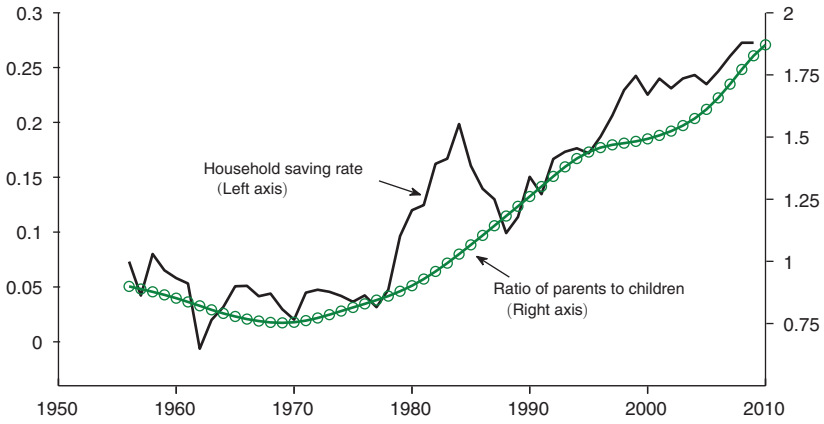


FIGURE 3. HOUSEHOLD SAVING RATE (left axis) AND RATIO OF PARENTS, AGE 20–63, TO CHILDREN, AGE 0–19 (right axis)

Source: United Nations World Population Prospects 2010 and various issues of the China Statistical Yearbook

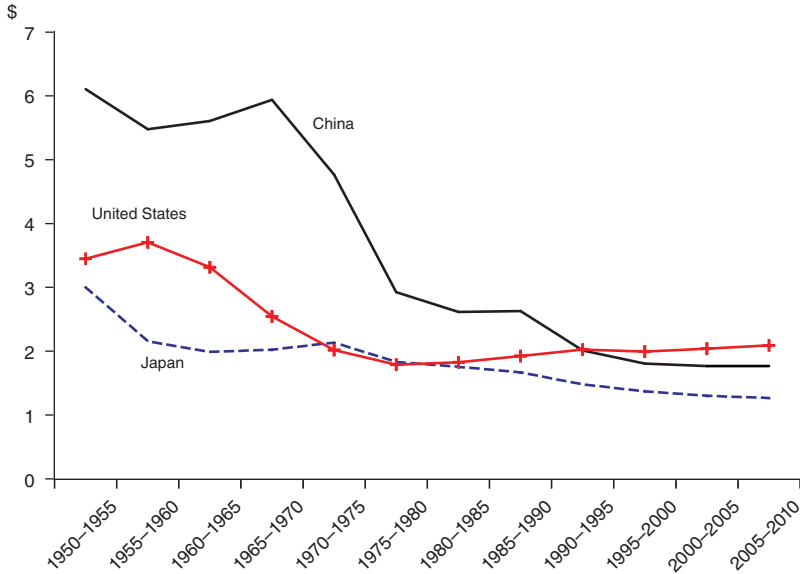


FIGURE 4. TOTAL FERTILITY RATES FOR CHINA, THE UNITED STATES, AND JAPAN, 1950–2010

Source: United Nations World Population Prospects 2010

20–63) to dependent children (ages 0–19) tracks the aggregate household saving rate quite closely over the 55-year period.

The decline in the dependent children share has been brought about by a rapid decline in the fertility rate. Figure 4 plots the fertility rates for China, the United States, and Japan. Whereas the average Chinese woman had slightly more than six children in the early 1950s, the Chinese fertility rate currently lies below the US rate. Much of the decline in China’s fertility rate was due to government policies on family planning. China’s one-child policy began in earnest in 1979 and officially remains in

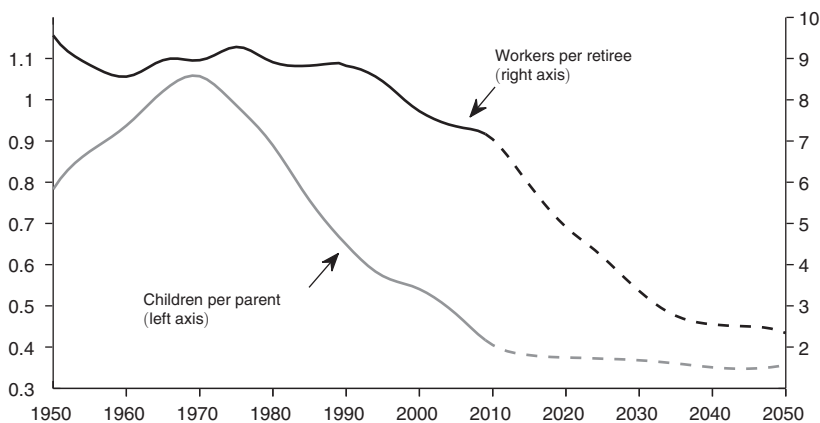


FIGURE 5. THE RATIO OF CHILDREN, AGES 0–19, TO PARENTS, AGES 20–63 (*left axis*) AND THE NUMBER OF WORKERS, AGES 20–63, PER RETIREE, AGES 64+ (*right axis*) FROM 1950 TO 2050

Source: United Nations World Population Prospects 2010

effect although enforcement differs among jurisdictions and rural and urban areas. Even before the one-child policy, other lesser known (and less rigorously enforced) fertility reduction programs were implemented. As can be seen in Figure 4, fertility rates had already begun to decline in response to the 1971 “Later-Longer-Fewer” campaign in which the government asked that families be limited to two children in urban areas and three in rural areas (Kaufman et al. 1989).

The second demographic channel works through the composition effect, which refers to the change in the saving rate induced by the change in the relative size of the working age population. Again looking at Figure 2, the share of the working age population increased from less than half of the population in 1970 to over 65 percent in 2009. Since the largest component of an economy’s saving is unconsumed labor income, we expect an increase in the share of the working age group to raise the household saving rate.

The third demographic channel concerns old-age support through intergenerational family transfers and the projected aging of the population. The proportion of working age people peaks in 2012, and the share of the oldest group will grow for the foreseeable future. Upon retirement, the current large working age cohort will have fewer workers to rely on for financial support. Figure 5 shows the retirement support ratio, the number of workers (ages 20–63) per retiree (ages 64+), and the ratio of children (ages 0–19) per worker from the United Nations data. The decline in family size means that there will be far fewer workers per retiree in the future. A 30-year-old in 2009, for example, is projected (in the dark dashed line) to have a support ratio of fewer than 3 upon retirement in 2033; whereas, current retirees enjoy a support ratio of over 6. Thus, those currently working should increase saving for retirement because they expect to receive relatively smaller old-age support.⁶

⁶See Attanasio and Brugiavini (2003) for evidence on how personal savings substitute for other old-age support in the case of Italy. Cai, Giles, and Meng (2006) examine whether children act as insurance against low pensions in China.

TABLE 1—THE EFFECT OF THE NUMBER OF CHILDREN ON THE HOUSEHOLD'S SAVING RATE, 2007

Explanatory variable	Dependent variable: saving rate	
	(1)	(2)
Number of children	-0.047 (0.015***)	-0.043 (0.018**)
Further restrictions	None	Omit HH with children age > 19
Observations	3,234	2,200
R^2	0.113	0.107

Notes: Saving rate is defined as (Income-Consumption)/Income. The data is restricted to nuclear families. Additional controls include a quartic in income, age, age squared, and the natural log of education. Standard errors are reported in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

B. Micro Data

The discussion above links micro-level household saving decisions to the evolution of macro data. Here, we look directly at micro data for evidence on the relationship between family size and household saving by running a cross-sectional regression of the household saving rate on the number of children in the household. The data comes from the 2007 Urban Household Survey of China, which is part of the Rural-Urban Migration in China and Indonesia survey (RuMCI).⁷ The survey reports household income from all sources and total consumption expenditures from which we construct the saving rate as (Income-Consumption)/Income. We restrict the sample to nuclear families (that may or may not contain dependent children) in which the head of the household is younger than 64.⁸ The regressions include control variables for the household head's education level, age, age squared, and income from the first to the fourth power.

Table 1 reports the results. Column 1 shows that having an additional child is associated with a reduction of household saving by 4.7 percentage points, which is statistically significant at the 1 percent level. In column 2, we omit families that have children older than 19 living at home. Again, having an additional child living at home is associated with a reduction of the household saving rate by 4.3 percentage points, which is statistically significant at the 5 percent level.

This regression evidence is based on a correlation. We are not asserting the direction of cause and effect here; that is the job of our quantitative model. Our

⁷The Longitudinal Survey on Rural Urban Migration in China (RUMiC) consists of three parts: the Urban Household Survey, the Rural Household Survey, and the Migrant Household Survey. It was initiated by a group of researchers at the Australian National University, the University of Queensland, and the Beijing Normal University and was supported by the Institute for the Study of Labor (IZA), which provides the Scientific Use Files. The financial support for RUMiC was obtained from the Australian Research Council, the Australian Agency for International Development (AusAID), the Ford Foundation, IZA, and the Chinese Foundation of Social Sciences.

⁸We do not necessarily want saving behavior associated with multigenerational households since that type of family structure is not part of the model and older people may be at a different stage in the life cycle. Banerjee, Meng, and Qian (2010), who use the same data, construct their sample in a similar way.

This regression evidence is based on a correlation. We are not asserting the direction of cause and effect here; that is the job of our quantitative model. Our estimates are, however, in line with others in the literature. Banerjee, Meng, and Qian (2010) estimate that an additional child lowers a Chinese household's saving rate by 7 to 11 percentage points, depending on the exact specification used. Ge, Yang, and Zhang (2012) and Gruber (2012) also find a negative relationship between the number of minor children in a household and the saving rate.⁹ While these cross-sectional regressions do not map directly into variation across successive generations, they provide supplementary motivation for incorporating family size into the modeling strategy.

To summarize, the patterns exhibited in the macro data between the large increase in the aggregate household saving rate and the dramatic demographic transition represent our main stylized facts. Household saving should increase in response to exogenously mandated reductions in family size because having fewer mouths to feed frees up resources that can be saved. The micro data exhibits this inverse relationship between the number of children and saving at the household level. The saving rate also should depend on the proportion of the working age population simply through changes in the composition (or share) of life cycle savers. Looking ahead, fewer children today means there will be fewer workers in the future to provide old age support, so the current working age cohort needs to save more aggressively for retirement. We use these observations to inform the specification of the structural model, to which we now turn.

II. A Life Cycle Model of Household Saving

This section presents the model of household saving used in the quantitative analysis. The model economy is populated by 66 overlapping generations of decision making agents. People live 85 periods or years, but only those aged 20 to 85 make decisions. All agents of the same age are identical, and they take the current and future age distribution as given.

We classify the population into three groups: children (age 0 to 19), working age parents (age 20 to 63), and retirees (age 64 to 85). For the first 19 years, people live as children dependent on their parents. They consume what their parents choose for them and do not save. A distinguishing feature of the model is that parental and dependent children's consumption both enter separately into household utility as in Barro and Becker (1989). People support children, supply labor inelastically, and receive labor income from ages 20 to 63. Even though parents support and have children in their utility function for up to 44 years, children who leave the household after age 19 no longer receive consumption from their parents. At age 64, the worker retires and no longer has children to support. These retired people live off of their accumulated assets, family transfers from their working-age children, and their pension (which we model as a pay-as-you-go scheme). People die with an age/cohort

⁹Interestingly, Gruber (2012) reports evidence that adult children positively affect saving rates. Similarly, in our model, household saving increases once children start leaving home.

specific probability prior to age 85 and with certainty at age 85. In the last year of life, utility depends only on consumption.¹⁰

A. Budget Constraints

Let $c_{t,j}$ be the year t consumption of an individual with decision-making age $j \in [0, 65]$, where $j = 0$ corresponds to real-life age 20. For a parent with age $j \in [0, 43]$, $n_{t,j}$ denotes the number of dependent children in the household, each of whom consumes $c_{t,j}^c$.¹¹ During the parenting years, agents choose their own consumption $c_{t,j}$, their dependent children's consumption $c_{t,j}^c$, and assets $a_{t+1,j+1}$ to take into the next period. We require asset holdings to be nonnegative (consumers are not allowed to borrow). Working age people take the gross return on savings $1 + r_t$ and labor income (age-dependent wage) $w_{t,j}$ as given and pay fraction τ_t of their wages into the formal pension system, while also transferring fraction τ^c of their wages to retirees through an informal family support network. The flow (period-by-period) budget constraints for households with children are

$$(1) \quad c_{t,j} = (1 - \tau_t - \tau^c) w_{t,j} + (1 + r_t) a_{t,j} - a_{t+1,j+1} - n_{t,j} c_{t,j}^c, \quad j \in [0, 43].$$

People continue working and supporting children until age 64 ($j = 44$). Retirees consume out of accumulated assets and (family and pension) transfers $p_{t,j}$ received from the current working generations. Retirees consume all remaining assets and die with certainty at age 85 ($j = 65$). The budget constraints for retirees are

$$(2) \quad c_{t,j} = p_{t,j} + (1 + r_t) a_{t,j} - a_{t+1,j+1}, \quad j \in [44, 65],$$

with $a_{t+1,66} = 0$.

Old-age support $p_{t,j} = g_{t,j} + f_{t,j}$ has two components to allow the system of government pension transfers g to differ from informal family transfers f . The tax rate τ_t is adjusted period-by-period to fund constant replacement rate government pension payments to retirees, where the replacement rate equals the percent of final working year ($j = 43$) wages received as a pension (i.e., $\frac{g_{t,j}}{w_{t+43-j,43}}$, $j \in [44, 65]$) and is the same for each retired cohort. In contrast, the rate τ^c for the informal family transfer remains fixed. Thus, the size of the family transfer $f_{t,j}$ received depends on the number of working adults paying support to each specific cohort of retirees. Retirees with more children receive a higher family transfer, all else constant, because they have more children providing support.

¹⁰We experimented with variations of the model including either an explicit bequest motive or accidental bequests due to early death. The simulation results were similar to the model without bequests. To maintain simplicity in the model, we proceed without bequests.

¹¹Consumption by children should be interpreted broadly to include things like spending on education and housing. Saving for future education or housing expenditures could be another mechanism relating family size to household saving, but our model does not explicitly include these considerations.

We can see elements of the three demographic channels at work through the budget constraints. First, in equation (1) a decline in the number of dependents ($n_{t,j}$) frees up resources for asset purchases ($a_{t+1,j+1}$). Second, a large cohort with ages $j \in [0, 43]$ increases the saving rate through increased numbers of people who are saving from labor income. Finally, looking at equation (2), a declining support ratio means there will be a relatively small family transfer $f_{t,j}$, making $p_{t,j}$ small for the current working age cohort when they retire. People can overcome this shortfall by aggressively accumulating assets during their working years.

B. Preferences

Preferences for households with dependent children are a variation of Barro and Becker (1989) in which consumption of parents and children enter separately into household utility. The per period utility function for a household head of decision-making age $j \in [0, 43]$ in year t is

$$u_{t,j} = \mu(n_{t,j})^\eta \frac{(c_{t,j}^c)^{1-\sigma}}{1-\sigma} + \frac{c_{t,j}^{1-\sigma}}{1-\sigma}, \quad j \in [0, 43].$$

The parameter σ is the inverse of the elasticity of inter-temporal substitution, and the parameters $\mu \in [0, 1]$ and $\eta \in [0, 1]$ characterize the weight parents put on utility from children's consumption. The number of children $n_{t,j}$ is expressed on a per person basis as households are interpreted as single-parent families. Beginning at age 64, individuals stop supporting children and have the flow utility function

$$u_{t,j} = \frac{c_{t,j}^{1-\sigma}}{1-\sigma}, \quad j \in [44, 65].$$

Let $\beta \in [0, 1]$ be the subjective discount factor, and $\delta_{t,j} \in [0, 1]$ be the cohort-specific probability of living to age $j \in [63, 85]$. All agents in the model live to at least age 63. A 20-year-old in year t chooses a sequence of consumption, consumption for children, and asset holdings in order to maximize lifetime utility,

$$(3) \quad U_t = \sum_{j=0}^{43} \beta^j \left(\mu(n_{t+j,j})^\eta \left(\frac{(c_{t+j,j}^c)^{1-\sigma}}{1-\sigma} \right) + \left(\frac{c_{t+j,j}^{1-\sigma}}{1-\sigma} \right) \right) + \sum_{j=44}^{65} \delta_{t+j,j} \beta^j \left(\frac{c_{t+j,j}^{1-\sigma}}{1-\sigma} \right),$$

subject to the budget constraints in equations (1) and (2). People make decisions taking the current and future demographic structure and family size ($n_{t,j}$) as exogenous and known. The observed fertility response to the one-child policy provides justification for the exogeneity assumption.

C. Family Size and Saving Behavior

The following proposition helps to show how family size affects saving through preferences.

PROPOSITION 1 (Effective Weight on Parental Utility): *Let $\bar{c}_{t,j}$ be total household consumption by parents and their children, $\bar{c}_{t,j} = n_{t,j}c_{t,j}^c + c_{t,j}$. Then, lifetime utility for an individual at age 20 can be rewritten as*

$$(4) \quad U_t = \sum_{j=0}^{43} \gamma_{t+j,j} \frac{\bar{c}_{t+j,j}^{(1-\sigma)}}{(1-\sigma)} + \sum_{j=44}^{65} \delta_{t+j,j} \beta^j \frac{c_{t+j,j}^{(1-\sigma)}}{(1-\sigma)},$$

where the effective weight on parental utility

$$(5) \quad \gamma_{t,j} = \beta^j \left(1 + \left[\mu n_{t,j}^{\eta+\sigma-1} \right]^{1/\sigma} \right)^\sigma,$$

is increasing in $n_{t,j}$ if $\eta + \sigma > 1$.

Proposition 1 exploits the Euler equation for the parent and child consumption choice to rewrite the lifetime utility function to look more like the standard model with no children.¹² The difference is that the effective weight on the utility during parental years, γ , depends on the number of dependent children in the household, n . Note, if $n_{t,j} = 0$ or $\mu = 0$, then $\gamma_{t,j} = \beta^j$. In our calibrated model, people age 20–63 have $\eta + \sigma > 1$. Therefore, according to Proposition 1, the effective weight on parental utility (γ) increases with family size, which makes the household with more children act as if it is less patient.

To see how this works, consider two household heads, A and B , of the same age. Household head A has many children and values current consumption with weight $\gamma_{t,j}^A$, while B has few children, such that $\gamma_{t,j}^B < \gamma_{t,j}^A$ for $j \leq 43$. Household head A places relatively more weight on utility during parental years, while B places relatively more weight on utility during the child-free stage of life. The result is that A will save less for retirement than B .¹³ Thus, family size affects saving by altering the household’s effective weight on utility during the parental years.¹⁴ Next we discuss the parameter values before using the model to quantify the size of the demographic effect.

¹² Appendix A contains a proof of Proposition 1.

¹³ That the consumer, B , with the lower γ saves more may seem counterintuitive. Note, though, household head B puts relatively more weight on future consumption than A does because both A and B have the same discount factor β upon retiring.

¹⁴ Choi, Mark, and Sul (2008) show that variation in the time discount factor (β) across countries can explain the trending current accounts in Japan and the United States. Our model is consistent with the Choi, Mark, and Sul hypothesis, in that the age structure affects choices in a similar way to the time discount factor.

TABLE 2—PARAMETER VALUES

Parameter	Symbol	Value
Coef. of relative risk aversion	σ	1.500
Discount factor	β	0.997
Weight on children	μ	0.580
Concavity for children	η	0.760
Transfer share	τ^c	0.040
Replacement rate	—	0.250
Interest rate	r	0.040

III. Parameterization

Table 2 reports the parameter values used in the model simulations. The inter-temporal elasticity of substitution ($1/\sigma$) is set to 0.67. We set the time discount factor β to 0.997, as in Song, Storesletten, and Zilibotti (2011). This value may seem high, but individuals also effectively discount the future due to the incorporation of survival probabilities δ . We calculate these age and cohort specific survival probabilities along with the age distribution from United Nations population estimates. This demographic data does not allow us to link generations to uncover the series of $n_{t,j}$. To construct the cohort-specific number of children $n_{t,j}$, we use the 2007 RuMCI micro data to estimate a cross-sectional fertility profile (relative number of children per parent). For example, the average 40-year-old has more children living at home than the average 20- or 60-year-old. Then, we assume the relative support ratio across age groups remains fixed over time, even as the number of children per working adult declines. Appendix BB2 contains additional details.

In specifying parent's attitudes toward children, we choose μ to minimize the sum of squared errors between the model generated saving rates and the data in the prereform period (1955–1978). The resulting μ equals 0.58, close to the value in Manuelli and Seshadri (2009). Manuelli and Seshadri set $\mu = 0.65$ and $\eta = 0.76$ in order to match US birth rates in a model featuring the Barro-Becker children in utility function and fertility choice. Our overall findings are robust over a range of values for η , so we keep η at the Manuelli and Seshadri value (0.76). We also experiment with other values for μ and η in the robustness checks presented below.

We set the share of labor income given to retired parents through the informal family transfer system τ^c to 0.04. Data on intergenerational transfers during the prereform period are scarce. As noted by Lee and Xiao (1998), prior to reforms in 1979 most people lived in rural areas and belonged to collective production units with elderly persons receiving resources directly from the collectives. Lee and Xiao study a 1992 survey covering children's support for elderly parents, and their results imply a value for τ^c around 0.08. More recently, Xie and Zhu (2009) find that the fraction of income contributed by urban men to their parents is only 0.03. Xie and Zhu (2009) also note that a nontrivial proportion of adults in urban areas receive financial support from their elderly parents, making net transfers small. Note, however, children are legally obligated to care for their parents in old age (Naughton 2007, 176), and transfers (especially nonfinancial transfers) are likely larger in rural areas. Choukhmane, Coeurdacier, and Jin (2014) undertake a more in-depth analysis

of the evidence than we attempt here. We use the value, $\tau^c = 0.04$, estimated by Choukhmane, Coeurdacier, and Jin (2014) based on a survey covering intergenerational transfers.

We set the government pension payments $g_{t,j}$ so that each retiree receives a 25 percent replacement rate in every year. Funding the model's pay-as-you-go constant replacement rate pension system requires the tax rate τ_t on labor income to change period-by-period. Like most of China's economy, the formal pension system has been in transition. A social system aimed at covering the urban workforce is in place de jure, but it is unfunded and broken de facto. Instead, retirees rely on personal savings and the Chinese family system, whereby children, especially males, are expected to care for elderly parents. The 1997 pension reform stipulates that most employees at urban state owned enterprises contribute to individual accounts (forced saving) and upon retiring receive additional transfers equal to a 20 percent replacement rate, with larger transition payments for older workers (Sin 2005). Prior to the 1997 reform, a government run program provided workers retiring from urban state-owned enterprises with more generous benefits, but this was a small portion of the population (Dunaway and Arora 2007). In 2004, the replacement rate in the formal pension system was a generous 75–80 percent of an individual's final working wage (Trinh 2006). However, Sin (2005) estimates that less than 25 percent of the working population participated in the formal pension system. Our choice of a 25 percent replacement rate is meant to reflect the average across those participating in the formal system and those not. We experiment with alternative values for τ^c and τ_t in the robustness checks and also when comparing urban and rural China.

We use the 2007 RuMCI data to calculate the average household labor income by age of the household head ($w_{2007,j}$). These numbers give us an estimate for the relative wages by age, or efficiency wages, in the cross section. For example, we find that household heads in their prime working years receive more labor income than younger workers, on average. Then, we assume the cross-sectional wage profile stays fixed throughout time.

To isolate the quantitative effects of the demographic channels, we first simulate the model economy with no wage growth ($w_{t,j} = w_{2007,j}$, for all t) and a constant interest rate of 4 percent. Sections IVD and IVE discuss wages and interest rates further and present simulation results in which r and w vary over time.

IV. Quantitative Results

We simulate the economy from 1955 to 2009. Initial assets equal zero for each 20-year-old (decision-age $j = 0$). To solve the utility maximization problem, a 20-year-old must take into account the next 65 years of demographic observations. Before 1979, agents believe the post-1979 demographic structure will evolve according to 1978 United Nations projections. In 1979, everyone realizes the one-child policy will alter the future demographics and that the 1978 projections were wrong (e.g., the projected fertility rate was too high). From 1979 on, agents' projections for family size come from the 2008 United Nations data, which in the model is perfect foresight. The demographic data consists of annual observations by single year age groups.

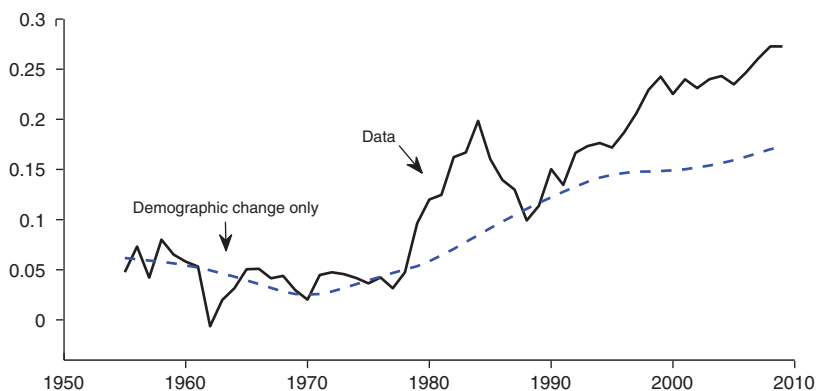


FIGURE 6. HOUSEHOLD SAVING RATES FROM 1955 TO 2009 IN THE CHINESE DATA AND IN THE MODEL WITH DEMOGRAPHIC CHANGE ONLY

Note: In the Demographic change only simulations, wages are fixed in the cross section and $r = 0.04$.

We begin in Section IVA by presenting model predictions generated only by the demographic variation. The model is able to explain the low saving rates in the prereform period and the high and rising saving rates in the postreform period. This result constitutes our main finding; in the context of our model, demographics explain a sizable portion of the variation in the aggregate household saving rate over time. We then conduct several experiments that turn on and off various components of the model in order to assess the relative contribution of the three demographic channels. The reduction in dependent children has a large effect on saving.

The remainder of the paper examines, within the basic structure of our model, the quantitative importance of other factors that are relevant to household saving. Section IVB discusses the model's implications for saving across age groups. Section IVC separates the analysis into urban and rural China. Finally, Sections IVD and IVE discuss versions of the model that incorporate time varying wages and interest rates.

A. Demographic Change Only

Figure 6 compares the Chinese data from 1955 to 2009 to the model economy's aggregate household saving rate when only the demographic composition and family size varies.¹⁵ The model generates the low saving rate in the prereform period and an upward trend during the postreform period. Between 1970 and 2009, the implied saving rate increases by nearly 15 percentage points (compared to 24 percentage points in the data). By 2009, the implied saving rate of over 17 percent is about two-thirds the size of the observed 27 percent rate. The timing for the increase in the model's saving rate also corresponds well with the data. However, the model misses

¹⁵Note, since we fix the life-cycle profile of wages, but the age distribution evolves, the aggregate average wage changes over time even in the demographic change only simulation. We also have run the model forcing the aggregate average wage to be constant, and the findings do not change appreciably.

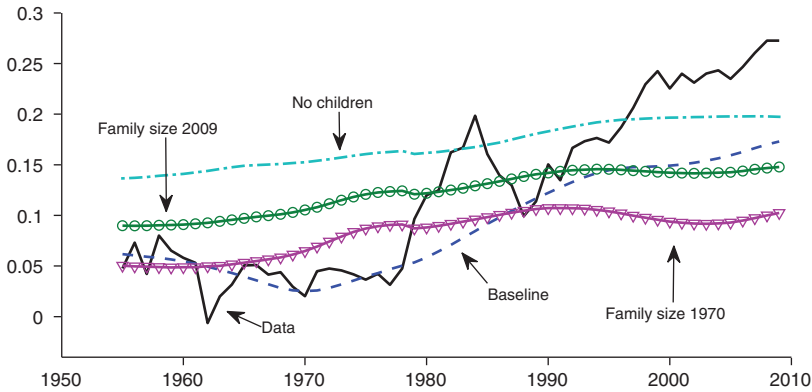


FIGURE 7. HOUSEHOLD SAVING RATES WITH NO CHILDREN AND VARIATIONS IN FAMILY SIZE

Notes: In the “No children” simulation, parents do not support dependent children ($\mu = 0$). In the “Family size” simulations, the number of dependent children per household is held constant at 1970 and 2009 levels.

the decline in household saving in the early 1960s and the big increase and decrease during the 1980s. The age distribution evolves too slowly to, by itself, explain the short and medium run fluctuations.

Clearly, institutional and societal factors beyond demographics have affected the saving rate in China. In Section IVD, we add time varying wages and interest rates to partially account for some of these factors; doing so improves the model’s performance on several dimensions. Note though, while exploiting only demographic variation, the model does a good job in explaining the low-frequency movements in the household saving rate. We conclude that the demographic structure has a large effect on the aggregate household saving rate within this model economy.

Next, we separately examine the role of the three demographic channels on the saving rate: the impact of the decline in the family size (the dependent children effect), the changing composition effect, and declining intergenerational family transfers through the projected decline in workers per retiree. In the following simulations, the model’s characteristics (utility functions, parameter values, demographic data, transfers, etc.) remain unchanged except for the particular channel studied.

Dependent Children.— To assess the importance of explicitly modeling dependent children in preferences, we shut off this channel by setting $\mu = 0$, which sets parent’s valuation of children’s utility from consumption to zero. The top line of Figure 7 (light dashed line) is the result. Ignoring dependent children causes the saving rate implied by the model to overstate saving (sometimes considerably) before 1996. The implied saving rate becomes much less variable and changes only by 6 percentage points between 1955 and 2009.

Next, we restore parental valuation of children’s consumption (setting $\mu = 0.58$) but consider the effect of alternative and counterfactual family sizes $n_{t,j}$. Figure 7 shows the saving rates generated by assuming that the number of children per household remains constant at 1970 and at 2009 levels. Two-parent households in 1970 had 1.6 more children on average than in 2009. The saving rate for the economy

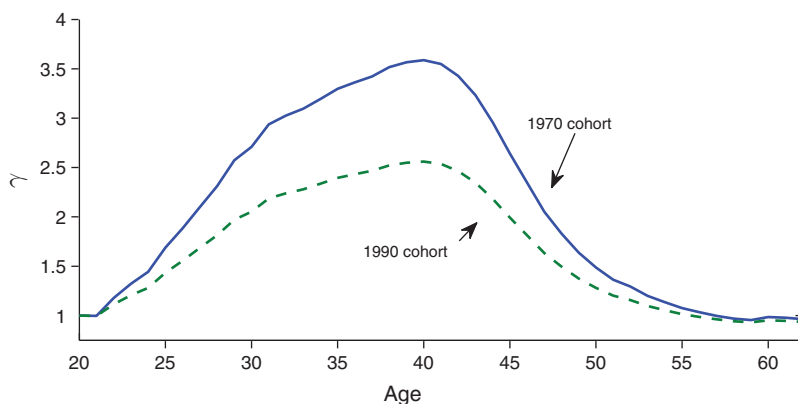


FIGURE 8. EVOLUTION OF γ FROM AGE 20–63 FOR COHORTS WHO WERE AGE 20 IN 1970 (solid line) AND AGE 20 IN 1990 (dashed line)

with large family households is about 5 percentage points lower on average than in the simulation with smaller families. In both cases, the increase in the saving rate between 1955 and 2009 is much smaller than when family size evolves according to the data.

Proposition 1 provides insight as to why households with fewer dependent children appear to be more patient. Figure 8 traces γ for two cohorts from age 20 to 63. The solid line is the effective weight γ for the cohort aged 20 in 1970, and the dashed line is for the cohort aged 20 in 1990. The hump shape of each series reflects that the number of dependent children is increasing until age 40 and approaches β as the number of dependent children declines.¹⁶ The difference in γ between cohorts means that agents in the 1970 cohort place relatively more weight on household consumption ($n_t c_t^c + c_t$) at each age (while parents) due to the higher number of dependent children. This causes the 1970 cohort to consume a higher (save a lower) share of their income at each age than the 1990 cohort.

The model predicts that a one child reduction per (two) parent household would have raised the saving rate by 5.5 percentage points in 1970 and by 4.2 percentage points in 2009. These numbers are similar to the 4.7 percentage point value implied by the cross-sectional regression estimate reported in Section IB. The two results may not be directly comparable because the model is dynamic in nature while the regression is from a single cross section. However, both the model and the data support our main point; reducing the number of dependent children raises the household saving rate, and the variation in household size over time has been a significant factor governing the evolution of China's saving rate.

Composition Effect.—To assess the quantitative importance of the composition effect, we decompose the model's implied saving rate in 2009 into contributions by age group. We then compare the implied 2009 saving rate to the “counterfactual”

¹⁶At age 64, the effective weight collapses to the subjective discount factor β because households no longer have dependent children.

saving rate implied by the 1970 demographic composition (holding the age-specific saving rates constant). Let the model's aggregate saving rate in 2009 be SR_{2009} , $N_{t,j}$ be the number of people of age j in year t , $\varphi_{t,j}$ be the age group's per capita income share, and $sr_{t,j}$ be the age-specific saving rate. The decomposition of the aggregate saving rate for 2009 is

$$(6) \quad SR_{2009} = \sum_{j=0}^{65} N_{2009,j} (\varphi_{2009,j}) (sr_{2009,j}).$$

To construct the counterfactual aggregate saving rate, we keep the age-specific saving rates at their 2009 values but set the age and income distributions to their 1970 values:

$$(7) \quad \widehat{SR}_{2009} = \sum_{j=0}^{65} N_{1970,j} (\varphi_{1970,j}) (sr_{2009,j}).$$

We expect that an increase in the share of those who save out of labor income will lead to an increase in the aggregate saving rate. The share of this population, aged 20–63, increased from 46 to 64 percent between 1970 and 2009. However, when we compute the difference $SR_{2009} - \widehat{SR}_{2009}$, we obtain an implied increase of only 2 percentage points in the saving rate, or about 14 percent of the model generated increase in the saving rate from 1970 to 2009.

While it is not trivial, the composition effect makes a relatively small contribution to the overall increase in the saving rate. Instead, an increase in saving rates (sr) over time for all age groups is responsible for the increase in saving within the model. We return to this point in Section IVB, when we discuss the model's cross-sectional implications.

Retirement Support Ratio.—Next, we consider how the decline in the retirement support ratio (workers per retiree) affects the saving rate. From 1970 to 2009, the support ratio declined from 9 to 7, and it is projected to fall below 3 by 2032. By 1979, households in the model foresee the plummeting retirement support ratio, which implies smaller future family transfers and heavier reliance on personal savings for retirement. The projected low support ratio captures the so-called “4-2-1” problem in China as consecutive generations have now been affected by the one-child policy.¹⁷

To show the support ratio's effect, we simulate the model under several alternative assumptions about the size of family transfers, $f_{t,j}$. The results are summarized in Table 3 rather than plotted, to conserve space. Row 1 reports the data and row 2 shows the results with the baseline specification (from Figure 6). Row 3 presents the saving rates when holding the support ratio constant at the 1970 level. In this simulation, people currently working save less because they can count on many (a support ratio of 9) workers for old age support. After 1979, the resulting saving rate is lower than in the simulations with varying support ratios, and by 2009, the saving

¹⁷The 4-2-1 refers to the situation where single children may be supporting four grandparents and two parents.

TABLE 3—VARIATIONS IN FAMILY TRANSFERS

	Average household saving rates in percent				Change 1979–2009
	1955–1979	1980–1989	1990–1999	2000–2009	
1. Data	4.5	14.2	18.4	24.7	17.6
2. Baseline, $\tau^c = 0.04$	4.3	8.8	14.0	15.9	11.9
3. Support ratio at 1970 levels	4.4	6.9	10.5	11.6	8.3
4. Support ratio at 2009 levels	5.8	8.2	11.8	13.0	8.4
5. Family transfer rate $\tau^c = 0.10$	1.0	5.4	10.3	13.4	12.7
6. Family transfer rate $\tau^c = 0$	9.8	12.1	15.5	16.7	8.1

is lower than in the simulations with varying support ratios, and by 2009, the saving rate is only 12.7 percent. Row 4 repeats the analysis with the support ratio held constant at the 2009 levels. Prior to 1979, current workers save more because they will have fewer workers to support them in retirement than in the actual data. After 1979, people save less than the baseline simulations because there will be more people to support them in retirement than in the actual data.¹⁸

In row 5, we return to the support ratio implied by the data, but increase old-age support by raising τ^c from 0.04 to 0.10. Not surprisingly, variations in the transfer rate affect the saving rate. A higher family transfer rate (share of labor income given to retired parents) lowers saving for two reasons. Workers who transfer a larger share of their income have fewer resources from which to save, and workers have less incentive to save because they anticipate more generous old age support in retirement. Given the documented evidence on transfers from children to the elderly, $\tau^c = 0.10$ seems unrealistically high. Such a value for τ^c would imply, for example, that new retirees in 2009 receive about a 60 percent replacement rate from family transfers alone.

Row 6 reports the implied saving rates with $\tau^c = 0$. In this experiment, the saving rate is much higher in the prereform period because parents can no longer count on retirement support from their children. The cohorts hit hardest by the reduction in support are those with more children. These cohorts, the working parents in the prereform period, respond by increasing their saving rates. We wait until Section IVE to report how variations in the formal pension affect saving. Next, we examine a few other ways in which demographics impact household saving decisions within the model.

Additional Analysis.—The increase in the average life-span (and therefore the share of time spent in retirement) raises implied household saving rates over time.¹⁹ Life expectancy at birth increased from 66.8 in 1979 to 74.7 in 2009, creating a significantly longer retirement. To quantify the effect of longer life, we examine a version of the model holding the survival probabilities (δ) fixed at the 1970 rates. The first two rows of Table 4 repeat the data and baseline results, and the third row reports the saving rates when survival rates do not increase over time. Not

¹⁸This simulation fixes the support ratio at around 7, but in the data presented in Figure 5 the support ratio continues to fall after 2009.

¹⁹We thank one of the referees for suggesting this additional demographic-based mechanism.

TABLE 4—ADDITIONAL EXPERIMENTS USING THE DEMOGRAPHIC CHANGE ONLY MODEL

	Average household saving rates in percent				Change 1979–2009
	1955–1979	1980–1989	1990–1999	2000–2008	
1. Data	4.5	14.2	18.4	24.7	17.6
2. Baseline	4.3	8.8	14.0	15.9	11.9
3. δ fixed at 1970	3.5	7.7	12.5	13.6	10.2
4. $\eta = 0.50$	5.2	9.2	13.7	15.4	10.5
5. $\eta = 1$	3.5	8.5	14.3	16.4	13.3
6. $\mu = 0.65, \eta = 0.76$	3.8	8.3	13.6	15.6	12.3
7. Perfect foresight throughout	4.2	8.8	14.0	15.9	11.8

Note: δ is the survival probability, η and μ are parameters on children's consumption in household utility.

surprisingly, the saving rate is lower when people die earlier. The overall change in the saving rate from 1979–2009 is 1.7 percentage points smaller than in the baseline simulation. As with the composition effect, the impact of longer lives on saving is not trivial, but it is not large either.

Next, we present two robustness checks on the utility function parameter η , which regulates the concavity on the number of children in the household. In the baseline version of the model, η equals 0.76, as taken from the Manuelli and Seshadri (2009) study. Rows 4 and 5 of Table 4 report the saving rates with η set to 0.5 and 1, respectively. A lower value for η decreases the effect on saving due to the reduction in family size because the additional children in the prereform period have a smaller effect on household consumption decisions. Conversely, a higher value for η strengthens the dependent children mechanism, making the overall increase in saving rates larger. In both cases, though, the results remain close to the baseline. The findings are robust over a range of values for η .

In row 6, we return η to 0.76 and increase the weight on children's consumption in the utility function from 0.58 to the Manuelli and Seshadri value of 0.65. The higher weight on children depresses saving. We also have tried other values. As with η , the effect of demographic change on household saving rates remains present over a range of μ values. However, as the experiment with $\mu = 0$ in Figure 7 makes clear, having children in the utility function is an important driver of the increase in the saving rate over time.

Finally, we examine whether the “surprise” nature for the implementation of the one-child policy has a large impact on our results. It does not. The last row of Table 4 reports the saving rates when agents fully anticipate the demographic changes (i.e., have perfectly correct foresight throughout). The time path for the aggregate saving rate is similar to the baseline case in which households did not fully anticipate the decline in fertility. The actual demographic pattern drives the increase in saving rates over time rather than the surprise nature of the one-child policy.

B. Saving by Age Group

Although the primary interest of this paper centers on understanding the time series of the aggregate household saving rate, our model also has implications for the cross section. This section addresses these cohort-specific cross-sectional implications.

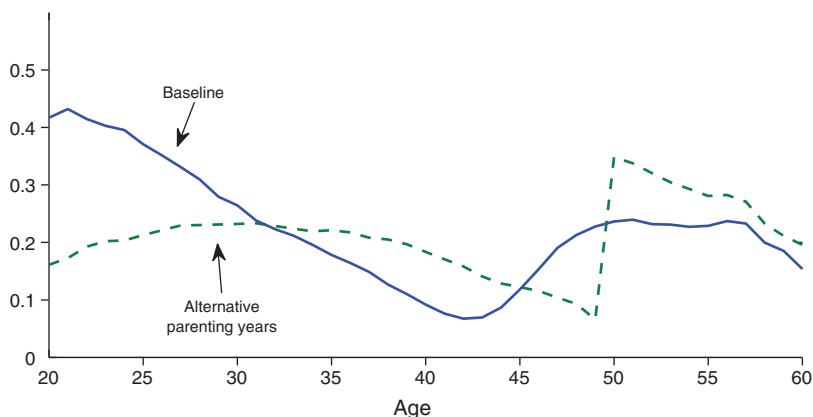


FIGURE 9. CROSS-SECTIONAL SAVING RATES BY AGE IN 2009 FOR THE BASELINE DEMOGRAPHIC CHANGE ONLY SIMULATION (solid line) AND FOR THE “ALTERNATIVE PARENTING YEARS” SIMULATION (dashed line)

Note: In the “Alternative parenting years” parents have a uniform number of dependent children from ages 20–49 and no dependent children thereafter.

The standard life-cycle model predicts the often observed upward sloping age-saving profile where the saving rate increases throughout people’s working life. Recent empirical work on China, such as Song and Yang (2010) and Chamon and Prasad (2010) report that the age-saving profile of working-age Chinese households is not upward sloping, but is instead U-shaped, challenging this aspect of the life-cycle model.

The solid line in Figure 9 shows the simulated household saving rates by age for 2009. Our model generates a U-shaped saving pattern because the model agents begin their decision-making life (at age 20) with few dependent children to depress saving. As agents age, they support more dependent children and save less. Then, as household size shrinks during the household head’s late 40s, saving rates rise.

We would like to conclude that our model does well explaining the cross section for saving rates; however, Song and Yang (2010) and Chamon and Prasad (2010) both present evidence indicating that the saving rates by age in China have not always been U-shaped. While data on Chinese saving rates by age group prior to the 1990s is difficult to come by, Song and Yang and Chamon and Prasad argue that the saving profile used to be upward sloping (or at least flat) but only recently became U-shaped. Our baseline model does not deliver on this stylized fact. Our simulated saving rate profile always displays the U-shape (because our cross-sectional fertility profile is fixed using 2007 data). In the baseline model, the cross section of saving by age is U-shaped in 2009 and in every other year.

How important is the shape of the cross-sectional saving profile for explaining the evolution of the aggregate saving rate? To answer this question, we simulate the model giving all people age 20–49 the same number of children n_t and no dependent children from age 50 onward ($n_{t,j} = n_t$ for $0 \leq j \leq 29$ and $n_{t,j} = 0$ for $j > 29$). The dashed line of Figure 9 shows the simulated saving rates by age. This experiment yields a hump shape in saving until age 50, when children leave home and workers save aggressively for retirement. Figure 10 compares the aggregate

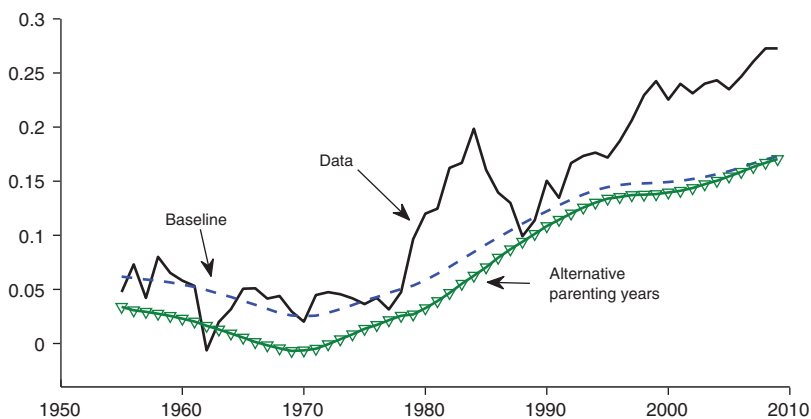


FIGURE 10. HOUSEHOLD SAVING RATES FROM 1955 TO 2009 IN THE DATA (*solid line*), THE BASELINE DEMOGRAPHIC CHANGE ONLY SIMULATION (*dashed line*), AND THE “ALTERNATIVE PARENTING YEARS” SIMULATION

Note: In the “Alternative parenting years” parents have a uniform number of dependent children from ages 20–49 and no dependent children thereafter.

household saving rate in this simulation to the baseline simulation. Although the cross-sectional saving profiles in each simulation are vastly different, the implied time series of the saving rates remain close to the baseline simulation and are fairly robust to these modifications. That is, modifying the model to alter the age-saving profile does not change our main result: demographic change can account for over half of the increase in saving. The change in the aggregate saving rate over time in our model is driven primarily by changes in the saving rate for all groups and not the differences across age groups.²⁰

While our model can be modified to generate an alternate age-saving profile, we do not claim that fertility patterns are the exclusive explanation for the observed changes in the cross-sectional saving pattern. Our point is that the saving pattern by age is relatively unimportant for explaining the time series of the aggregate household saving rate within our model. This robustness is important for our story; the failure of the baseline model to match the evolution of the cross section does not invalidate the model’s predictions for the time series.

C. Saving in Urban and Rural China

People in urban and rural China experienced different demographic dynamics and have access to different old-age support systems. The decline in fertility rates for urban households was larger and more rapid than for rural households. In 1970, average family size in urban and rural areas were about the same. By 1995, the child support ratio had decreased by almost 40 percent in rural China and by over 60 percent in urban China. The one-child policy has not been as strictly enforced in rural

²⁰Song and Yang (2010); Ge, Yang, and Zhang (2012); and Chamon and Prasad (2010), among others, study the available micro evidence on the change in saving rates by age group for urban Chinese since the 1990s. These papers report an increase in saving rates across all age groups, although the size and timing varies.

TABLE 5—URBAN VERSUS RURAL CHINA

	Average household saving rates in percent				Change 1979–2009
	1955–1979	1980–1989	1990–1999	2000–2009	
1. Baseline	4.3	8.8	14.0	15.9	11.9
2. Urban	3.9	10.6	12.5	13.6	8.0
3. Rural	5.9	10.3	16.6	18.3	12.3

areas or for some racial and ethnic groups. After 1984, rural couples could have a second child if the first child was a girl and/or if hardship factors were involved. Additionally, non-Han Chinese ethnic groups who live outside the urban areas were not subject to the policy (Naughton 2007).

Moreover, the formal pension system (in particular the high pensions promised by state-owned enterprises) does not cover most rural households; instead, rural elderly rely primarily on children for support (Naughton 2007). Thus, to separately simulate urban and rural household saving behavior, we input different demographics and modify the old-age support systems. In the urban case, the formal pension replacement rate is set to 50 percent and the share τ^c of income transferred to elderly parents is set to 0.02. For rural households, we assume no access to the formal pension system ($\tau = 0$), while τ^c equals 0.06.²¹

In addition to imposing different values for τ and τ^c between the urban and rural areas, we had to make a number of assumptions to calculate the urban and rural age-by-age, year-by-year demographic structure. Appendix BB1 contains more details, but we lay out the two main issues here. First, China's urbanization has occurred quickly, and reliable data separating the population into rural and urban areas is sparse. We use intermittent information from 1964 to 2009. Inside that range, we interpolated the population growth rates and the urbanization rate by age. We also assumed the rate of urbanization occurred slowly before 1978 and that the urbanization rate will gradually taper off after 2009 (from about 2.5 percent per year currently), until the rate reaches US levels (about 1 percent per year). Second, the prevalence of migrant workers plagues the analysis. By some estimates, over 100 million Chinese work and/or live in a city in which they are not an official resident (or holder of a hukou), at least part of the year. Many of these migrant workers come from the more rural provinces. How the migrant workers get counted in the data is not clear.

Table 5 compares the household saving rates generated by separately simulating the model using the demographic structure in urban and rural China against the baseline (aggregated) case. In the prereform era, rural households save a higher share of their income than urban households. After 1979, saving rates initially increase more sharply for urban households. By the early 1990s, though, the saving rate is again higher in rural areas. The available evidence suggests that rural households did tend

²¹ We believe these choices capture the salient differences between urban and rural areas in terms of old-age support. See Song et al. (2013) for a detailed description of the formal pension plan and how it has changed. In short, the replacement rate has shrunk over time, but coverage has gone up. We consider a time-varying replacement rate in Section IVE.

to save more prior to reforms. The switch in the relative saving rates after reforms also appears in the data, as reported in Horioka and Wan (2007).

For urban households, the increase in the simulated saving rate slows down after 1995. This slowdown does not occur in the data. Instead, urban Chinese accelerated their saving during this time period (Chamon and Prasad 2010). As discussed at the beginning of this paper, several other hypotheses for this increase in saving rates are plausible, including higher labor income risk for urban Chinese. Chamon, Liu, and Prasad (2010) and Choi, Lugauer, and Mark (2014) document the high levels of uncertainty around urban household income in China. Urban households also may have had better investment opportunities.²²

Comparing urban to rural China further highlights how demographics (and old age support) can affect saving decisions. However, given the difficulties associated with splitting the analysis along the urban and rural dimension and that our model does not explicitly address this divide, we employ the aggregate demographic data in the remainder of the paper.

D. Complete Model with Time Varying Interest Rates and Wages

From this point on, the model simulations allow the interest rate r_t and household income (wage) $w_{t,j}$ to vary over time as informed by the data. Households have perfect foresight over r_t and $w_{t,j}$, and the other aspects of the model are unchanged. The analysis remains one of partial equilibrium. The idea behind introducing variation in r_t and $w_{t,j}$ is to capture, in a simple way, many of the institutional and policy changes (in addition to demographic change) that may have influenced household saving decisions throughout this time period via wages and interest rates. Before presenting the simulated saving rates from the complete model, we briefly describe the construction of the wage and interest rate time series. Section B of the Appendix provides further details.

While we refer to w as the wage, in the model it includes all household income (e.g., labor income and non-pension government transfers) except pension and family transfers and income derived from savings. To estimate the counterpart to w we use data on the sources of household income from the *China Health and Nutrition Survey* (1989 through 2009 waves).²³ Subsequent to the implementation of economic reforms in 1978, the Chinese economy has grown at a torrid pace; however, the share of output going to households has declined. Our estimated w time series grows at a little over 5 percent per year on average in the postreform period. This growth rate is in line with the rate generated in Song, Storesletten, and Zilibotti (2011) within a model of the Chinese economy and also close to the rate used in Song et al. (2013). We assume no wage growth prereform, and a gradual

²²Wages have grown at different rates in urban and rural areas, too. As we show in the next section, expected wage growth affects saving behavior.

²³Relative wages across age groups remain fixed in the cross section throughout our analysis. Here, we estimate the change in the aggregate average of noninvestment, nonfamily-transfer income over time net of changes to the age structure.

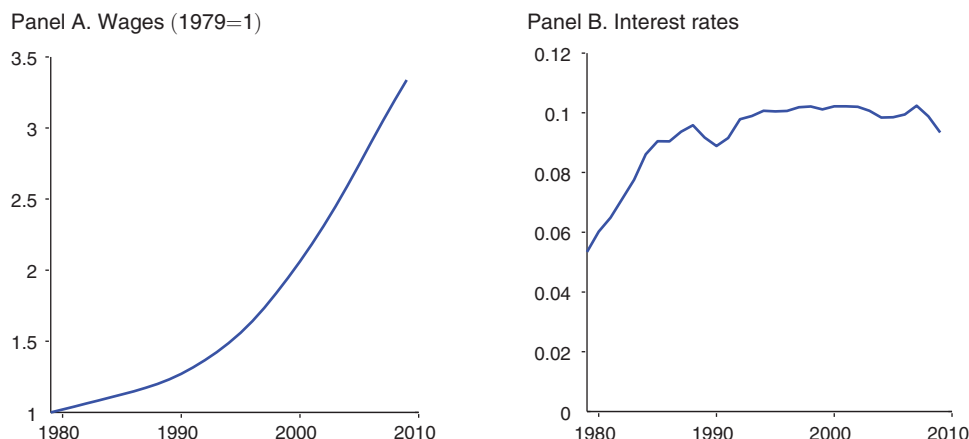


FIGURE 11. LOG WAGES AND INTEREST RATES USED IN COMPLETE MODEL SIMULATIONS

acceleration from 1978 to 1989.²⁴ Since we are focused on explaining the trend of the household saving rate rather than the cyclical component, we smooth the annual wage series with the Hodrick-Prescott filter (smoothing parameter $\lambda = 100$). Figure 11, panel A, plots the time series of w fed into the complete model simulation, with 1979 normalized to 1.

Figure 11, panel B, shows the constructed interest rate series. We select interest rates to reflect the rate of return on total household saving. Our interest rate measure is intended to go beyond savings account interest and include other savings vehicles that have become available over time. Since the break from central planning in 1978, households have had increasing access to the returns on the national capital stock. This encompasses household farms, private companies, and TVEs (Township and Village Enterprises).²⁵ Huang (2008) reports that the overwhelming majority of TVEs were private even during the early stages of reform. By 2002, the last year that Huang reports, less than 1 percent of the 21.3 million TVEs were collectively owned.²⁶ With the privatization of urban work units beginning in the 1990s, many urban households also have invested in real estate by acquiring their own living quarters, and land leases for rural households (nearly all rural households have some land to farm) have also increased in duration. As Naughton (2007) notes, there has been an explosion in investment opportunities for households.

We implement the increase in the interest rate over time in a simple way, which still reflects the changes in the marginal product of capital and the changes in the

²⁴These choices are informed by the data studied in Yang, Chen, and Monarch (2010). Our estimate for the growth rate in household income in the postreform period is lower than the growth rate for the average wage estimated in Yang, Chen, and Monarch because unemployment increased during the 1990s. Yang, Chen, and Monarch focus on average wages paid per employed worker; whereas, our model concerns the income households receive.

²⁵See Curtis (2014) for more on the Chinese transition from state owned enterprises to private companies.

²⁶Huang (2008) explains that the TVE is a locational concept and does not necessarily mean the enterprise is owned by the township or village. The collective TVEs are larger on average; however, in terms of employment, Naughton (2007) reports for 2003 that only 12.5 percent of TVE employment is in those collectively owned.

real interest rate on bank deposits. We keep the prereform interest rate at 4 percent.²⁷ When the initial round of reforms occur in 1979, we assume households obtain the marginal product of capital on 30 percent of their saving.²⁸ The remaining 70 percent of saving only returns the prevailing real rate on cash deposits (as reported by the World Bank). Then, we gradually increase the return on saving by assuming households gain greater access to the returns from capital investment. Each year, households place 1 percent more of their saving into assets, getting the higher rate of return (the marginal product of capital), until the split between cash deposits and other investments reaches 50/50. Thus, r_t averages 8.8 percent in the postreform period, higher than the average real rate on saving deposits (2.8 percent) but lower than the average marginal product of capital (17 percent).²⁹

Our construction of the time series r_t is similar in spirit to the return to total household saving used in Song, Storesletten, and Zilibotti (2011). Song, Storesletten, and Zilibotti assume that entrepreneurs capture the full return to their invested capital and that more and more households can invest in entrepreneurial activities over time. The evidence backs up the implicit claim that households have been investing in private businesses. According to Dollar and Wei (2007), 8 percent of capital for private firms comes from family and friends, and the return to capital is higher for private firms than for state-owned enterprises. According to the *China Statistical Yearbook*, 15 percent of investment in new physical capital is done by private individuals. Other investment opportunities have become available, as well. The stock market began to operate in the early 1990s, and even saving done through the bank is often invested in CDs, private company bonds, and investment trusts; all yielding higher average returns than the government mandated rate on bank deposits.

Figure 12 shows the simulated saving rates from the complete model economy. Incorporating time varying r and w improves the model's predictions by raising the saving rate in the more recent years. As in the data, aggregate household saving before the mid-1970s is relatively low and then it begins to rise. While the implied trend break toward high saving in this model slightly leads the data, the model now generates a saving boomlet and bust in the 1980s.³⁰ The implied saving rates from 1990 to 2005 are about 5 percentage points lower than in the data. By 2009 though, households in the model save 25 percent of their income, close to the observed 27 percent. As we saw above, more than half of the rise in the saving rate is due to the changing age distribution alone. The rest of the increase in the household saving rate comes from the interest rates and wages, and their interaction with the changing demographics.

Figure 13 compares the simulated cross section of saving rates by age to the RuMCI data for 2007. While not perfect, the model generates a saving rate profile

²⁷ Using a lower interest rate in the prereform era increases the overall change in saving generated by the model.

²⁸ Online Appendix BB5 details our calculation of the marginal product of capital.

²⁹ The marginal product of capital in China might seem high relative to more developed countries. Despite years of heavy investment, China remains a relatively capital poor country. Moreover, our estimated return on capital series post-1979 is in line with estimates by other researchers. For example, Bai, Hsieh, and Qian (2006) estimates an average of about 20 percent per year from 1978 to 2005.

³⁰ The run-up starts earlier than in the data because households have perfect foresight over r and w . If instead, households in the pre-reform period believed r and w would remain fixed, prereform saving rates would be identical to those in the simulations with only demographic change.

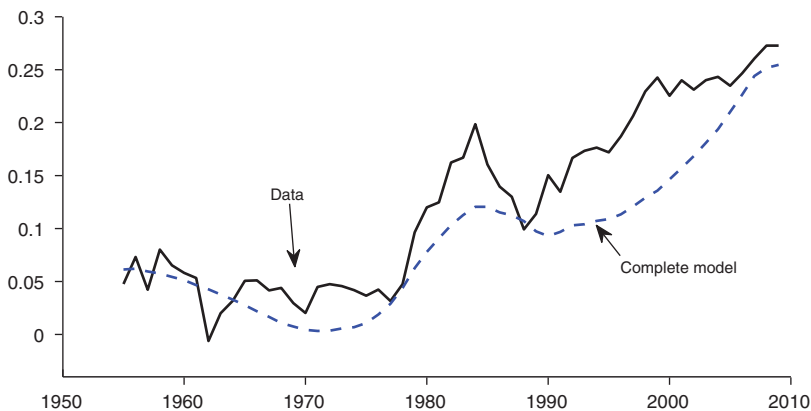


FIGURE 12. HOUSEHOLD SAVING RATES FROM 1955 TO 2009 IN THE CHINESE DATA (solid line) AND THE COMPLETE MODEL (dashed line) WITH TIME VARYING WAGES AND INTEREST RATES

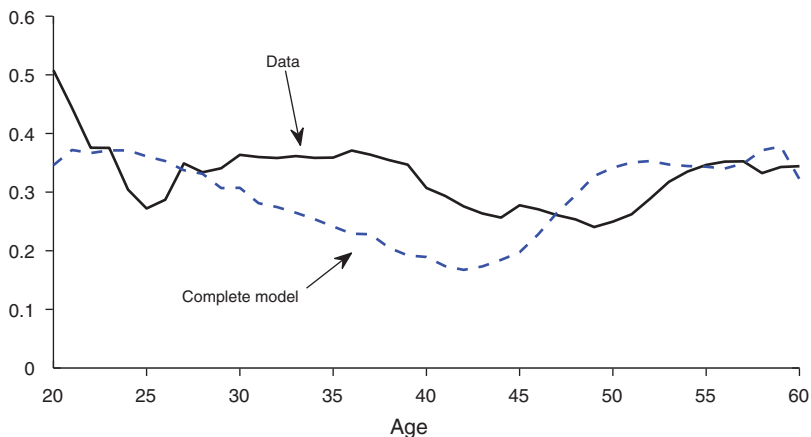


FIGURE 13. CROSS-SECTIONAL SAVING RATES BY AGE IN 2007 IN THE RUMCI DATA (solid line) AND THE COMPLETE MODEL (dashed line) WITH TIME VARYING WAGES AND INTEREST RATES

that is similar to the data. In particular, both the data and the model generated saving rates feature the U-shaped pattern, with younger and older households saving more than households with more children.

E. Additional Experiments

This section reports on additional experiments that explore the sensitivity of our results. We consider alternative wage and interest rate sequences and alternative retirement transfer schemes. Table 6 compares these experiments to the saving rates in the data (row 1), the baseline demographic change only simulation (row 2), and the baseline complete model simulation (row 3).

TABLE 6—ADDITIONAL EXPERIMENTS USING THE COMPLETE MODEL

	Average household saving rates in percent				Change 1979–2009
	1955–1979	1980–1989	1990–1999	2000–2009	
1. Data	4.5	14.2	18.4	24.7	17.6
2. Baseline	4.3	8.8	14.0	15.9	11.9
3. Complete model	3.1	11.5	11.4	20.5	16.8
4. Reduced wage growth w	3.1	10.5	11.1	19.8	19.2
5. Higher interest rates r	23.4	37.9	39.2	41.4	18.3
6. Replacement rate 20 percent	3.6	11.3	12.2	20.9	20.1
7. Replacement rate 40 percent	1.6	8.2	7.9	16.2	17.6
8. Declining replacement rate	2.1	10.4	11.5	21.2	20.5

later time when wages are high. Hence, a slowing down of that growth raises current saving.³¹ Clearly, wage growth affects saving behavior; however, the time pattern of low pre-reform growth and high post-reform growth works against explaining the time-path of the saving rate. In light of this, demographic considerations seem to be a critical component in understanding the saving rate.

Variations in Interest Rates.—Row 5 of Table 6 shows the model saving rates when the interest rate is set as the marginal product of capital throughout the postreform period instead of r increasing more gradually over time. With this higher interest rate, the model generates a saving rate that lies substantially above the data. This scenario is unrealistic, however, because during the time period of interest most production was owned and carried out by state-run companies and other collectively owned enterprises. Households did not own these firms and therefore did not exercise decision making over retained earnings. The investment/saving choices made by the state-owned enterprises may not impact household decisions because the (virtually nonexistent) dividend policy is controlled by government appointed managers. Certainly this was true during the central planning period.

We do not report but have carried out several more robustness checks on the choice of interest rates and the growth of household income, including feeding in the interest rates on cash deposits (from the World Bank estimates), setting r to the marginal product of capital and w to the marginal product of labor (both based on our estimates), and varying the projected values for r and w .³² To summarize, higher interest rates increase household saving and higher (expected) wage growth tends to decrease saving. We believe our choice for the time series of interest rates and wages in the baseline complete model are reasonable given the available data. They are also in line with values that have been used elsewhere in the literature.

Variations in the Pension.—Our treatment of the formal pension is a simple τ_t transfer of labor income from the working to the retired, maintaining a constant

³¹ We also simulated the model using the higher wage growth rates for 1997 on, as reported in Yang, Chen, and Monarch (2010). The saving rates are lower, but, as argued above, we do not think these wages directly map into w .

³² We think that the inevitable slowing of growth will happen sooner rather than later, as does (apparently) the Chinese leadership. The *Wall Street Journal* reports that Chinese Premier Wen Jiabao set the 2012 growth target at 7.5 percent, significantly lower than the actual growth rate in 2011 of 9.2 percent. [Davis, Bob. 2012. "China Settles In for Lower Growth; Lower Target Signals Comfort With Economic Shift." *Wall Street Journal*, March 5.]

decrease saving. We believe our choice for the time series of interest rates and wages in the baseline complete model are reasonable given the available data. They are also in line with values that have been used elsewhere in the literature.

Variations in the Pension.—Our treatment of the formal pension is a simple τ_t transfer of labor income from the working to the retired, maintaining a constant replacement rate (at 25 percent) social security system. Under this system, retirees receive a constant fraction of their final working year's wage throughout retirement. The transfer rate τ_t is adjusted each period to equate payments from workers and designated benefits for retirees. Here we examine variations in the pension plan.

First, in row 6 of Table 6, we decrease the replacement rate to 20 percent, the currently mandated replacement rate for urban workers. When faced with a lower expected pension (and lower current taxes), households save more. As shown in row 7, setting the replacement rate to 40 percent lowers the saving rate. The level of the defined benefits primarily affects the saving rate level rather than the trend. Thus, the overall increase in saving between 1955 and 2009 generated via the demographics channels is not overly sensitive to the choice of replacement rate.

Next, we run the model with a declining replacement rate over time. Chamon, Liu, and Prasad (2010) argue that the effective support for the aged, which was high during central planning (the “iron rice bowl”), has declined. In row 8, we set the replacement rate at 40 percent from 1955 to 1997, then 20 percent for cohorts who retire after 1997 (the year of the most recent large reform in pension coverage). These simulations produce saving dynamics that are almost identical to the constant replacement exercises, except the total change in saving from 1979–2009 is slightly higher since workers retiring before 1997 save less.

The reformation of China's pension system is currently a matter of speculation and debate (Song et al. 2013). Along with interest rates and wage growth, expected pension support is obviously an important factor in determining the rate of household saving, both within our model and in the real world. Our analysis indicates that, in addition to these factors, the changing demographic structure is also important for understanding the evolution of China's household saving rate.

V. Conclusion

The primary purpose of our paper is to investigate the quantitative impact of demographic change on the household saving rate. Because China has experienced large variation in both variables, it provides a fertile laboratory for such an investigation. Some of the more conspicuous facets of China's saving rate include its relatively low level prior to the implementation of the one-child policy, its upward trend beginning in the late 1970s, and its current high level.

As saving is a multifaceted phenomenon, many explanations have been proposed for the increasing Chinese saving rate, including the precautionary saving motive in conjunction with high income uncertainty, persistent cultural differences, changes in the social welfare structure, features of the age-earnings profile, the male:female sex imbalance, and life-cycle considerations combined with demographic change. These mechanisms are not mutually exclusive, and each probably has at least some

quantitative significance for understanding this complex issue. We have focused on the last mechanism by examining the ability of standard life-cycle considerations combined with demographic changes to explain the evolution of household saving in China from 1955 to 2009.

We find that demographic variation alone explains over half of the current household saving rate. Using only changes to the demographic profile, the model generates low household saving rates in the prereform era and a dramatic increase during the postreform period, which is largely in line with the data. Projecting forward, our model predicts that the household saving rate should moderate as the Chinese population ages, and it is aging quite rapidly. The Chinese external surpluses currently observed, to the extent that they are driven by household saving, may also be a temporary phenomenon.

Two aspects of the model are central to the analysis. The first is that consumption by dependent children enters into household utility. The second is the changing demographic distribution over time. We conclude that a large component of the increased saving rate can be attributed to the reduction in family size brought about through population control policies and that the model mechanisms linking demographics to household saving behavior are quantitatively important for explaining the time path of the saving rate. We have refrained from modeling specific events in recent Chinese history and other structural changes to the Chinese economy except through their impact on interest rates and wages. We think demonstrating that demographics have a large quantitative effect on household saving within a relatively simple life cycle model is, in itself, an important step toward understanding the massive rise in the Chinese household saving rate.

APPENDIX A: PROOF OF PROPOSITION 1

The lifetime Lagrangian for a household at age 20 is

$$\begin{aligned}
 (A1)L = & \sum_{j=0}^{43} \beta^j \left(\mu(n_{t+j,j})^\eta \left(\frac{(c_{t+j,j}^c)^{1-\sigma}}{1-\sigma} \right) + \left(\frac{c_{t+j,j}^{1-\sigma}}{1-\sigma} \right) \right) + \sum_{j=44}^{65} \delta_{t+j,j} \beta^j \left(\frac{(c_{t+j,j})^{1-\sigma}}{1-\sigma} \right) \\
 & + \sum_{j=0}^{43} \lambda_{t+j,j} (n_{t+j,j} c_{t+j,j}^c + c_{t+j,j} + a_{t+j+1,j} \\
 & - (1 - \tau_{t+j} - \tau^c) w_{t+j,j} - (1 + r_{t+j}) a_{t+j,j}) \\
 & + \sum_{j=44}^{65} \lambda_{t+j,j} (c_{t+j,j} + a_{t+j+1,j} - p_{t+j,j} - (1 + r_{t+j}) a_{t+j,j}).
 \end{aligned}$$

The first-order conditions of consumption for households with ages $j \in (0, 43)$ and dependent children are

$$(A2) \quad \beta^j c_{t+j,j}^{-\sigma} - \lambda_{t+j,j} = 0,$$

$$(A3) \quad \beta^j \mu (n_{t+j,j})^\eta (c_{t+j,j}^c)^{-\sigma} - n_{t+j,j} \lambda_{t+j,j} = 0.$$

Equating the marginal utility of individual and children's consumptions, (A2) and (A3), implies

$$(A4) \quad c_{t+j,j}^c = n_{t+j,j}^{\frac{\eta-1}{\sigma}} \mu^{\frac{1}{\sigma}} c_{t+j,j}.$$

We next denote the total household consumption as \bar{c} for households with dependent children as

$$(A5) \quad \bar{c}_{t+j,j} = n_{t+j,j} c_{t+j,j}^c + c_{t+j,j}, j \in (0, 43).$$

This definition allows us to express utility for households with dependent children in terms of total household consumption.

Using (A4) and incorporating (A5) gives

$$(A6) \quad c_{t+j,j} = \frac{\bar{c}_{t+j,j}}{\left[1 + \mu^{\frac{1}{\sigma}} n_{t+j,j}^{\frac{\eta-1+\sigma}{\sigma}} \right]},$$

$$(A7) \quad c_{t+j,j}^c = \frac{\mu^{\frac{1}{\sigma}} n_{t+j,j}^{\frac{\eta-1}{\sigma}} \bar{c}_{t+j,j}}{\left[1 + \mu^{\frac{1}{\sigma}} n_{t+j,j}^{\frac{\eta-1+\sigma}{\sigma}} \right]}.$$

These are the optimal consumption choices for households with $j \in (0, 43)$. We can therefore rewrite lifetime utility of an agent at age 20 (3) using (A6) and (A7) as

$$(A8) \quad U_t = \sum_{j=0}^{43} \beta^j \left(\mu (n_{t+j,j})^\eta \left(\frac{\left(\frac{\mu^{\frac{1}{\sigma}} n_{t+j,j}^{\frac{\eta-1}{\sigma}} \bar{c}_{t+j,j}}{1 + \mu^{\frac{1}{\sigma}} n_{t+j,j}^{\frac{\eta-1+\sigma}{\sigma}}} \right)^{1-\sigma}}{1-\sigma} \right) + \left(\frac{\bar{c}_{t+j,j}^{1-\sigma}}{1 + \mu^{\frac{1}{\sigma}} n_{t+j,j}^{\frac{\eta-1+\sigma}{\sigma}}} \right)^{1-\sigma} \right) \\ + \sum_{j=44}^{65} \delta_{t+j,j} \beta^j \left(\frac{c_{t+j,j}^{1-\sigma}}{1-\sigma} \right).$$

Algebraically, (A8) can be rearranged and simplified to

$$U_t = \sum_{j=0}^{43} \gamma_{t+j,j} \frac{\bar{c}_{t+j,j}^{1-\sigma}}{1-\sigma} + \sum_{j=44}^{65} \delta_{t+j,j} \beta^j \frac{c_{t+j,j}^{1-\sigma}}{1-\sigma},$$

where

$$\gamma_{t,j} = \beta^j \left(1 + \left[\mu n_{t,j}^{\eta+\sigma-1} \right]^{1/\sigma} \right)^\sigma.$$

This last expression increases with n as long as $\eta + \sigma > 1$.

APPENDIX B: THE DATA

We use the model to predict the saving rate starting in 1955. Thus, the model simulations begin in 1890, which is when an 85-year-old in 1955 starts his or her economic life. Data that covers 1890 to 2009 are drawn from multiple sources as described in this Appendix.

A. Demographics over Time

Most of the demographic data comes from the *United Nations Population Prospects*, which reports annual population by age from 1950 to the present and projections to 2050. To arrive at population by age back to 1890, we assume that population shares between 1890–1949 remained constant at their 1950–1955 averages and then apply them to the backcasted total population using annual population growth rates from the *Angus Maddison Historical Data* (www.ggd.net/maddison/oriindex.htm) on population. The youngest cohort in 2009 makes its forward looking consumption and saving decisions based on observations extending to 2074. To provide households with these future values, we forecast demographics beyond the United Nations projections by holding the number of newborns constant at the 2050 level and assuming that age-specific survival rates are constant at their 2050 rates. The saving rates in our time frame of 1955–2009 are largely unaffected by alternative assumptions on future (after 2050) demographic compositions.

In most of the simulations, households in the prereform era do not foresee the implementation of the one child policy. Instead, households believe that the age distribution will evolve in a manner consistent with the United Nations projections published in 1978. In other words, households incorrectly anticipate that from 1980 to 2000 the age distribution (and therefore family size) will be as predicted by the United Nations in 1978. The 1978 United Nations projections are in 5-year age groups, so we set the distribution of people within these groups to the same distribution observed in 1980. The projected age distribution for years between 1980 and 2000 that are not available in the 1978 report have been linearly interpolated. The households believe that, in the years after 2000 (the last year forecast in 1978), the age distribution will converge to the same distribution as projected in the subsequent *United Nations Population Prospects* forecasts, only 25 years later. In the simulations, the households realize in 1979 that their projections for post-1980 are wrong (i.e., the one-child policy will curtail fertility). The households then switch to believing the projections from the more recent *United Nations Population Prospects*, which is perfect foresight in the model.

The United Nations data does not distinguish between urban and rural status, so, to run the simulations with urban and rural separated, we rely on data from *Chinese Population Statistics* 1949–1985, several editions of the *Chinese Population*

Statistics Yearbook,³³ and recent years (2007–2010) of the *Chinese Population and Employment Yearbook*. All together, these sources only contain 16 years of useable data on the complete age distribution, with the earliest year being 1964. We use this data to calculate the rural/urban population ratio by age for each year, keeping the total population (urban plus rural) as reported in the United Nations data. We follow the same procedure as above to fill in missing years. Except, in accordance with the aggregate data (e.g., see Naughton 2007), we assume the urbanization rate was slow in the pre-reform period. We backcast the population as above, again with the slow urbanization rate. Going forward, post-2009, we assume the age-specific rural-to-urban migration patterns will slow from an average of 2.5 percent per year (the current rate according to the CIA Factbook) to 1 percent per year (the rate in the United States) by 2050. Agents have perfect foresight throughout the urban and rural simulations.

B. Family Size and Support Ratios in the Cross Section

In the model, the number of children in the household varies with the age of the household head, producing a hump shaped age-to-family-size profile (i.e., the average 20-year-old and 59-year-old have fewer children to support than the average 40-year-old within any given year). We use the 2007 Rural-Urban Migration in China and Indonesia survey (RuMCI) data to calculate the average number of children supported by household head with age j . Call this $n_{2007,j}$.

We have information on the average number of children per parent (by age of parent) in the cross section for only one year. We use this information to calculate the implied number of children per parent (by age) for the rest of the time series by assuming the relative number of children across cohorts stays the same (although the total number of children changes), as follows

$$n_{t,j} = \frac{n_{2007,j}}{\sum_{j=0}^{43} n_{2007,j}} N_{t,j}^c$$

where $n_{2007,j}$ is the average number of dependent children per parent that cohort j had in 2007 (from the RuMCI data), $N_{t,j}$ is the total number of parents with age j in year t (from the United Nations data), and N_t^c is the aggregate number of children in year t . This calculation ensures that the number of children used in the simulations agrees with the United Nations data in every year.

We estimate the number of working age children supporting each retiree (separately for each cohort) using the model in conjunction with the United Nations data. Specifically, we set the number of working children for a given cohort of retired parents equal to the maximum number of children that the specific cohort ever supported in their household at one time (in the model). The intergenerational family transfers from working children to retired parents are distributed accordingly. For example, an 85-year-old in 2009 receives transfers from more workers than a

³³We thank Jing Wang for assembling this data.

65-year-old in 2009 because the 85-year-old cohort had more children on average than the 65-year-olds.

C. Wages in the Cross Section

As with family size, we calculate the average wages in the cross section (by age) using the 2007 RuMCI data. Call this $w_{2007,j}$. For the “demographic change only” simulations, $w_{t,j} = w_{2007,j}$ for all t .

D. Wages over Time

In the “complete model,” wages vary over time. Since we only have a single cross section to calculate wages by age, we assume the relative wages stay fixed in the cross section even as the observed aggregate average wage grows. Thus, the time varying, age specific wage is given by the following

$$w_{t,j} = \frac{w_{2007,j}}{\sum_{j=0}^{43} w_{2007,j} N_{t,j}} W_t N_t,$$

where $w_{2007,j}$ is the average wage per household head with age j in 2007 (from the RuMCI data), $N_{t,j}$ is the total number of people with age j in year t (from the United Nations data), N_t is the total population in year t , and W_t is the aggregate average wage per worker.

We use household income data from the *China Health and Nutrition Survey* (1989, 1991, 1993, 1997, 2000, 2004, 2006, and 2009 waves) to estimate the growth rate for the aggregate average wage W_t . We use this micro-data because it has income broken down by source, allowing us to choose a measure of household income consistent with the wage in the model. In particular, we set labor income to total non-capital income, omitting net family transfers. We assume no wage growth pre-reform, and from 1978 to 1989, we assume the growth rate for w gradually increases. Finally, we smooth the annual wage series with the Hodrick-Prescott filter (smoothing parameter $\lambda = 100$).

E. Interest Rates

In the “demographic change only” simulations, the interest rate r_t equals 4 percent for all t . In the “complete model,” the interest rate varies as follows. Before 1978, the interest rate remains at 4 percent. Beginning in 1978, we assume households obtain the marginal product of capital on 30 percent of their saving. The remaining 70 percent of saving only returns the prevailing real rate on cash bank deposits. Then, we gradually increase the return on saving by assuming households gain greater access to the returns from capital investment. Each year, households place 1 percent more of their saving into assets getting the higher rate of return (the marginal product of capital), until the split between cash deposits and other investments reaches 50/50. As with wages, we smooth the interest rate with the Hodrick-Prescott filter.

The year-by-year real rate of return on bank deposits comes from the *World Bank World Development Indicators*. We calculate the year-by-year marginal product of capital based on the following data sources. From 1952 to 1978, GDP, investment, and the price index are from the *China Statistical Data Compilation*; from 1979 to 2009, they are from various issues of the *China Statistical Yearbook*. GDP from 1890 to 1952 were taken from the *Angus Maddison Historical Data* with linear interpolation for missing values (primarily in years between 1890–1930). We then estimate the capital stock K using the perpetual inventory method (with a depreciation rate δ of 0.10) and take the stock of labor as the number of individuals aged 20–63. Then, assuming a representative firm with a constant returns to scale production function (producing output Y), the interest rate is set to the marginal product of capital less depreciation

$$r_t = (1 - \alpha) \frac{Y_t}{K_t} - \delta.$$

We backcast presample investment observations and forecast postsample observations. From 1890 to 1952, we assume that labor's share $\alpha = 0.60$ and the interest rate $r = 0.04$. This gives a capital-output ratio of 2.87 for 1952, close to Chow's (1993) estimate of 2.97. From 1955 to 2009, the calculations become more involved due to the observed decline in labor's share over this time period. See Karabarbounis and Neiman (2012), Hu and Khan (1997), and Hsieh and Klenow (2009) for estimates of the decline. As informed by these papers, we keep $\alpha = 0.6$ in the prereform years (1955–1978), and then decrease labor's share by 0.02 per year between 1979 and 1988 until it reaches 0.4, where it remains from 1989 onward. The choice of labor's share affects the saving rate only through its effect on interest rates. Future values of the interest rate are generated by assuming a gradual transition of output growth to a steady state rate of 1.0 percent with a half-life of adjustment equal to 3.1 years and with the slowdown beginning in 2012.

Our partial equilibrium model does not require that assets held by the households equal the capital stock. Implicitly, we are assuming that a national intermediary bank holds the difference. The national bank finances the capital stock and clears excess supply or demand for capital on an (unmodeled) international market. Changes in the intermediary's foreign asset position do not correspond to the actual current account because the model only considers household saving. Finally, we use the same data and methodology as above to calculate the time varying wage for the simulation mentioned in the main text in which w is given by the marginal product of labor.

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