The One-Child Policy and Household Savings*

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Abstract

We ask how much the advent of the 'one child policy' can explain the sharp rise in China's household saving rate. In a life-cycle model with endogenous fertility, intergenerational transfers and human capital accumulation, we show a macroeconomic and a microeconomic channel through which restrictions in fertility raise aggregate saving. The macro-channel operates through a shift in the composition of demographics and income across generations. The micro-channel alters saving *behaviour* and education decisions at the individual level. A main objective is to quantify these various channels in the data. Exploiting the birth of twins as an identification strategy, we provide direct empirical evidence on the micro-channel, at the same time imputing roughly 40% of the rise in aggregate household saving rate to the policy since its inception in 1980. More than two-thirds of this rise is found to be attributed to the micro-channels alone. Our quantitative OLG model can explain from 30% to 55% of the rise in aggregate saving rate; equally important is its implied shift in the level and shape of the *age-saving profile* consistent with micro-level estimates from the data.

Keywords : Life Cycle Consumption/Savings, Fertility, Intergenerational transfers
JEL codes: E21, D10, D91

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1 Introduction

China's household saving rate is staggeringly high in comparison to most other countries, and increasing at a rapid rate. Between 1986 and 2009 it rose from 11.3% to 30.7%.[1] By standard theories, households in a rapidly growing economy should borrow against future income to bring forward consumption, and therefore face a declining saving rate rather than a rise. The conundrum has been referred to by both academics and policymakers as a 'Chinese Saving Puzzle' (Modigliani and Cao (2004)), spurring many attempts at explaining it. This paper evaluates the contribution of the 'one-child policy' in accounting for this puzzle.

The 'one-child policy', implemented in the late 1970s as part of China's population control program, is a relatively under-studied event— with economic ramifications to a large extent unknown. An immediate question that comes to mind is whether, and to what degree, it has impacted the national saving rate. That concomitant shifts in demographic compositions— of young workers and middle-aged savers—can directly influence the rate of saving at the aggregate level is well-understood through the classic formulations of the life-cycle motives for saving (Modigliani (1976)).[2] Yet, fertility drops can also impinge on saving *behavior*. If intergenerational transfers from children to parents are a primary means of old-age support, the reduction in the number of offspring may considerably alter saving decisions at the individual level.

In the case of China, intergenerational transfers are not only commonplace but also account for a large share of old-age income. An everyday Chinese adage crystallizes the essence of its purpose: "rear children to provide for old-age" (*yang lao fu you*). In a life-cycle model with endogenous fertility, intergenerational transfers and human capital accumulation, we show that an exogenous reduction in fertility induces higher saving for retirement—in anticipation of lower overall transfers received from children (the 'transfer effect'). Parents, however, can substitute quantity towards quality in the form of higher investment in children's education, though the rise in wages due to human capital accumulation is not enough to compensate for the overall reduction in transfers due to a fall in the number of children. Another effect is the reduction in expenditures associated with a fall in the number of children that tend to raise household saving (the 'expenditure effect'). These forces constitute the basic *micro-channel* that we analyze, quantify and test. We find that in accounting for the rise in household saving, the micro-channel is significantly more important than the macro-channel conventionally emphasized. More broadly though, the policy can also be exploited as a natural experiment of an exogenous restriction in fertility to analyze the relationship between fertility, household saving and human capital accumulation in developing countries.

This paper thus makes three main contributions. First, our conceptual framework relevant for analyzing fertility and saving incorporates two new elements to the standard lifecycle model (with endogenous fertility): intergenerational transfers and human capital accumulation. The model's inherent tractability lays bare the fundamental mechanisms driving this relationship, and permits a precise decomposition of the policy's overall effect to the contribution of its component parts—the various macro and micro-level channels that we analyse, and subsequently test and quantify. The theory proves to be

[1] Average household saving rate was 4% in OECD economies and 1.7% in the U.S. in 2007.

[2] If the young save less than the middle-aged, then the rising share of the middle-aged during the demographic transition following the policy would raise aggregate saving.

useful also in showing how the micro-channel can be identified through a *cross-sectional* comparison of twin-households and only-child households. Compared to other works examining the relationship between fertility and saving, the joint determination of fertility and education decisions in analyzing saving is critical and has been hitherto absent.[3]

Our second contribution is to exploit the incidence of twins under the one child policy as an exogenous deviation to fertility, in order to empirically 1) provide some direct evidence on the specific micro-level channels that underlie the model, and 2) give an estimate of the overall impact of the policy on saving, while 3) inferring the quantitative contributions of the micro and macro channels from the data. Three pieces of direct evidence for the micro-channels are: twin-households have a lower saving rate than households with an only child—but only in the presence of fertility controls; twin-households have lower education expenditures and attainment per child; and transfers from children to parents rise in the quantity and quality of the children.

Based on these estimates from twins, we perform a counterfactual exercise that assesses how much of the rise in aggregate saving rate can be attributed to the one child policy. We find that in 2009, aggregate household saving rate would have been 40 percentage points lower had the parents born on average two children rather than one. If however, the natural fertility rate would have been above 2 children per household, this estimate would serve as a lower bound for the overall effect. In other words, the policy can explain *at least* 40% of the 20 percentage-point-increase in the household saving rate since the commencement of the one-child policy in 1980. The data reveals that the micro channels are significantly more important in its quantitative contribution than the standard macro-channel–accounting for two-thirds of the total effect.

The third main contribution is to develop a quantitative multi-period version of the theoretical model that can be calibrated to Chinese household-level data. The model yields a finer and more realistic *age-saving profile* and bears distinct implications on the level and shape of the age saving profile following the one child policy. The model can capture some key patterns characterizing the evolution of the age saving profile observed between 1986-2009, while a standard OLG model without transfers and human capital accumulation cannot. We find that the model performs well in its quantitative predictions of the micro channel and the overall effect of the policy on household saving—yielding estimates close to those of the data. Depending on the natural fertility rate that would have prevailed in the absence of fertility controls over this period, the model imputes about 30-55% of its rise since 1980 to the one child policy.

Importantly, the ability to match these micro-evidence on saving behavior across generations gives further credence to the model's macroeconomic implications. It is in this sense that a distinguishing feature of our paper, and one that sets it apart from the rest of the literature, is our endeavor to bridge the micro-level approach with the macro-level approach in linking demographics to saving. Works such as Modigliani and Cao (2004), Horioka and Wan (2007), Curtis, Lugauer, and Mark (2011) find ample evidence supporting the link between demographics and saving at the aggregate level, but meet difficulty when confronting micro-data, and in particular, the puzzling pattern that the young cohort's saving rate rose faster than the middle-aged cohort's saving rate in the past two

[3]These works include Modigliani and Cao (2004), Boldrin and Jones (2002), Chakrabarti (1999), Cisno and Rosati (1992), and Raut and Srinivasan (1994). These studies, however, do not include human capital investment decisions made by parents for their children.

decades.[4] In our framework this pattern arises naturally: along the initial stages of the demographic transition, two differentially-affected cohorts coexist in the economy: the younger ones subject to the one child policy—and therefore to the micro-channels that raise saving—and the older cohorts not subject to the policy— and therefore saw no change in their saving behavior. This observation, though seemingly perverse, is in fact consistent with our (modified) lifecycle model.

One important departure of this paper from the literature linking fertility, demographics and saving is, in this respect, to evaluate and quantify the extant micro- and macro-channels through which fertility affects saving. There are common theoretical elements shared with recent works, however. The closest one is Banerjee, Meng and Qian (2010), which also brings to the forefront intergenerational transfers in relating the impact of fertility to saving, while emphasizing gender differences in the propensity to transfer. There are nevertheless important differences in both theory and empirics. First, their paper sidesteps human capital accumulation and costs to children issues. Indeed, the strength of the 'transfer channel' on saving depends on the ability of parents to substitute quantity for quality. In the absence of costs to educating children, fertility would not matter for saving. The joint decision between human capital and saving decisions is thus critical.[5] At the same time, some of our empirical findings are mutually reinforcing. They find a negative, causal relation from fertility to saving—- albeit using an entirely different identification strategy and an altogether different dataset.[6] Apart from the use of a richer model which allows for a rigorous quantitative evaluation and more direct evidence on cohort behavior, this work goes beyond these existing studies from an empirical standpoint in providing more direct evidence on the specific micro-channels (education decisions and intergenerational transfers).[7]

Oliveira (2012) adopts a microeconomic approach in analyzing, specifically, the relationship between fertility and old-age support when fertility decisions are subject to a quantity-quality tradeoff—a key component common to both of our conceptual frameworks. However, the analysis between household saving and fertility is absent and not a focal point in her work. The paper finds a causal effect of fertility on transfers in the data that corroborates and complements one of our main empirical findings, although under a different identification strategy and dataset. Using twins *at first births* in Indonesia and China—she finds that transfers from children to parents are increasing in the quantity and quality of children, but that transfers per child are decreasing in the number of siblings. The stylized two-period model however is not suited for a quantitative evaluation.

[4]This is first noted by Song and Yang (2010) and Chamon and Prasad (2010).

[5]Banerjee, Meng and Qian (2010) acknowledge that their model falls short of explaining both the levels of saving rates and the responsiveness of saving to an additional child. One channel that is also missing in their model is the 'expenditure channel', which we show can have a quantitatively significant impact on saving. The absence of these effects may explain the quantitative shortfall.

[6]They exploit the changes in the demographic structure induced by family planning policies—the degree of which differed across provinces and over time—and find a negative causal relationship between fertility and saving. Another difference is that their work highlights the importance of children's gender in determining parents' saving behavior–a facet of reality we do not consider in current work.

[7]Another recent paper is Ge, Yang and Zhang (2012), which investigates empirically how demographical compositional changes following population control policies affect saving. Their paper has a slightly different focus— to empirically estimate the impact of these policies on the saving behavior at various ages. Their identification strategy relies on exogenous variations in cohort-specific fertility caused by the differential timing of population control policies that affected different birth cohorts, and by the interaction of birth cohorts with fines across provinces on unauthorized births under the one-child policy. Their empirical results lend support to the age saving profile implications of our quantitative model.

Finally, our paper relates to and complements other works aimed at understanding China's perplexingly high national household saving rate in recent years. A few compelling explanations that various past works have explored include: (1) precautionary saving (Blanchard and Giavazzi (2005), Chamon and Prasad (2010) and Wen (2011));[8] (2) demographic structural changes (Modigliani and Cao (2004), Curtis, Lugauer and Mark (2011), and Ge, Yang and Zhang (2012)); (3) income growth and credit constraints (Coeurdacier, Guibaud and Jin (2012)), potentially also in housing expenditures (Bussiere et al. (2013)); (4) changes in income profiles (Song and Yang (2010), Guo and Perri (2012)); (5) gender imbalances and competition in the marriage market (Wei and Zhang (2009)); Yang, Zhang and Zhou (2011) provide a thorough treatment of aggregate facts pertaining to China's saving dynamics, and at the same time present the challenges some of these theories face. The recent availability of household-level data should enable researchers to probe into micro-level patterns and behavior to bear out these macro-level theses—an attempt we make in the current work.

The paper is organized as follows. Section 2 provides certain background information and facts that motivate some key assumptions underlying our framework. Section 3 provides a simple theory that links fertility and saving decisions in an overlapping generations model. Section 4 undertakes an empirical investigation on the main theoretical mechanisms using twin births as source of identification and provides some quantitative guidance on the overall impact of the one child policy on aggregate household saving in China. Section 5 develops a calibrated quantitative model to simulate the impact of the policy on aggregate saving as well as age-saving profiles. Macro and micro-level predictions of the model are confronted by their empirical counterpart. Section 6 concludes.

2 Motivation and Background

Based on various aggregate and household level data sources from China, this section provides stylized facts on (1) the background of the 'one-child policy' and its consequences on the demographic composition in China; (2) the direction and magnitude of intergenerational transfers, as well as (3) education expenditures incurred by households over their lifecycle. The quantitative relevance of these factors as shown by the subsequent preliminary evidence motivates the main assumptions underlying the theoretical framework. The various micro and macro data sources we use are described in Appendix B.

2.1 The One-Child Policy and the Chinese demographic transition

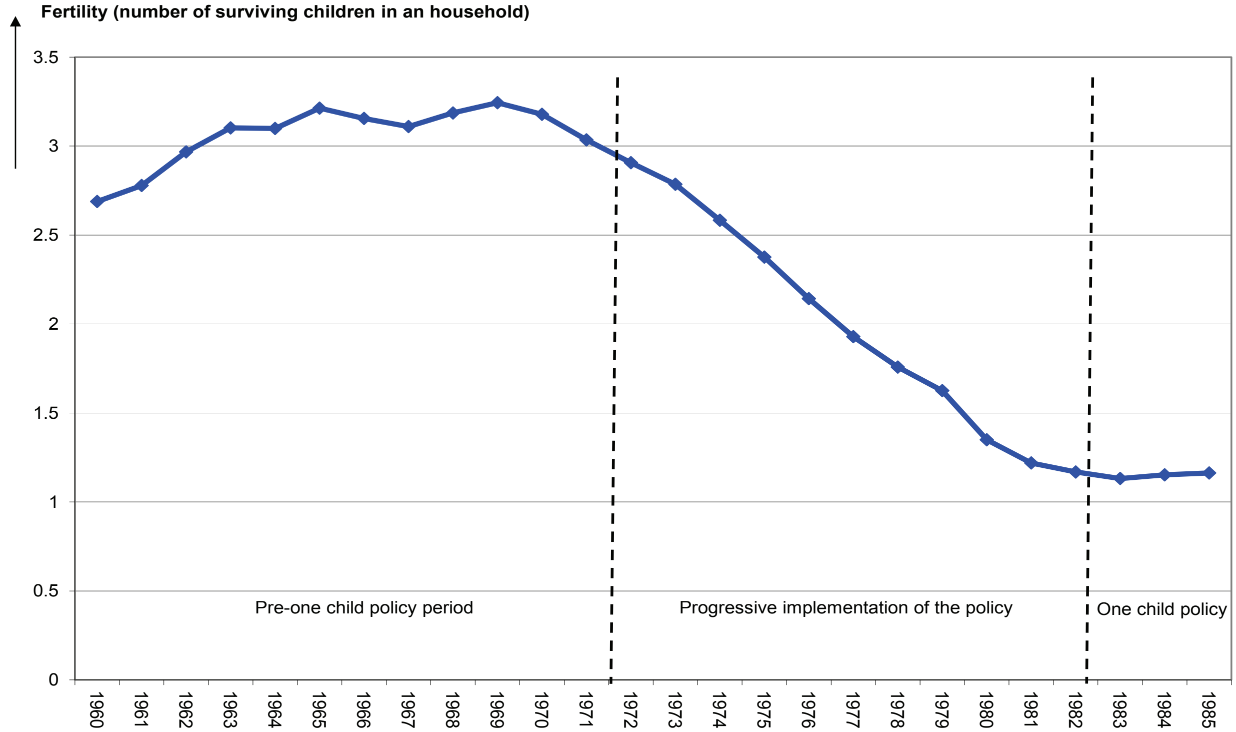
The one child policy decreed in 1979 aimed to curb the population growth spawned by the Maoist pronatality agenda. The policy was strictly enforced in urban areas and partially implemented in rural provinces.[9] The consequence was a sharp drop in the nation-wide fertility rate— from 5.5 children per woman in 1965-1970 to 2.6 between 1980-1985. Figure 1 displays the evolution of the fertility rate for urban households, based on Census data: a bit above three (per household) before 1970, it started

[8]These papers argue that rising unemployment risk and income uncertainty for the workers during a period of economic transition since the 1980s have triggered precautionary saving motives. However, this line of explanation would not fit with the evidence in Yang, Zhang and Zhou (2011) that these uncertainties have in fact decreased over the last ten years in China.

[9]In contrast to urban areas, rural provinces allowed the birth of two children in the event of a first-born girl.

to decline during the period of 1972-1980—when the one child policy was progressively implemented– and reached very close to one after its strict implementation by 1982.[10]

Figure 1: Fertility in Chinese urban areas



Notes: Data source: Census, restricted sample where only urban households are considered.

Fertility constraints being binding is a clear imperative for the purpose of our study. Household-level data (Urban Household Survey) manifests a strict enforcement of the policy for urban households, albeit less so for rural households: over the period 2000-2009, 96% of urban households that had children had only one child.[11] Urban households and their saving behavior are therefore a natural focal point in our empirical analysis.

The demographic structure has thus evolved accordingly, following fertility controls (Table 1). Some prominent patterns are: (1) a sharp rise in the median age— from 19.7 years in 1970 to to 34.5 years in 2010; (2) a rapid decline in the share of young individuals (ages 0-20) from 51% to 27% over the period, and (3) a corresponding increase in the share of middle-aged population (ages 30-60). While the share of the young is expected to drop further until 2050, the share of the older population (above 60) will increase sharply only after 2010— when the generation of only child ages. In other words, the 'one-child policy' leads first to a sharp fall in the share of young individuals relative to middle aged adults, followed by a sharp increase in the share of the elderly only one generation later.

[10]See Banerjee et al. (2010) for a detailed description of the progressive implementation of the policy in the 1970s.

[11]Some urban households had more than one child. If we abstract for the birth of twins, accounting for 0.9% of households, we conjecture that these remaining 3% households accounts for a sufficiently small portion to be discarded.

Table 1: Demographic structure in China

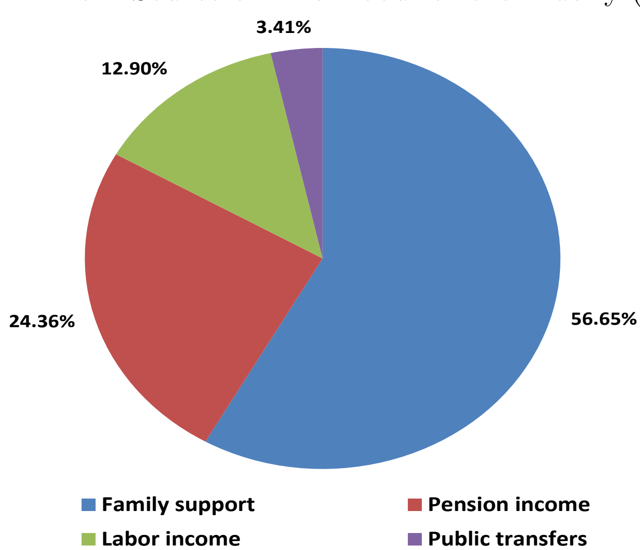
	1970	2010	2050
Share of young (age 0-20/Total Population)	51%	27%	18%
Share of middle aged (age 30-60/Total Population)	28%	44%	39%
Share of elderly (age above 60/Total Population)	7%	14%	33%
Median age	19.7	34.5	48.7
Fertility (children per women, urban areas)	3.18 (1965-70)	1.04 (2004-09)	- n/a -

Note: UN World Population Prospects (2011).

2.2 Intergenerational Support

Intergenerational support is the bedrock of the Chinese family and society. Beyond cultural mores, it is also stipulated by Constitutional law: "children who have come to age have the duty to support and assist their parents" (article 49). Failure in this responsibility may even result in law suits. According to Census data in 2005, the elderly (+65) urban population expect family transfers to contribute to more than half of their old age support (Figure 2).

Figure 2: Main Source of Livelihood for the Elderly (65+) in Cities



Note: Census (2005). Sample size: 236, 247.

China Health and Retirement Longitudinal Study (CHARLS) provides detailed data on intergenerational transfers. The pilot survey was conducted in 2008 for two provinces: Zhejiang (a prosperous coastal province) and Gansu (a poor inland province). The sample includes only households with at least one member above the age of 45 years, but for the purpose of our study the sample is first restricted to urban households in which at least one member (respondent or spouse) is older than 60 years of age. Transfers include those within households, i.e. when children and parents are co-residing in the same household. We consider children who are 25 years old and above as adults.

Intergenerational transfers can take on broadly two forms: financial transfers ('direct' transfers) and 'indirect' transfers in the form of co-residence or other in-kind benefits. According to Table 2, 45% of the elderly reside with their children in urban households. Positive (net) transfers from adult children to parents occur in 65% of households and are large in magnitude—constituting a significant share of old-age income of on average 28% of all elderly's pre-transfer income (and up to 47% if one focuses on the sample of transfer receivers). Table 2 also shows that the average transfers (as a % of pre-transfer income) are increasing in the number of children. The flip side of the story is that restrictions in fertility will therefore likely reduce the amount of transfers conferred to the elderly. This facts bears the central assumption underlying our theoretical framework.

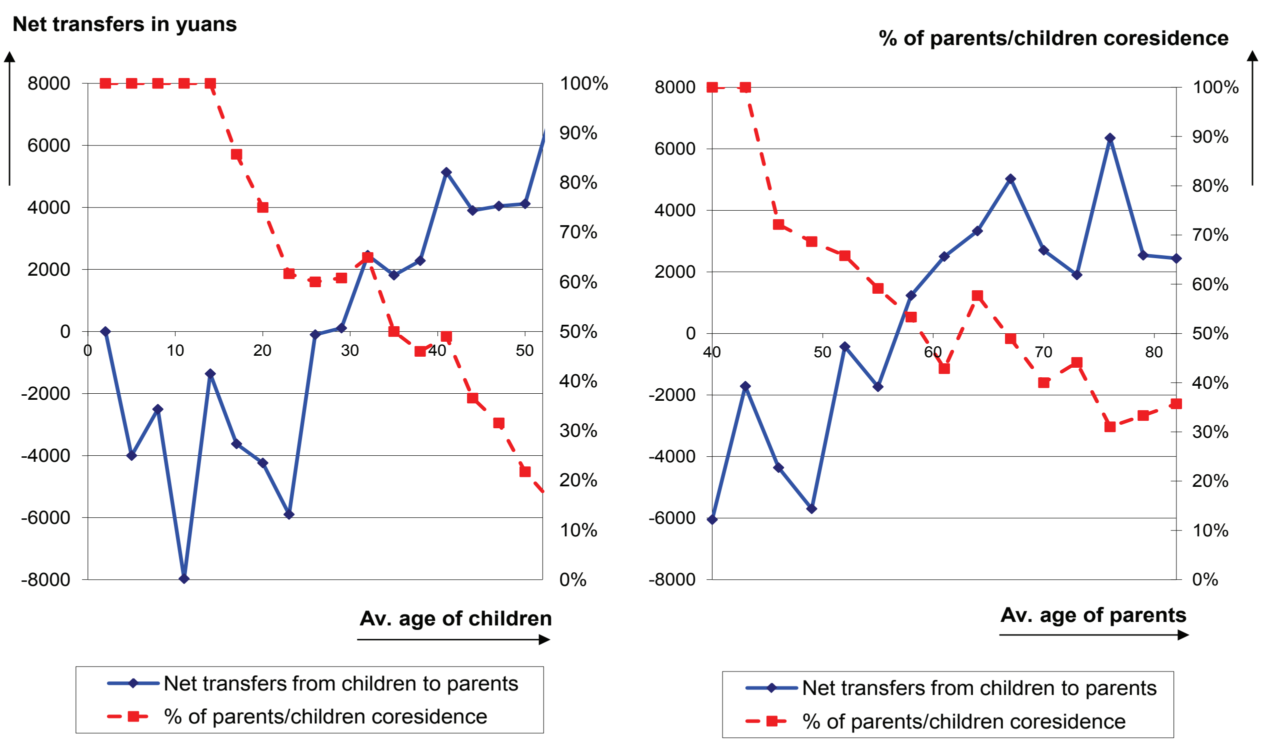
Table 2: Intergenerational Transfers: Descriptive Statistics

Number of households	321
Average number of adult children (25+)	3.4
Share living with adult children	45%
Incidence of positive net transfers	
- from adult children to parents	65%
- from parents to adult children	4%
Net transfers in % of parent's pre-transfer income	
- All parents	28%
Of which households with:	
- One or two children	10.5%
- Three children	34.6%
- Four children	45.9%
- Above Five children	69.7%
- Transfer receivers only	47%

Note: Data source: CHARLS(2008). Restricted sample of urban households with a respondent/spouse of at least 60 years of age with at least one surviving adult children aged 25 or older. Transfers is defined as the sum of regular and non-regular financial transfers and the yuan value of in-kind transfers. This includes transfers within households. Gross transfers are defined to be transfers from children to parents. Net Transfers are transfers from children to parents less the transfers received by children.

We next turn to the timing of these transfers—- paid and received at various ages of adulthood. Figure 4 displays the evolution of net transfers to, and subsequently from, one's children, in monetary values (left panel). Net transfers are on average negative, and continuously declining before one's child reaches the age of 25. This pattern concords with the conjecture that education investment is the main mode of transfers to children (see section 2.3 below). After this age, children on average confer increasing amounts of transfers to parents. If co-residence can be considered as another form of transfers, a similar pattern emerges (right panel of Figure 4): children leave the parental household as they grow up; later on, parents return to live with their children at later stages of their lives (above 78). The timing (and direction) of transfers between children and parents, as well as their magnitude, motivates our theoretical framework and provides guidance to subsequent calibrations of our quantitative model.

Figure 3: Net Transfers from Children to Parents



Note: CHARLS (2008), urban households, whole sample of adults. The figure plots the average amount of net transfers from children to parents and % of coresidence, by the average age of children (left panel) and of parents (right panel).

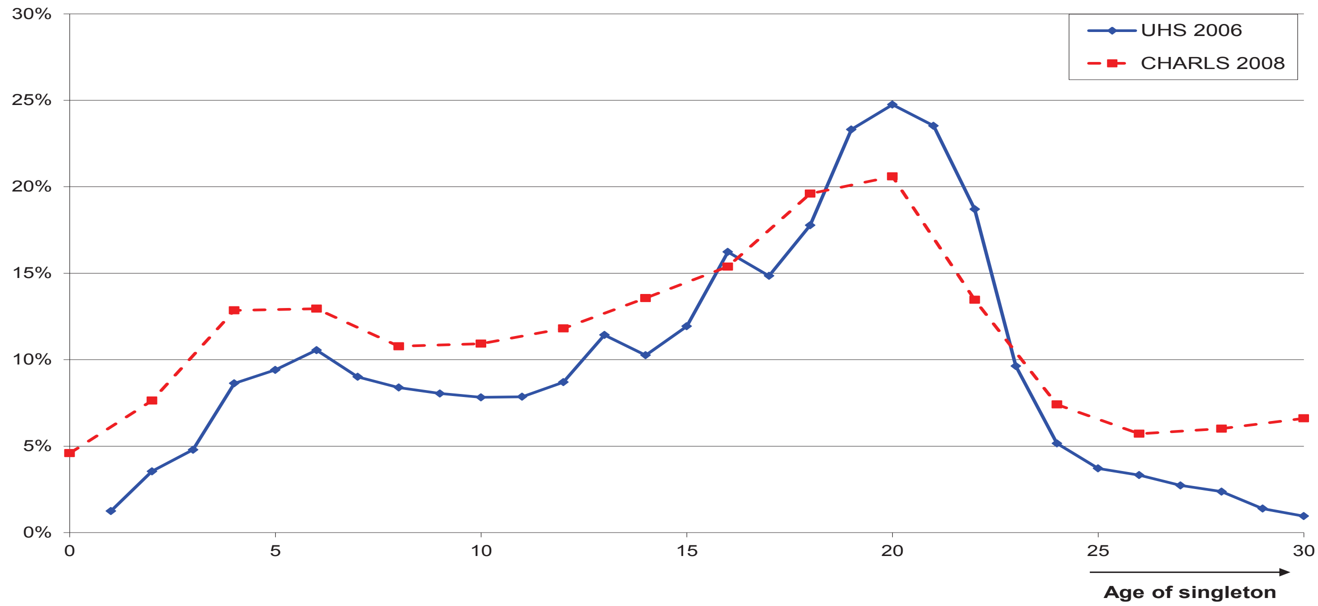
2.3 Saving motives and education expenditures

Our central thesis that household saving is motivated by education for children in earlier stages of parenthood and for old-age retirement in later stages is born out by basic observations from the data. Education and retirement planning are cited to be among the three most important reasons for saving, according to more than half of Chinese households in 2008 (Yao et al (2011)). For 69 percent of rural households, education or retirement are the most important motive for saving.

Using data from Urban Household Surveys (UHS) in 2006 and RUMICI (2008), we provide broad empirical evidence on the importance of education expenses in household budgets.[12] Restricting our

[12] As a robustness check, we use the alternative dataset the Chinese Household Income Project (CHIP) in 2002, which

Figure 4: Education Expenditures by Age



Notes: Data source: UHS (2006) and CHARLS (2008). Samples are restricted to households with an only child. This graph plots the average education expenditure (as a share of total expenditures) by the age of the only child.

attention to families with an only child, Figure 4 displays the share of education expenditures (in total expenditures) in relation to the age of the child; it ranges from roughly 10% when the child is below 15 and increases significantly up to 15-25% between the ages of 15 and 22. Data from the Chinese Household Income Project (CHIP) in 2002 (not displayed) provides some evidence on the relative importance of 'compulsory' and 'non-compulsory' (or discretionary) education costs: not surprisingly, the bulk of expenditures (80 to 90%) incurred for children above 15 are considered as 'non-compulsory', whereas the opposite holds for children below 15. This evidence motivates our assumption that education costs can be viewed as a fixed-cost (per child) for young children but a choice that is subject to a quantity-quality trade-off for older children.

3 Theoretical Analysis

We develop a simple and tractable multi-period overlapping generations model with intergenerational transfers, endogenous fertility and human capital accumulation. Semi-closed form solutions that arise from a parsimonious model reveal the key mechanisms that underlie the long-run relationship between fertility and saving (Section 3.1). The dynamic impact of the 'one child policy' is analyzed in Section 3.2, where we show theoretically how the impact of the policy on aggregate saving rate can be decomposed into a microeconomic and a macroeconomic channel. We then show how the time-series implication o of human capital accumulation evolution and the micro-channel of saving can identified based on cross-sectional observations of twin-households compared to only child-households.

yields similar estimates albeit slightly smaller in magnitude.

These theoretical findings form directly the basis for our empirical investigation taken up in Section 4. A quantitative version of the model as developed in Section 5 yields a more intricate and detailed individual age-saving profile which we compare to the data, but the main mechanisms are elucidated in the following simple four-period model.

3.1 Model

3.1.1 Set-up.

Consider an overlapping generations economy in which agents live for four periods, characterized by: childhood (k), youth (y), middle-age (m), and old-age (o). The measure of total population N_t at date t comprises the four co-existing generations: $N_t = N_{k,t} + N_{y,t} + N_{m,t} + N_{o,t}$.

An individual born in period $t-1$ does not make decisions on his consumption in childhood, $c_{k,t-1}$, which is assumed to be proportional to parental income. The agent supplies inelastically one unit of labor in youth and in middle-age, and earns a wage rate $w_{y,t}$ and $w_{m,t+1}$, which is used, in each period, for consumption and asset accumulation $a_{y,t}$ and $a_{m,t+1}$. At the end of period t, the young agent then makes the decision on the number of children n_t to bear. In middle-age, in $t+1$, the agent chooses the amount of human capital h_{t+1} to endow to each of his children, and at the same time transfers a combined amount of $T_{m,t+1}$ to his n_t number of children and parents— to augment human capital of the former, and consumption of the latter. In old-age, the agent consumes all available resources, which is financed by gross return on accumulated assets, $Ra_{m,t+1}$, and transfers from children $T_{o,t+2}$. A consumer thus maximizes the life-time utility including benefits from having n_t children:

$$U_t = \log(c_{y,t}) + v\log(n_t) + \beta\log(c_{m,t+1}) + \beta^2\log(c_{o,t+2})$$

where $v > 0$ reflects the preference for children, and $0 < \beta < 1$. The sequence of budget constraints for an agent born in $t-1$ obeys

$$\begin{aligned} c_{y,t} + a_{y,t} &= w_{y,t} \\ c_{m,t+1} + a_{m,t+1} &= w_{m,t+1} + Ra_{y,t} + T_{m,t+1} \\ c_{o,t+2} &= Ra_{m,t+1} + T_{o,t+2}. \end{aligned} \tag{1}$$

Because of parental investment in education, the individual born in period $t-1$ enters the labor market with an endowment of human capital h_t, which, along with experience $e < 1$, and a deterministic level of economy-wide productivity z_t, determines the wage rates:

$$w_{y,t} = ez_t h_t^{\alpha} \tag{2}$$

$$w_{m,t+1} = z_{t+1} h_t^{\alpha}. \tag{3}$$

We assume that the gross interest rate R is constant and exogenous. By making this assumption, we sever the link in which saving affects interest rates, and also the potential aggregate feedback of fertility onto interest rates.

Without loss of generality, the cost of raising kids are assumed to be paid by parents in middle-age, in period $t+1$, for a child born at the end of period t. This assumption corroborates with the empirical fact that the bulk of education costs are born in the period before the child enters the labor market–equivalent to the ages of 15 to 25. The total cost of raising n_t children falls in the mold of a time-cost that is proportional to current wages, $n_t\phi(h_{t+1})w_{m,t+1}$, where $\phi(h) = \phi_0 + \phi_h h_{t+1}$, and $\phi_0 > 0$ and $\phi_h > 0$. The consumption expenditure, including compulsory education expenditure, per child is a fraction ϕ_0 of the parents' wage rate, and the discretionary education cost $\phi_h h_{t+1}$ is increasing in the level of human capital—to capture the rising cost of education over a child's course of study.[13]

Transfers made to the middle-aged agent's parents amount to a fraction $\psi n_{t-1}^{\varpi-1}/\varpi$ of current labor income $w_{m,t+1}$, with $\psi > 0$ and $\varpi > 0$. This fraction is decreasing in the number of siblings—to capture the possibility of free-riding among siblings sharing the burden of transfers.[14] The transfer function is admittedly assumed for analytical convenience, but its main properties are tightly linked to the data and therefore to some extent justifiable. For instance, as we show in Section 4.4, transfers given by each offspring is indeed decreasing in the number of offspring, and the income elasticity of transfers is close to 1. The combined amount of transfers made by the middle-aged agent in period $t+1$ to his children and parents thus satisfy

$$T_{m,t+1} = -\left(n_t\phi(h_{t+1}) + \psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\right)w_{m,t+1}.$$

In old-age, agents become receivers of transfers from a total of n_t number of children:

$$T_{o,t+2} = \psi\frac{n_t^{\varpi}}{\varpi}w_{m,t+2}.$$

The life-time resource constraint thus requires that

$$c_{y,t} + \frac{c_{m,t+1}}{R} + \frac{c_{o,t+2}}{R^2} = w_{y,t} + \frac{w_{m,t+1}}{R}\left[1 - n_t\phi(h_{t+1}) - \psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\right] + \frac{\psi n_t^{\varpi}}{\varpi}\frac{w_{m,t+2}}{R^2}.$$

Assumption 1 *The young are subject to a credit constraint which is binding in all periods:*

$$a_{y,t+1} = -\theta\frac{w_{m,t+1}}{R}, \tag{4}$$

which permits the young to borrow up to a constant fraction θ of the present value of future wage income. For a given θ, the constraint is more likely to bind if productivity growth is high (relative to R) and the experience parameter e is low—conditions which we show to be met by the data. This assumption is necessary to generate realistic saving behaviour of the young—-that is, to avoid a counterfactual sharp borrowing that would have otherwise emerged under fast growth and a steep income profile (see also Coeurdacier, Guibaud and Jin (2012)).

The assumption of log utility implies that the optimal consumption of the middle-age is a constant fraction of the present value of lifetime resources, which consist of disposable income—of what remains

[13] This is a key departure from the quantity-quality trade-off models of Becker and Lewis (1973), later adopted by Oliveira (2012). They assume that costs to quality are independent of the level of quality.

[14] See Boldrin and Jones (2002) for such an endogenous outcome in a 'game of giving' among siblings.

after the repayment of debt from the previous period—and the present value of transfers to be received in old-age, less current transfers to children and parents:

$$c_{m,t+1} = \frac{1}{1+\beta}\left[\left(1-\theta-n_t\phi(h_{t+1})-\psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\right)w_{m,t+1}+\frac{\psi}{R}\frac{n_t^{\varpi}}{\varpi}w_{m,t+2}\right]$$

It follows from Eq. 1 that the optimal asset holding of a middle-aged individual is

$$a_{m,t+1} = \frac{\beta}{1+\beta}\left[\left(1-\theta-n_t\phi(h_{t+1})-\psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\right)w_{m,t+1}-\frac{\psi}{\beta R}\frac{n_t^{\varpi}}{\varpi}w_{m,t+2}\right]. \tag{5}$$

The old, by consuming all resources and leaving no bequests, enjoy

$$c_{o,t+2} = \frac{\beta}{1+\beta}\left[R\left(1-\theta-n_t\phi_m(h_{t+1})-\psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\right)w_{m,t+1}+\psi\frac{n_t^{\varpi}}{\varpi}w_{m,t+2}\right].$$

3.1.2 Fertility and Human Capital

Fertility decisions hinge on equating the marginal utility of bearing an additional child compared to the net marginal cost of raising the child:

$$\frac{v}{n_t} = \frac{\beta}{c_{m,t+1}}\left(\phi(h_{t+1})w_{m,t+1}-\frac{\psi n_t^{\varpi-1}w_{m,t+2}}{R}\right) \tag{6}$$

$$= \frac{\beta}{c_{m,t+1}}\left(\phi(h_{t+1})-\frac{1+g_{z,t+1}}{R}\psi n_t^{\varpi-1}\left(\frac{h_{t+1}}{h_t}\right)^{\alpha}\right)w_{m,t+1}, \tag{7}$$

where $g_{z,t+1} \equiv z_{t+2}/z_{t+1}-1$ is the growth rate of productivity. The right hand side is the net cost, in terms of the consumption good, of having an additional child. The net cost is the current marginal cost of rearing a child, $\partial T_{m,t+1}/\partial n_t$ less the present value of the benefit from receiving transfers next period from an additional child, $\partial T_{o,t+2}/\partial n_t$. In this context, children are like investment goods. But what matters for the desired number of children is the factor $\mu \equiv (1+g_{z,t+1})/R$— productivity growth relative to the gross interest rate. Higher productivity growth raises the number of children—by raising future benefits relative to current costs. But saving in assets is an alternative form of investment, which earns a gross rate of return R. Thus, the decision to have children as an investment opportunity depends on this relative return.

In this partial equilibrium model, we treat R as exogenous—for analytical tractability and for the purpose of distilling the most essential forces governing the fertility-saving relationship without undue complication of the model. But what clearly emerges from the model is that interest rates matter insofar as it competes with productivity growth. Faster productivity growth may raise the rate of return, but it is the relative return that matters.[15]

The optimal choice on the children's endowment of human capital h_{t+1} is determined by

$$\frac{\psi}{R}\frac{n_t^{\varpi}}{\varpi}\frac{\partial w_{m,t+2}}{\partial h_{t+1}} = \phi_h n_t w_{m,t+1}, \tag{8}$$

[15] All else constant, the relationship between fertility and interest rates is negative—as children are considered as investment goods. This relationship is the opposite of the positive relationship in Barro and Becker (1989).

where the marginal gains of having more educated children support oneself in old-age is equalized to the marginal cost of further educating each child. Using Eq. 3, the above expression yields the optimal choice for h_{t+1}, given n_t and the parent's own human capital h_t, which is predetermined:

$$h_{t+1} = \left[\frac{\alpha\psi}{\phi_h} \mu_{t+1} \frac{1}{h_t^{\alpha} \varpi n_t^{1-\varpi}} \right]^{\frac{1}{1-\alpha}}. \tag{9}$$

A greater number of children n_t reduces the gains from educating them—a quantity and quality trade-off. This trade-off arises from the fact that the net benefits in terms of transfers are decreasing in the number of children. Indeed, if there were no decreasing returns to transfers, $\varpi = 1$, then there is also no trade-off. For $\varpi < 1$, the slope of the trade-off depends on $\alpha\psi/\phi_h\mu_{t+1}$. Given any number of children n_t, incentives to provide further education is increasing in the returns to education (α) and relative productivity growth ($\mu_{t+1} \equiv (1 + g_{z,t+1}/R)$—which gauges the relative benefits of investing in children. Greater 'altruism' of children for parents (high ψ) increases parental investment in them. Higher marginal cost of education ϕ_h (parents' opportunity cost of h_t) reduces human capital accumulation.

The optimal number of children n_t, combining Eq. 7 and 9 satisfies

$$n_t = \left(\frac{v}{\beta(1+\beta)+v} \right) \left(\frac{1-\theta-\psi\frac{n_{t-1}^{\varpi-1}}{\varpi}}{\phi_0 + \phi_h\left(1-\frac{\omega}{\alpha}\right)h_{t+1}} \right). \tag{10}$$

Equations 9 and 10 are two equations that describe the evolution of the two key endogenous variables of the economy $\{n_t; h_{t+1}\}$.

Eq. 10 elucidates the equilibrium relationship between the number of children to bear n_t in relation to the amount of education to provide them h_{t+1}. There are two competing effects governing this relationship: the first effect is that higher levels of education per child raises transfers per child, thus motivating parents to have more children. The second effect is that greater education, on the other hand, is more expensive and raises the cost per child, and thus reduces the incentives to having more children. The first effect dominates if diminishing returns to transfers is relatively weak compared to diminishing returns to education, $\omega > \alpha$—in which case the relationship between n_t and h_{t+1} is positive. The second effect dominates when the diminishing returns to education is relatively weak, $\omega < \alpha$, and the relationship between n_t and h_{t+1} is negative. The two effects cancel out when $\omega = \alpha$, and decisions on n_t become independent of human capital decisions.

Definition of Saving Rates. The aggregate saving of the economy in period t, denoted as S_t, is the sum of the aggregate saving of each generation $\gamma = \{y, m, o\}$ coexisting in period t. Thus, $S_t = \sum_\gamma S_{\gamma,t}$, where the overall saving of each generation $S_{\gamma,t}$ is: $S_{y,t} \equiv N_t^y a_{y,t}$, $S_{m,t} \equiv N_t^m (a_{m,t} - a_{y,t-1})$, and $S_{o,t} \equiv -N_t^o a_{m,t-1}$. Saving is by definition the change in asset holdings over a period, and optimal asset holdings $a_{\gamma,t}$ are given by Eq. 4 and Eq. 5.

Let the aggregate saving rate at t be

$$s_t \equiv S_t/Y_t,$$

where Y_t denote aggregate labor income: $Y_t \equiv w_{y,t}N_{y,t} + w_{m,t}N_{m,t}$. We define the individual saving rate

$s_{\gamma,t}$ of cohort γ to be the change in asset holdings over a period divided by the cohort's corresponding labour income (for the the young and middle-aged) or capital income (for the old):[16]

$$s_{y,t} \equiv \frac{a_{y,t}}{w_{y,t}} \ ; \quad s_{m,t} \equiv \frac{a_{m,t} - a_{y,t-1}}{w_{m,t}}; \quad s_{o,t} \equiv -\frac{a_{m,t-1}}{(R-1)a_{m,t-1}} = -\left(\frac{1}{R-1}\right)$$

The aggregate saving rate can thus be decomposed into the saving rate of an individual belonging to generation γ and the entire generation's contribution to aggregate labor income:

$$\begin{aligned} s_t &= s_{y,t}\left(\frac{w_{y,t}N_{y,t}}{Y_t}\right) + s_{m,t}\left(\frac{w_{m,t}N_{m,t}}{Y_t}\right) + s_{o,t}\left(\frac{(R-1)\,a_{m,t-1}N_{o,t}}{Y_t}\right) \\ &= s_{y,t}\left(\frac{n_t w_{y,t}}{y_t}\right) + s_{m,t}\left(\frac{w_{m,t}}{y_t}\right) + s_{o,t}\left(\frac{(R-1)\,a_{m,t-1}}{n_{t-1}y_t}\right), \end{aligned} \tag{11}$$

where aggregate labour income per middle-aged household, $y_t = Y_t/N_{m,t}$, is introduced for convenience. The aggregate saving rate is thus a weighted average of the young and middle-aged's individual saving rate, less dissavings of the old, where the weights depend on both the population and relative income of the contemporaneous generations coexisting in the economy—at a certain point in time. We show that changes in fertility will affect the aggregate saving rate through a 'microeconomic channel'—through changes in the individual saving behavior (in particular $s_{m,t}$)—and a 'macroeconomic channel'– through changes to the composition of population and income.

3.1.3 Steady-state Analysis

In the steady state, $h_{t+1} = h_t = h_{ss}$ and $n_t = n_{t-1} = n_{ss}$. Equations (9) and (10) are, in the long run:

$$\frac{n_{ss}}{1-\theta-\psi\frac{n_{ss}^{\varpi-1}}{\varpi}} = \left(\frac{v}{\beta(1+\beta)+v}\right)\left(\frac{1}{\phi_0+\phi_h\left(1-\frac{\omega}{\alpha}\right)h_{ss}}\right) \tag{NN}$$

$$h_{ss} = \left(\frac{\alpha\psi}{\phi_h}\mu\right)\frac{n_{ss}^{\varpi-1}}{\varpi}. \tag{QQ}$$

Figure 5 depicts graphically these two curves—the (NN) curve, which describes the response of fertility to higher education. Its positive slope ($\varpi \geq \alpha$) captures the greater incentive of bearing children when they have higher levels of human capital—which raises transfers. The curve (QQ) shows the combination of n and h that satisfies the quantity/quality trade-off in children. Its negative slope captures the greater cost of education associated with more children and hence lower human capital investment per child.

The limiting values of n_{NN} and n_{QQ} as $h \to 0$ is such that $lim_{h\to 0}(n_{QQ}) > lim_{h\to 0}(n_{NN})$. This condition ensures that the curves intersect at least once. So long as $\varpi \geq \alpha$, the slopes of these two curves are respectively positive and negative throughout, thus guaranteeing that their intersection is unique. This leads to the following proposition:

Proposition 1 If $\varpi \geq \alpha$, there is a unique steady-state for the number of children $n_{ss} > \left(\frac{v}{\beta(1+\beta)+v}\right)\left(\frac{1}{\phi_0}\right)$

[16]For analytical convenience, capital income and transfers are not included in the disposable income of the relevant generations in this theoretical decomposition. Results do not alter much except entailing more cumbersome expressions. The complete analysis is available upon request.

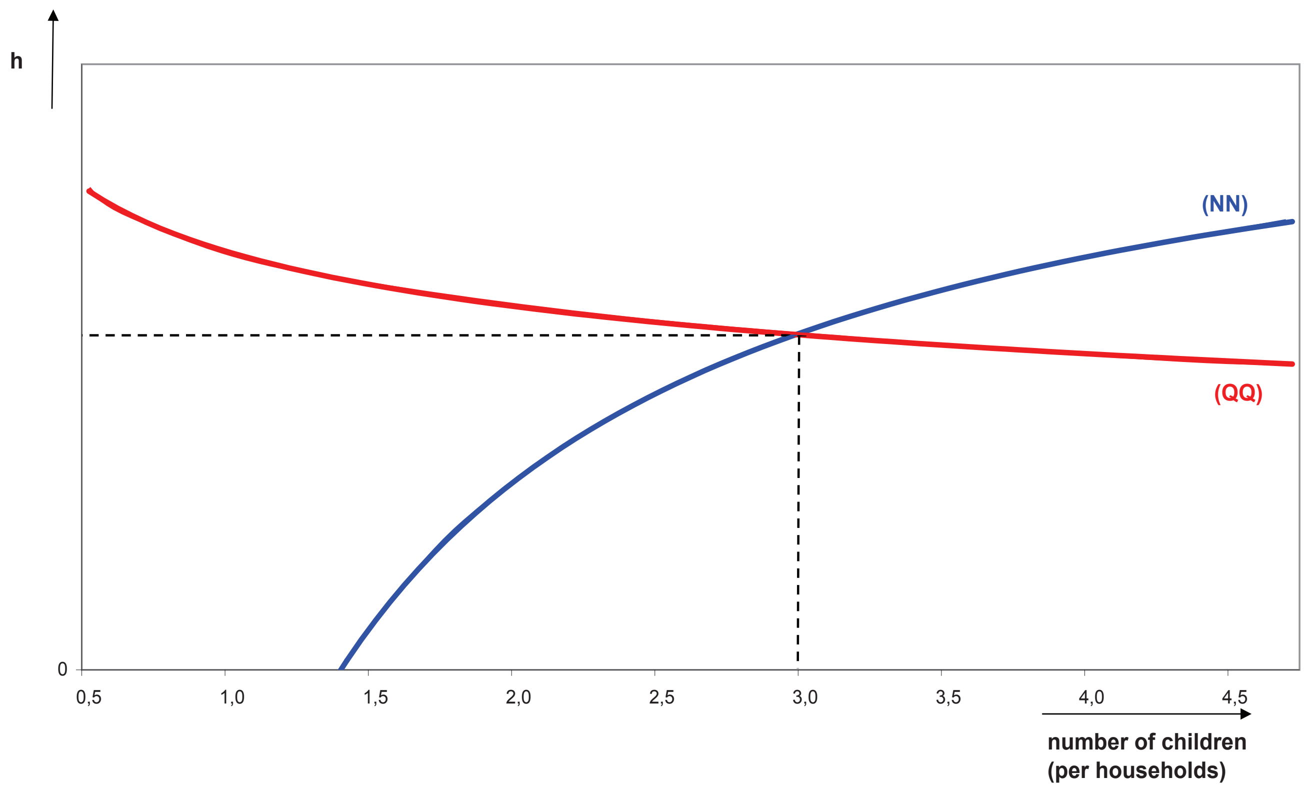
and their education choice $h_{ss} > 0$ to which the dynamic model defined by equations (9) and (10) converges. Also, comparative statics yield

$$\begin{aligned} \frac{\partial n_{ss}}{\partial \mu} &> 0 \text{ and } \frac{\partial h_{ss}}{\partial \mu} > 0 \ ; \ \frac{\partial n_{ss}}{\partial R} < 0 \text{ and } \frac{\partial h_{ss}}{\partial R} < 0 \\ \frac{\partial n_{ss}}{\partial v} &> 0 \text{ and } \frac{\partial h_{ss}}{\partial v} < 0; \ \frac{\partial n_{ss}}{\partial \phi_0} < 0 \text{ and } \frac{\partial h_{ss}}{\partial \phi_0} > 0. \end{aligned}$$

Proof: See Appendix.

The intuition behind these comparative statics is straightforward: higher productivity growth relative to interest rate increases the incentives to invest in children, both in terms of quantity and quality. A stronger preference towards children (or lower costs of raising them) makes parents willing to have more children, albeit less educated (lower 'quality').

Figure 5: Steady-State Human Capital and Fertility Determination



Notes: Steady-state, with an illustrative calibration using l$\phi_0 = 0.1$, $\phi_h = 0.1$, $\psi = 0.2$, β=0.975 per annum (0.6 over 20 years), $R = 2\%$ per annum, $g_z = 4\%$ (per annum), $\theta = 0$, $\varpi = 0.8$, $\alpha = 0.65$. $v = 0.1$ set such that $n_{ss} = 3/2$ (3 children per households).

Aggregate saving. We proceed to analyze how exogenous changes in long-run fertility impacts the aggregate saving rate. Such changes can be brought about by shifts in the preference for children ν, which alters the birth rate but does not exert any impact other than through its effect on n_{ss}. The saving rate, decomposed into the contribution of contemporaneous generations, is, in the long-run version of Eq. 11

$$s = \frac{n_{ss}e}{(1+n_{ss}e)} \underbrace{\left(\frac{-\theta(1+g_z)}{R} \right)}_{s_y} + \frac{1}{(1+n_{ss}e)} \underbrace{\left(\kappa(n_{ss}) + \frac{\theta}{R} \right)}_{s_m} - \frac{\kappa(n_{ss})(R-1)}{n_{ss}(1+n_{ss}e)(1+g_z)} \underbrace{\left(\frac{1}{R-1} \right)}_{s_o}, \quad (12)$$

where $\kappa(n_{ss}) \equiv a_{m,t}/w_{m,t}$ is given by the steady-state equivalent of Eq. 5:

$$\kappa(n_{ss}) = \frac{\beta}{1+\beta} \left[(1-\theta) - \underbrace{\left(\phi_0 n_{ss} + \alpha\psi\mu \frac{n_{ss}^{\varpi}}{\varpi} \right)}_{\text{cost of children}} - \underbrace{\psi \frac{n_{ss}^{\varpi-1}}{\varpi}}_{\text{cost of parents}} - \underbrace{\frac{\psi\mu}{\beta} \frac{n_{ss}^{\varpi}}{\varpi}}_{\text{benefits from children}} \right],$$

using $h_{ss}n_{ss} = \alpha\psi\mu n_{ss}^{\varpi}/\varpi$ from Eq. 9.

Micro-Economic Channel. The above expression illuminates the three channels through which a reduction in long-run fertility affects optimal asset holdings of a middle-aged individual, and therefore his saving *behavior*. The first channel is to reduce the total cost of children—both because there are 'fewer mouths to feed' ($\phi_0 n_{ss}$ falls) and because total (discretionary) education costs have fallen in spite of the rise in human capital per child ($\alpha\psi\mu n_{ss}^{\varpi}/\varpi$ falls).[17] The second effect comes through the impact on the 'cost of parents'—the amount of transfers given to the middle-aged individual's parents ($\psi n_{ss}^{\varpi-1}/\varpi$ rises). As there are fewer siblings among whom the individual can share the burden, total transfers to parents rise, thus reducing the saving rate. The third channel is through the transfers made by the middle-aged's children (the term $\psi(1+g_z)/Rn_{ss}^{\varpi}$). With a reduction in fertility, the overall amount of transfers received from children falls—despite higher human capital per child. Lower intertemporal wealth in turn raises the need to save (the 'transfer channel'). The overall micro-economic effect of a reduction in n_{ss} can be summarized as

$$\kappa'(n_{ss}) = \frac{\beta}{1+\beta} \left[-\phi_0 - \frac{(1+\alpha\beta)\psi}{\beta} \mu {n_{ss}}^{\varpi-1} + \frac{\psi(1-\varpi)}{\varpi} {n_{ss}}^{\varpi-2} \right].$$

One can see that under the weak assumption that $(1+\alpha\beta)/(\beta)\mu n_{ss} > (1-\varpi)/\varpi$, a fall in the steady-state number of children *raises* the steady-state saving rate of the middle-aged. As ϖ approaches 1, the transfers made to the parents are independent of the number of siblings, and a fall in n_{ss} does not reduce saving owing to greater transfers to parents—-that is, the third term disappears. In this case, $\kappa'(n_{ss})$ is unambiguously negative.

Macro-Economic Channel. The macro-economic channels comprise of changes in the composition of population, and the composition of income attributed to each generation. This is evident by

[17] The total cost of education is $n_{ss}h_{ss}$ which is increasing in n_{ss}. In other words, the rise in human capital per child rises by less than the fall in the number of children. This is because the overall reduction in transfers coming from fewer children also reduces incentives to educate heavily in them.

examining the overall impact of n_{ss} on aggregate saving rate, given by Eq. 12:

$$\frac{\partial s}{\partial n_{ss}} = \underbrace{-\frac{e}{(1+n_{ss}e)}\cdot s - \frac{\kappa'(n_{ss})}{n_{ss}\,(1+n_{ss}e)\,(1+g_z)}}_{\text{income composition effect}} + \underbrace{\frac{1}{1+n_{ss}e}\left[-\theta e\mu + \frac{\kappa(n_{ss})}{n_{ss}^2}\frac{1}{(1+g_z)}\right]}_{\text{population composition effect}}$$
$$+ \underbrace{\frac{\kappa'(n_{ss})}{1+n_{ss}e}}_{\text{micro-economic effect (-)}},$$

which shows that apart from the micro-economic channel (the last term of the equation)—changes to aggregate saving occur through macro-level compositional changes. The first compositional change is an 'income composition effect': a reduction in fertility reduces the proportion of the young's contribution to aggregate income, $n_{ss}e$. Thus, more aggregate income attributed to the middle-aged savers of the economy and less to the young borrowers tend to raise the aggregate saving rate. On the other hand, when $\kappa'(n_{ss}) < 0$ is satisfied under the aforementioned weak assumption, lower fertility increases the interest payments to old dissavers (since aggregate wealth over income in the economy increases) and thus their share in total income—hence reducing the aggregate saving rate. This effect is therefore ambiguous.

The second aggregate compositional effect is demographic. A reduction in n_{ss} reduces the proportion of young borrowers (relative to the middle-aged)—thus tending to raise aggregate saving rate—but also increases the proportion of the old dissavers (relative to the middle-aged)—-thus tending to reduce it. The overall effect of population compositional changes is also ambiguous. However, it is important to note that along the transition path towards a steady state with lower fertility, both the income and population composition effects will unambiguously *raise* aggregate saving rate. The reason is that the proportion of the young (relative to the middle-age) immediately falls but the proportion of the dependent elderly will take one generation to increase. Likewise, the share of the young's income (relative to that of the middle-aged) falls before the share of income of the old (relative to that of the middle-aged) rises.

3.2 The 'One-child Policy'

We first examine the theoretical impact of the one child policy on the aggregate saving rate, by comparing the implied saving rate to the saving rate under unconstrained fertility. We then show theoretically how one can identify the effect of the one-child policy on individual saving behavior (the micro-economic channel) by examining the case under twin births–an exogenous deviation from the policy. Conditions under which one can infer a lower bound for the *micro-channel* impact of the policy on the aggregate saving rate immediately follows. Suppose that the government enforces a law that compels each agent to have up to a number $n_{\max}$ of children over a certain period $[t_0; t_0+T]$ with $T > 1$. In the case of the one-child policy, the maximum number of children each individual can have is $n_{\max} = 1/2$. We now examine the transitory dynamics of the key variables following the implementation of the policy, starting from an initial steady-state of unconstrained fertility characterized by $\{n_{t_0-1}; h_{t_0}\}$.

3.2.1 Human Capital and Aggregate Saving

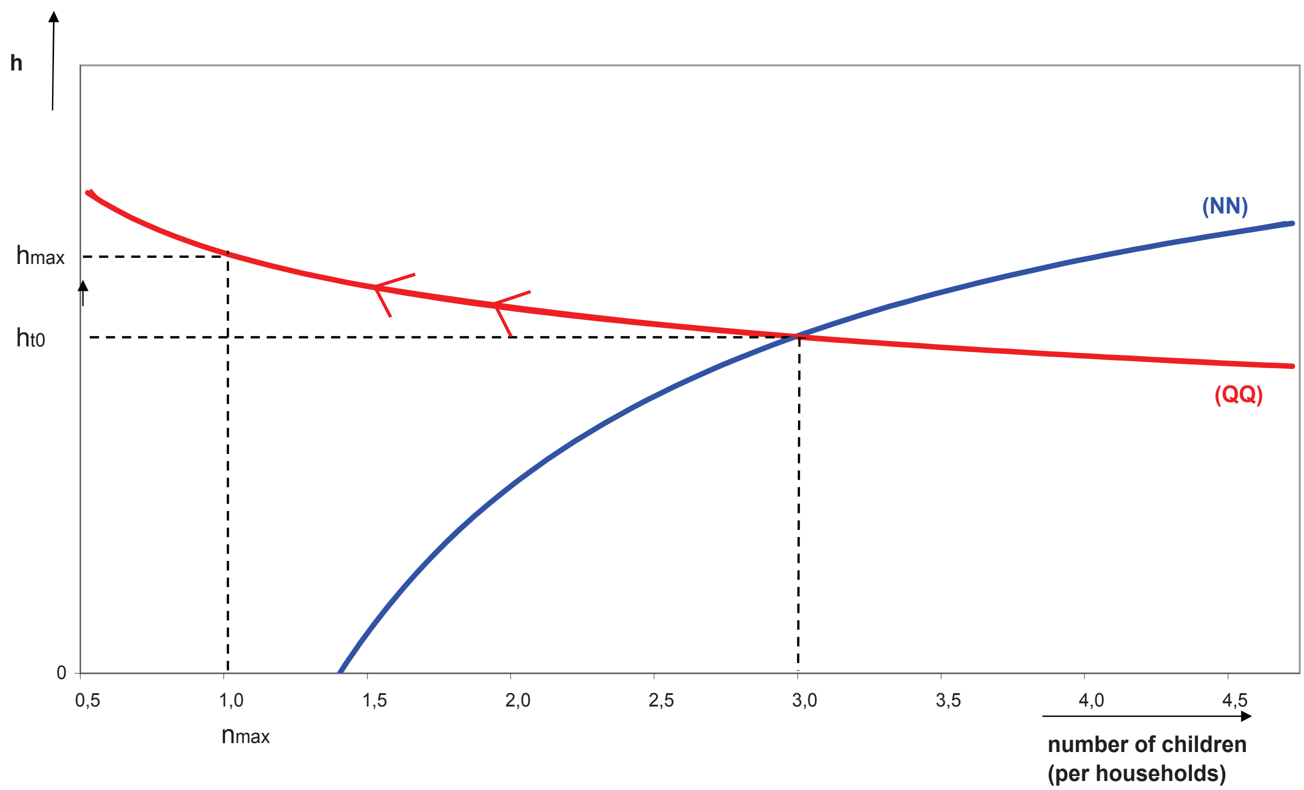
The additional constraint $n \leq n_{\max}$ is now added to the original individual optimization problem. In the interesting scenario in which the constraint is binding, a byproduct of the policy is given by the following Lemma:

Lemma 1: Assuming $\alpha < 1/2$. As $T \to \infty$, human capital converges to a new (constrained) steady-state $h_{\max}$ such that:

$$h_{\max} = \left(\frac{\alpha\psi}{\phi_h}\mu\right)\frac{n_{\max}^{\varpi-1}}{\varpi} > h_{t_0}$$

The policy aimed at reducing the population inadvertently *increases* the long-run level of per-capita human capital, thus moving the equilibrium along the (QQ) curve, as shown in Figure 6.

Figure 6: Human Capital and Fertility Determination under the 'one-child policy'



Notes: Steady-state of the constrained model for an illustrative calibration: $\phi_0 = 0.1$, $\phi_h = 0.1$, $\psi = 0.2$, β=0.975 per annum (0.6 over 20 years), $R = 2\%$ per annum, $g_z = 4\%$ (per annum), $\theta = 0$, $\varpi = 0.8$, $\alpha = 0.65$. $n_{max} = 1/2$ (1 child per households).

Proof: From Eq. 9, where $n_{\max}$ substitutes for the choice variable n_t, the dynamics of $\log(h_{t+1})$ is given by

$$\log(h_{t+1}) = \frac{1}{1-\alpha}\log\left(\frac{\alpha\psi}{\phi_h}\frac{n_{\max}^{\varpi-1}}{\varpi}\right) + \frac{1}{1-\alpha}\log(\mu_{t+1}) - \frac{\alpha}{1-\alpha}\log(h_t),$$

where $\log(h_{t+1})$ is mean-reverting due to $-\frac{\alpha}{1-\alpha} < 1$ for $\alpha < 1/2$. It follows from $n_{t_0-1} > n_{\max}$ that $h_{\max} > h_{t_0}$.

Assuming constant productivity growth to interest rate ratio μ, we next examine the one-period impact of the one-child policy implemented in t_0 on the dynamics of the aggregate saving rate between t_0 and t_0+1, given by the following lemma:

Lemma 2: For $\omega > 1/2 > \alpha$, imposing the constraint $n_{t_0} \leq n^{max}$ in period t_0 leads to a rise in aggregate saving rate over one period:

$$s_{t_0+1} - s_{t_0} > 0.$$

Proof: See Appendix.

The change in aggregate saving rate over the period after the implementation of the policy can be written as:

$$\begin{aligned} s_{t_0+1} - s_{t_0} &= \underbrace{\frac{(n_{t_0-1} - n_{\max})\, e}{1+n_{\max} e} s_{t_0} + \frac{1}{1+n_{\max} e}\theta\mu \left(n_{t_0-1} - n_{\max} \left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha}\right)}_{\text{macro-channel (composition effects)}} \\ &+ \frac{1}{1+n_{\max} e} \underbrace{\frac{\beta}{1+\beta}\left[\phi_0 \left(n_{t_0-1} - n_{\max}\right) + \frac{(1+\beta\alpha)}{\beta}\frac{\psi}{\varpi}\mu \left(n^{\omega}_{t_0-1} - n^{\omega}_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha}\right)\right]}_{\text{micro-channel}}. \end{aligned} \tag{13}$$

The channels through which constrained fertility affects the change in saving rate during the transition are the three channels emphasized before. However, the main difference is that the income and population composition effects apply only to the proportional reduction in the young cohort. This reduction in fertility has not yet fed into increasing the proportion of the dependent elderly in one generation, and therefore the old's negative impact on saving is absent. All channels exert pressure on the saving rate in the same direction, and aggregate saving rate *rises unambiguously* in the period following the implementation of the policy.[18]

3.2.2 Identification through 'twins'

Consider the scenario in which all middle-aged individuals exogenously deviate from the 'one-child policy' by having twins. From Eq. 9, the per-capita human capital of the twins (denoted $h^{twin}_{t_0+1}$) must satisfy:

$$\left(h^{twin}_{t_0+1}\right)^{1-\alpha} h^{\alpha}_{t_0} = \left(\frac{\alpha\psi}{\phi_h R}\frac{z_{t+2}}{z_{t+1}}\right)\frac{(2n_{\max})^{\varpi-1}}{\varpi} < \left(\frac{\alpha\psi}{\phi_h R}\frac{z_{t+2}}{z_{t+1}}\right)\frac{(n_{\max})^{\varpi-1}}{\varpi} = \left(h_{t_0+1}\right)^{1-\alpha} h^{\alpha}_{t_0},$$

which leads to our first testable implication:

Test 1: Quantity-Quality Tradeoff. With

$$\frac{1}{2} < \left(\frac{h^{twin}_{t_0+1}}{h_{t_0+1}}\right) = \left(\frac{1}{2}\right)^{\frac{1-\varpi}{1-\alpha}} < 1 \qquad (\varpi > \alpha), \tag{14}$$

[18] Along the transition path, we show that $n_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha} < n_{t_{0-1}}$ and $n^{\omega}_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha} < n^{\omega}_{t_0-1}$ under the assumption that $\omega > 1/2 > \alpha$.

the quantity-quality trade-off driving human capital accumulation can be identified by comparing twins and an only-child. This ratio as measured by the data also provides some guidance on the relative strength of ϖ and α. Despite the tradeoff, the fall in human capital per capita is less than the increase in the number of children, so that total education costs still rise for twins.

Test 2: Identifying the Microeconomic Channel The micro-economic impact of having twins on the middle-age parent's saving rate decisions comprise an 'expenditure channel' and a 'transfer channel'. In Appendix A, we show that the difference in the saving rate in the case of an only-child compared to twins in $t_0 + 1$ satisfies, for $\varpi > \alpha$:

$$s_{m,t_0+1} - s^{twin}_{m,t_0+1} = \frac{\beta}{1+\beta}\left[n_{\max}\phi_0 + \frac{(1+\alpha\beta)}{R\beta}\frac{\psi(1+g_z)}{\varpi}n^{\varpi}_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha}\left(2^{\frac{\varpi-\alpha}{1-\alpha}} - 1\right)\right] > 0.$$

A Lower Bound for the Micro-Channel
Let the micro-economic impact of moving from unconstrained fertility n_{t_0-1} to n_{max} on saving be $\Delta s(n_{t_0-1})$ (third term of Eq. 26):

$$\Delta s(n_{t_0-1}) = \frac{\beta}{1+\beta}\left[\frac{(1+\beta\alpha)}{R\beta}\frac{\psi\,(1+g_z)}{\varpi}\left(n^{\omega}_{t_0-1} - n^{\omega}_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha}\right) + \phi_0\,(n_{t_0-1} - n_{\max})\right].$$

Lemma 3: If $n_{t_0-1} = 2n_{\max}$, then

$$\Delta s(n_{t_0-1}) = s_{m,t_0+1} - s^{twin}_{m,t_0+1}.$$

Proof: See Appendix A.
Under the condition that the initial unconstrained fertility is twice that of the constrained fertility, we can identify precisely the micro-economic impact of the policy on the aggregate saving rate— by comparing the saving rate of a middle-aged individual with n_{max} kids to one with $2n_{max}$ kids. We can also deduce a lower-bound estimate for the overall impact of the policy on the middle-aged's saving rate—if the unconstrained fertility were greater than 2 (as is the case for China prior to the policy change). That is, if $n_{t_0-1} > 2n_{\max}$, then

$$\Delta s(n_{t_0-1}) > s_{m,t_0+1} - s^{twin}_{m,t_0+1}.$$

These theoretical results demonstrate that observations from twin-households can inform us of the impact of the one child policy on saving behavior. However, the underlying assumption is that there are no inherent underlying differences in the saving behavior of twin-households from other households prior to the policy implementation. We will show that this assumption is indeed supported by the data.

4 Empirical Evidence: the Micro Channel

The previous theoretical analysis shows how one may identify the change in aggregate saving rate as per the micro-channel based on a cross-sectional observation of twin households vs. only child households. Apart from quantifying the micro-channel and the impact on human capital accumulation, our empirical analysis also tests the key implications of our model: that higher fertility leads to (1) lower household saving rate; (2) lower education investment per child; (3) transfers from children to parents rise in the quantity and quality of the children. These micro findings are used to calibrate our quantitative model and assess its performance in Section 5. Lastly, we show how one can decompose the overall impact of the policy on the aggregate saving rate into its component micro and macro-channels highlighted by the previous theoretical analysis, and quantify their various contributions.

Twinning under the one child policy can be considered as an exogenous deviation in fertility—thereby serving a sensible instrument to variations in household size.[19] Our empirical results point to the fact that the incidence of twinning itself had no bearing on saving rate in the absence of the one child policy, but a significant and negative impact when these restrictions took effect—suggesting that there were no inherent underlying differences in households with twins.

4.1 Descriptive Statistics

We first provide descriptive statistics on the household saving rates across different types of households, in particular comparing saving rates for households with twins before *and* after the start of the one-child policy (1982). Household saving rate is computed using UHS data and is defined to be total household income less total consumption expenditure divided by household income. For the sample period 2002-2009, education transfers from parents to children residing in another city (possibly attending school elsewhere) are observed, and thus added to total household expenditure when computing household saving rate. Children belong to a household so long as they either (1) reside in the household, or (2) remain financially dependent on the parents even if living outside the household.

Table 3 shows first that households with twins, if anything, had higher saving rates compared to households without twins before the one child policy (pre-1982)—though the difference is rather small. In contrast, households with twins born after 1982 have had on average a lower saving rate (by a bit less than 4 %) than those without twins. Second, if we focus on nuclear households (and incorporate education transfers to children living in another city into household expenditures), the difference is even more striking: households with twins save on average 7.5% less than households with an only child. The difference is as large for all income brackets when dividing the population by income quintile.

4.2 The 'Twin Effect' on Household Saving Rate

We next turn to regression analyses to examine whether twin households systematically save at a lower rate than only-child households. The first set of empirical regressions use the whole sample in UHS (1986 and 1992-2009), which includes households that had children both before and after the

[19] In the absence of fertility controls, the incidence of twinning itself is not independent of family size. Since the incidence of twinning increases with the number of children, household with twins may be systematically different from other households—for instance, in having higher preferences for children. Rosenzweig and Wolpin (1980) show that the incidence of twinning at first birth can serve as an appropriate instrument, on the presumption that these women who gave birth first to twins are likely to have preferred the same number of children to those who had singletons during first birth. This is the strategy adopted by Oliveira (2012) to examine the causal effect of fertility and transfers from children to parents. Twinning under the one child policy serves arguably as an even more desirable instrument for exogenous changes in fertility.

Table 3: Comparison of Saving Rate for Twin and Non-Twin Households: Descriptive Statistics

	Non-twin Households	**Twins Households**
All households - UHS 1986 and 1992 to 2009 *		
Oldest child born in or before 1978		
Nbr. of observations	5,398	75
Av. household savings rate	10.7%	11.0%
Nbr. children in the household	1.76	2.94
Av. children age (in years)	13.6	13.6
Born from 1978 to 1982		
Nbr. of observations	10,033	81
Av. household savings rate	9.3%	10.9%
Nbr. children in the household	1.10	2.12
Av. children age (in years)	12.6	12.2
Born after 1982		
Nbr. of observations	70,011	598
Av. household savings rate	20.5%	16.9%
Nbr. children in the household	1.04	2.07
Av. children age (in years)	10.6	10.9
Nuclear households - UHS 2002-09 (including educ. transfers)		
Nbr. of observations	42,275	394
Av. household savings rate	21.3 %	12.8 %
- lowest 20% income	6.4 %	-2.9 %
- second lowest	18.3 %	16.6 %
- middle income group	23.7 %	10.3 %
- second highest	27.4 %	19.5 %
- highest 20% income	33.4 %	25.4 %

Notes: Data source: UHS (1986, 1992-2009). Children are considered up to the age of 18 years. Households with saving rate below (over) 90% (-90%) are excluded (1.23% of observations). Household saving rate is defined to be total household income less total consumption expenditure divided by household income. Expenditures using UHS (2002-2009) include education transfers to children living in another city (but are excluded when considering the whole sample staring in 1986). See Appendix B for details on UHS.

implementation of the one child policy.[20] The following regression is performed for a household h living in province p at a particular date $t = \{1986, 1992, ..., 2009\}$:

$$s_{h,p,t} = \alpha + \alpha_t + \alpha_p + \beta_1 D_{h,t}^{\text{Twins}} + \beta_2 D_{h,t}^{\text{Twins born} \geq 1982} + \gamma Z_{h,t} + \varepsilon_{p,h,t}, \tag{15}$$

where $s_{h,p,t}$ denotes the household saving rate of household h (defined as the household disposable income less expenditures over disposable income); α_t and α_p are respectively time and province fixed-effects, $D_{h,t}^{\text{Twin}}$ is a dummy that equals one if twins are observed in a household, $D_{h,t}^{\text{Twin born} \geq 1982}$ is a dummy that equals 1 if the twins associated with a household are born after the full implementation of the one-child policy (post 1982), $Z_{h,t}$ is a set of household level control variables and $\varepsilon_{p,h,t}$ is the

[20]Only households that have children of up to 18 or 21 years of age residing in the household are considered.

residual. While β_1 measures the overall effect of giving birth to twins on the household saving rate over all years (assumed to be zero in the quantitative exercise of Section 5.5), β_2 measures the effect of having twins *after* the policy implementation.

Table 4: Household Saving Rate: Twin Identification

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Sav. rate	Sav. rate	Sav. rate	Sav. rate	Sav. rate inc.	educ. transfers
Oldest child	Up to 18y	Up to 18y	Up to 21y	Up to 18y	Up to 18y	Up to 21y
Sample UHS	1986 and 92-09	1986 and 92-09	1986 and 92-09	2002-2009	2002-2009	2002-2009
Type of household	All	All	All	Nuclear only	Nuclear only	Nuclear only
Twins born $\geq$ 1982	-0.0574***	-0.0567***	-0.0654***	-0.0525***	-0.0675***	-0.0660***
	(0.0163)	(0.0157)	(0.0150)	(0.0118)	(0.0124)	(0.0121)
Twins	0.0121	0.0119	0.0164			
	(0.0130)	(0.0127)	(0.0120)			
Log av. parents age	-0.0110	-0.0458***	-0.0325***	-0.0304**	-0.0913***	-0.146***
	(0.00892)	(0.00850)	(0.00778)	(0.0126)	(0.0129)	(0.0121)
Log child age	-0.0214***	-0.0126***	-0.0141***	-0.0129***	-0.00883***	-0.0118***
	(0.00217)	(0.00207)	(0.00200)	(0.00295)	(0.00298)	(0.00293)
Log household income		0.139***	0.142***	0.142***	0.141***	0.143***
		(0.00182)	(0.00168)	(0.00253)	(0.00255)	(0.00238)
Multigenerational	-0.00182	-0.0143***	-0.0144***			
	(0.00278)	(0.00267)	(0.00253)			
Observations	85,955	85,955	102,247	42,026	41,992	50,835
R-squared	0.085	0.177	0.168	0.155	0.157	0.159
Years Dummies	YES	YES	YES	YES	YES	YES
Province Dummies	NO	YES	YES	NO	NO	NO
Prefecture Dummies	NO	NO	NO	YES	YES	YES

Notes: Data source: UHS (1986, 1992-2009). We take one observation per household. Outliers with saving rate over (below) 90% (-90%) of income are excluded. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Columns (5) and (6) include education transfers to children living in another city as part of consumption expenditures when computing households saving.

Columns 1-3 in Table 4 display the coefficient estimates of the impact of twins on household saving rate before and after the policy implementation. The important finding is that the twin effect (*Twins*) on household saving is insignificant when the one child policy was not binding in the earlier years, but is significant and negative in the later years when it was enforced (*Twins born* $\geq$ 1982). In other words, households who had twins were not saving at systematically different rates from households without twins in the absence of fertility controls–consistent with previous casual observation. The estimated coefficients on $D_{h,t}^{\text{Twin born} \geq 1982}$ show that under the one child policy, households with twins saved (as a share of disposable income) on average 5 to 6 percentage points less than household with an only child. Moreover, the magnitude is similar under different specifications and across samples.[21]

The second set of regressions restricts the sample to nuclear households (unigenerational) that have only one incidence of births—either bearing an only child or twins. The advantage of pooling

[21] In Column 1, household income is excluded as it could be an outcome variable—household members may decide to work more to meet higher expenditures with a larger number of children, or, lower the labor supply of mothers. Column 2 shows that the results do not change very much even when controlling for household income. Column 3 includes all children up to the age of 21 years old.

all households that are unigenerational is that the same demographic composition (up to the presence of twins) applies to all households —making this exercise the closest to the quantitative experiment performed in Section 5. Unlike the full sample in equation (15), the restricted sample cannot identify the 'twin effect' independent of the policy, as all households in that sample are treated by the policy. Using the same notation as before, the following regression for a household h living in prefecture p at date $t = \{2002, ..., 2009\}$ is thus performed:

$$s_{h,p,t} = \alpha + \alpha_t + \alpha_p + \beta D^{\text{Twin}}_{h,t} + \gamma Z_{h,t} + \varepsilon_{p,h,t} \tag{16}$$

Columns 4-5 in Table 4 display results for the restricted sample. The estimated 'twin impact' on saving rates (β_2) in Column 4 is similar in magnitude to our estimates for the whole sample of households: households with twins have on average a 5.25 percentage points lower saving rate than those with an only child. In other words, the simple-difference in the cross-section of treated households gives similar estimates to the double-difference estimates of Columns 1-3. The result is perhaps unsurprising since no difference in the saving behavior of household with twins from those without was detected before the policy. Finally, in Columns 5-6, we compute an alternative and more accurate measure of the saving rate by incorporating education transfers to children residing outside of the household as part of household expenditures (only available in the sample starting in 2002). The more precise measure of saving rate gives an even larger twin effect: households with twins save on average 6.75 percentage points less than those with an only child. Therefore, the estimates from Columns 1-3 can be seen as a lower bound for the overall twin effect—when education transfers to children residing outside of the households are omitted from overall expenditures. In a nutshell, our results show that having (exogenously) one more child under the one-child policy reduces saving rates by at least 5 percentage points and up to 7 percentage points.

To uncover the channels through which the presence of twins reduce household saving in the data, we proceed to investigate the components of expenditures most affected by twin-births. The following regression for a household h at date $t = \{2002, ..., 2006\}$:[22]

$$\exp^s_{h,p,t} = \alpha + \alpha_t + \alpha_p + \beta_1 D^{\text{Twins}}_{h,t} + \beta_2 D^{\text{Twins with parents}\geq 45}_{h,t} + \gamma Z_{h,t} + \varepsilon_{p,h,t} \tag{17}$$

where $\exp^s_{h,p,t}$ denotes household expenditure in sector $s = \{\text{Education; Food; Other}\}$ as a share of household disposable income.

Results of regression (17) are shown in Table 5. We observe first that the largest increase in expenditure for twin-households compared to only-child households is in education costs, with twin parents spending on average 6 to 7 percentage points more on education than parents of only children (Columns 1-2). Worth mentioning is that such large effects do not contradict the quantity-quality trade off: households may spend more on total education costs but still less on education costs *per* child— as we show later in Section 4.3. Parents with twins also spend more on food (2.5 % more on average, Column 3), and even more when they are older (4.4 % when above 45 compared to 1.7% when below 45, column 4). Similarly, they spend more on other expenditures as well, and again mostly

[22] A change in the definition of the various components of expenditures in 2007 in the UHS prevents us from using the most recent years of data.

Table 5: Expenditures: Twin Identification

VARIABLES (in % of household income)	(1) Education exp.	(2) Education exp.	(3) Food exp.	(4) Food exp.	(5) Other exp.	(6) Other exp.
Twins	0.0702***	0.0606***	0.0247***	0.0173**	0.0279**	0.0130
	(0.0106)	(0.0108)	(0.00685)	(0.00743)	(0.0132)	(0.0135)
Twins with parents $\geq$ 45		0.0525		0.0417**		0.0818**
		(0.0332)		(0.0180)		(0.0403)
Parents above 45		0.0136***		-0.00597**		0.0146***
		(0.00360)		(0.00279)		(0.00534)
Log av. parents age	0.121***	0.0920***	0.0374***	0.0482***	-0.0356***	-0.0672***
	(0.00860)	(0.00910)	(0.00750)	(0.00942)	(0.0135)	(0.0171)
Log child age	0.0176***	0.0211***	0.00510***	0.00378*	-0.0114***	-0.00759**
	(0.00164)	(0.00164)	(0.00188)	(0.00201)	(0.00325)	(0.00350)
Log household income	-0.0131***	-0.0129***	-0.135***	-0.135***	0.00935***	0.00959***
	(0.00124)	(0.00124)	(0.00173)	(0.00173)	(0.00255)	(0.00255)
Observations	23,800	23,800	23,800	23,800	23,800	23,800
R-squared	0.106	0.107	0.430	0.430	0.042	0.043
Years Dummies	YES	YES	YES	YES	YES	YES
Prefecture Dummies	YES	YES	YES	YES	YES	YES

Notes: Data source: UHS (2002-2009). restricted sample of nuclear households: those with either an only child or twins. Outliers with saving rate over (below) 90% (-90%) of income are excluded. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

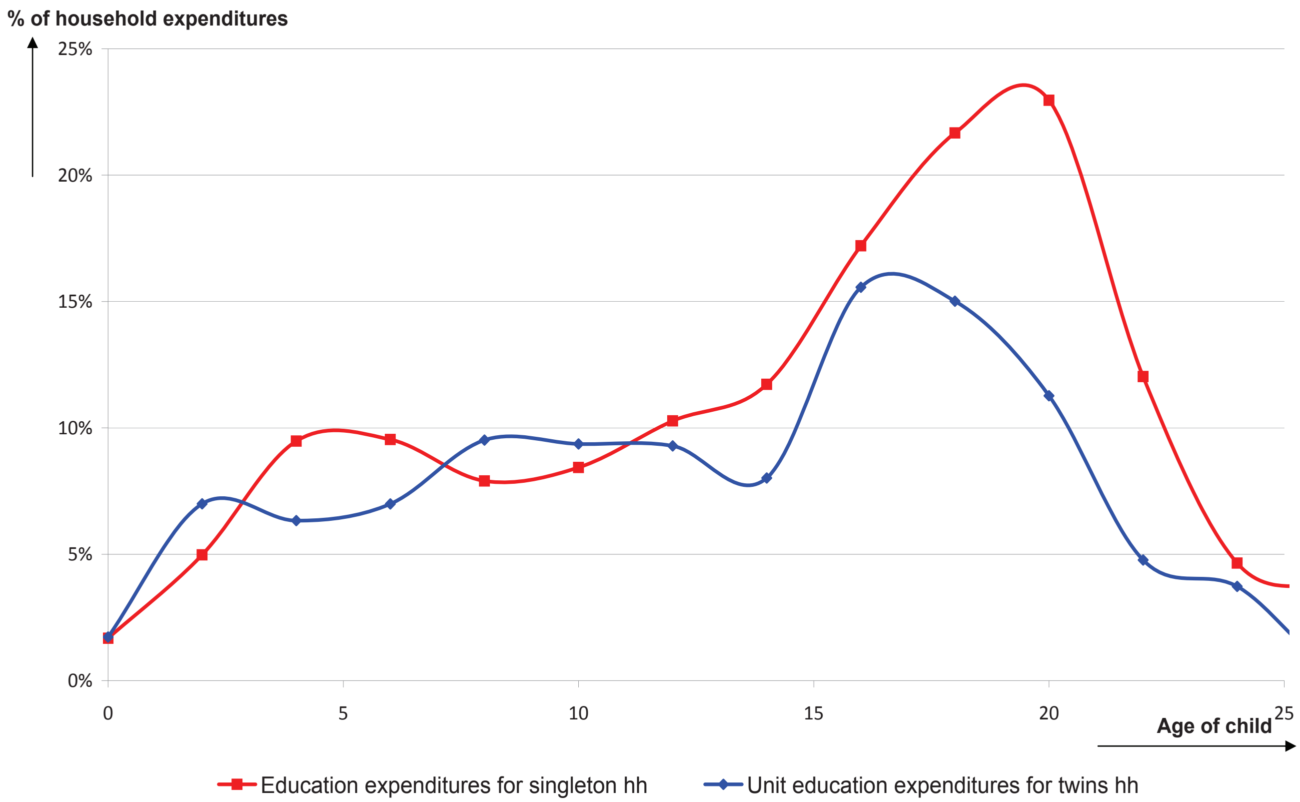
when older (2.8 % on average - column 5 - but 8.2 % more when above 45, although the estimate is less precisely estimated, column 6).

Two main observations can be drawn from these results. First, there is strong evidence that the one-child policy increased saving through an expenditure effect ('fewer mouths to feed' and lower education costs). Second, the results suggest that the expenditure channel is not the only channel that raised saving: expenditures that are not ostensibly child-related are higher across the board for households with twins, and even more so for parents that are older (Columns 4 and 6). The 'transfer channel' seems to be in operation, and above and beyond the 'expenditure channel'. It is difficult however, given limitation of data, to establish a more direct evidence on this channel: ideally, one would need to observe the differences in parental expenditures between twin parents and only child parents *after* the offspring have left the households and became financially independent. At these ages (50-60 in our model), the 'transfer channel' could be identified as *the* source of variations of saving rates across households with different number of children (if anything, the 'expenditure channel' tends to increase the saving rates of families with more children for this age group due to consumption smoothing; see Fig. 13). However, in our data, we can only observe children (whether only child or twins) when they are still living in the household (or when they live in the household but remain financially dependent).

4.3 The Quantity-Quality Trade-Off

A quantity-quality trade-off in children emerges endogenously in our theoretical framework: parents are incentivized to increase children's education in order to compensate for the reduction in the number of children in considering old-age transfers. To identify and quantity whether this trade-off exists in the data, one can use the same strategy based on observations from twin households. But even casual evidence, as in Figure 7, is strongly indicative of this view: the per-capita education expenditure on a twin is significantly lower than on an only child— for children above the age of 15. The difference reaches about 50% at age 20.

Figure 7: Education Expenditures: Only Childs vs. Twins



Notes: UHS (2002-2006), restricted sample of nuclear households. This figure displays the average education expenditure per child (as a share of of total household expenditure) by age of the child, over the period 2002-2006.

Evidence affirming this relationship can be examined by regression analysis. The regression performed for a household h at date $t = \{2002, ..., 2006\}$ is

$$\frac{\exp^{Educ.}_{h,p,t}}{n_{h,t}} = \alpha + \alpha_t + \alpha_p + \beta D^{\text{Twin}}_{h,t} + \gamma Z_{h,t} + \varepsilon_{p,h,t}, \tag{18}$$

where $\frac{\exp^{Educ.}_{h,p,t}}{n_{h,t}}$ denotes the education expenditure household h spends on each child at date $t = \{2002, ..., 2006\}$.[23]

[23]Note that we focus only on treated households and cannot identify a separate effect of twinning on education achievements—-the reason for which is the absence of education expenditures data before the policy implementation.

Results of regression (18) are shown in Columns 2 and 4 of Table 6. For the sake of comparison, the impact of twins on overall education expenditures of the household is also shown, as in regression 17 (Columns 1 and 3). We find that education investment (*per* child) in twins is much lower than in an only child: while households with twins significantly raise education expenditures (as a share of household income) on average (Column 1), they reduce education expenditures spent on each child—by an average of 2.3 percentage points (Column 2). As conjectured, this trade-off applies only to older children (above 15), whose education attainment becomes discretionary (Column 4). These estimates match fairly well the findings of our quantitative model (compare with Table 12).

The quantity-quality trade-off is also manifested in differences in education attainment. LOGIT regression results on dummies that measure the level of school enrollment (academic high school, technical high school and higher education) are displayed in Table 7. Comparing education attainment of twins versus only childs over the period 2002-2009, we find that twins are on average 40% less likely to pursue higher education than their only-child peers, with an odds ratio of 0.58 (Column 2). For secondary education, Columns 4 and 6 show that twins are 40% less (resp. more) likely to pursue an academic secondary education (resp. technical high school).[24] This estimate is quantitatively large.

One would then, ideally, want to observe the difference of transfers made towards parents between an ('high quality') only child and a (less-educated) twin. But since the first generation of parents with an only child is not yet retired, such data is not available. To circumvent this difficulty, we analyze next how the amount of bestowed transfers depend on the number of children and their quality focusing on a sample of parent with multiple children (before the policy implementation).

4.4 Transfers

We investigate whether transfers from children to parents are increasing in the quantity (and quality) of children–a requisite condition for the new channels that fertility and saving to take effect. If such patterns are absent in the data, then there is no straightforward reason to believe that parents would modify their saving behavior as per the 'transfer channel' and education decisions following fertility controls. CHARLS provides data on transfers from children to parents for the year 2008 and the 'Three cities survey' for the year 1999 (see Appendix B for data description). We estimate the effect of the number of children and their education level (or income) on transfers received by the parents, for a sample of urban households.[25]

The following regression is performed for a child i belonging to a family f in province p (or city) for given cross-section (CHARLS (2008) or 'Three cities survey' (1999)):

$$\log(T_{i,f,p}) = \alpha + \alpha_p + \beta_n \log(n_f) + \beta_x \log(x_i) + \gamma Z_{i,f} + \varepsilon_{i,f,p} \tag{19}$$

where $T_{i,f,p}$ denotes transfers from children i to parents, defined as the sum of regular and non-regular

[24]It is possible that twins are of potential lower quality compared to singletons–for example, by having lower weights at birth (net of family-size effects)—and parents may in turn invest less in their education and substitute investment towards their singleton offspring— a concern raised by Rosenzweig and Zhang (2009). The problem is less serious, however, when households are allowed only one birth in China. Also, Oliveira (2012) finds no systematic differences between singletons and twins.

[25]'Three cities survey' include only urban households, whereas CHARLS include both rural and urban households. When performing robustness checks on the whole sample of urban and rural households, we find very similar results.

Table 6: Education Expenditures per Child: Twin identification.

VARIABLES (in % of household income)	(1) Education exp. total	(2) Education exp. per child	(3) Education exp. total	(4) Education exp. per child
Twins	0.0674***	-0.0231***	0.0606***	-0.00726
	(0.0123)	(0.00620)	(0.0139)	(0.00676)
Twins above 15			0.0184	-0.0313**
			(0.0255)	(0.0127)
Child above 15			0.0536***	0.0540***
			(0.00187)	(0.00186)
Log av. parents age	0.209***	0.206***	0.143***	0.140***
	(0.00947)	(0.00935)	(0.00971)	(0.00956)
Log child age	0.0226***	0.0230***	0.00244	0.00277
	(0.00198)	(0.00194)	(0.00176)	(0.00174)
Log household income	-0.0172***	-0.0170***	-0.0167***	-0.0166***
	(0.00159)	(0.00159)	(0.00158)	(0.00158)
Observations	31,820	31,820	31,820	31,820
R-squared	0.108	0.106	0.124	0.122
Years Dummies	YES	YES	YES	YES
Prefecture Dummies	YES	YES	YES	YES

Notes: UHS (2002-2006), restricted sample of nuclear households: those with either an only child or twins. Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Education Attainment: Twin Identification (LOGIT)

VARIABLE	Higher education		Academic high school		Technical high school	
(logistic regression)	(1) estimate	(2) odds ratio	(3) estimate	(4) odds ratio	(5) estimate	(6) odds ratio
Twins	-0.542***	0.582***	-0.519***	0.595***	0.317**	1.373**
	(0.169)	(0.0981)	(0.140)	(0.0834)	(0.160)	(0.220)
Log child age	17.76***	5.157e+07***	-7.910***	0.000367***	11.07***	64,430***
	(0.348)	(1.796e+07)	(0.293)	(0.000108)	(0.317)	(20,423)
Log av. parents age	2.333***	10.31***	0.550*	1.734*	0.137	1.146
	(0.319)	(3.291)	(0.282)	(0.489)	(0.296)	(0.340)
Log av. parents educ. level	1.804***	6.072***	1.503***	4.495***	-1.131***	0.323***
	(0.111)	(0.671)	(0.0949)	(0.427)	(0.0996)	(0.0322)
Log household income	0.255***	1.290***	0.179***	1.196***	-0.00150	0.998
	(0.0417)	(0.0538)	(0.0345)	(0.0413)	(0.0380)	(0.0379)
Observations	15,336	15,336	15,336	15,336	15,336	15,336
Years dummies	YES	YES	YES	YES	YES	YES
Province dummies	YES	YES	YES	YES	YES	YES

Notes: UHS (2002-2006) restricted sample of nuclear households: those with either an only child or twins. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

financial transfers and the yuan value of measured in-kind transfers. The number of children belonging to the family is denoted as n_f, x_i is a numerical indicator of the child's quality and $Z_{f,i}$ a vector of control variables (child's gender, child's and parents' age, dummy for the co-residence of parents). The sample is restricted to parents above the age of 60—those who were largely unaffected by the one child policy. Only UHS data has income information for the children. The way we measure a child's quality x_i is therefore either by his education level, provided in CHARLS and the 'Three cities survey' (Columns 1-2 and 4-5), or his survey-based income range in the 'Three cities survey' (Column 6), since direct information on the children's income is not observed in these data. Income, together with observable characteristics of the offspring, however, are duly observed in UHS data. In Column 3, we use this information to impute an income to each child. In particular, we assign to the child an income associated with an individual of the same set of characteristics (provided in UHS) as the child (provided in CHARLS). The Poisson Pseudo-Maximum-Likelihood (PPML) estimator is employed to treat the zero values in our dependent variable (see Gourieroux, Monfort, and Trognon (1984) and Santos and Tenreyro (2006)). Results are displayed in Table 8.

Validation of our assumed Transfer Function. In both samples and across all specifications, we find that the amount of transfers received by the parents is decreasing in the number of siblings and increasing in the children's quality — using either education or income-based measures of quality. THe elasticity of transfers to a child's income and to the number of siblings can be estimated and in turn, assess the validity of our theoretical formulation of the transfer function. When estimating equation 19, we are in effect estimating our assumed transfer function $\psi \frac{n^{\varpi-1}}{\varpi} w_m$ (in log) (with $\beta_n = \varpi - 1$ and $\beta_x = 1$). The addition of a child leads to a significant negative impact on the amount of transfers: the elasticity β_n is equal to -0.34 using CHARLS data (and -0.49 using the 'Three cities survey'). This suggests that everything else equal, transfers are increasing by less than one for one with an additional child—in accordance with our theoretical assumption. The estimates for the corresponding elasticity ϖ are 0.66 in CHARLS (0.51 in 'Three cities survey'). The elasticity with respect to (imputed) income is very close to unity (Column 3)–again, validating the formulation of our assumed transfer function. These empirical results suggest that the parametrization of our transfer function and its functional form itself are validated by the data.

4.5 Counterfactual Exercise

Using the empirical estimates of the twin effect on saving and human capital accumulation, the counterfactual saving rate had a 'two-children policy' been implemented since 1977 can be backed out. Another way to put it, given the difficulty in knowing what the natural fertility rate in China would have been over this period, is that we can estimate a *lower-bound* for the overall impact of the one child policy on the aggregate saving rate (micro and macro channels combined)— assuming that the natural rate of fertility would not have fallen below 2. We also point out that the full impact of the policy on aggregate saving rate is not yet realized, as the generation of only-children has yet to grow old and exert a greater impact on the economy, both in terms of their demographic weight and in terms of their income weight via their higher human capital.

The procedure involves estimating the age-saving profile and aggregate saving rate that would have prevailed in 2009 if, after 1977, all households had two children. One needs to also identify all channels through which having two children rather than one affect household saving. Four different

Table 8: Urban Household-level Transfers (Children to Parents)

VARIABLES Sample	(1) Transfers CHARLS 08	(2) Transfers CHARLS 08	(3) Transfers CHARLS 08	(4) Transfers Three-cities 99	(5) Transfers Three-cities 99	(6) Transfers Three-cities 99
Log nbr children	-0.349**	-0.344**	-0.336**	-0.532***	-0.489***	-0.539***
	(0.167)	(0.172)	(0.168)	(0.118)	(0.128)	(0.121)
Log educ. level	1.302***	1.199***		0.796***	0.761***	
	(0.205)	(0.191)		(0.169)	(0.169)	
Log income (UHS)			0.987***			
			(0.143)			
Log financial level						1.706***
						(0.152)
Child age		0.0273**	0.0151		-0.0118	-0.0184**
		(0.0125)	(0.0126)		(0.00908)	(0.00881)
Avg. parents' age		-0.0305***	-0.0320***		0.00313	0.00428
		(0.0112)	(0.0109)		(0.00901)	(0.00887)
Coresidence		-0.406**	-0.585***		0.0800	0.229*
		(0.184)	(0.193)		(0.118)	(0.119)
Child gender		-0.0651	0.442**		0.142	0.0889
		(0.157)	(0.197)		(0.0952)	(0.0945)
Observations	1,489	1,489	1,475	5,201	5,192	5,092
City dummies	NO	NO	NO	NO	YES	YES

Notes: Data source: CHARLS (2008) for Columns 1-3 and 'Three cities survey' (1999) for Columns 4-6. We take one observation per child. Estimation using Poisson Pseudo-Maximum-Likelihood (PPML). Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

mechanisms constitute the macro-economic and micro-economic effects— including (i) composition of income and education; (ii) composition of population; (iii) expenditure channel; (iv) transfer channel. We decompose the quantitative contribution of each of these different channels in Table 9, noting however that (iii) and (iv) are difficult to disentangle empirically.

Macro-channels.

Composition of Population. First, one needs to account for the shifts in the demographic composition. This involves multiplying the number of observations of individuals born after 1982 by a factor of 2 and the number of individuals born in between 1978-1981 by a factor of 1.5, in the 2009 sample. Holding constant the age-saving profile, aggregate saving are now about 1.45 % lower under a 'two-child policy' due to the demographic composition effect.

Composition of Education and Income. Second, the incremental individual human capital that is attributed to the one child policy alters household saving to the extent that those with higher education tend to save more; it also alters the composition of income across age groups. Therefore, we need to 'purge' the additional human capital caused by the policy. Using estimates of the twin effect on education attainment provided in Table 7, we give young cohorts a 40 percent less likelihood of attaining higher education under the two-child scenario. The overall impact on aggregate saving, holding everything else constant, is however very small—less that 0.3 %. The effect being minute is not surprising since it concerns only a fraction of households in the whole sample at this point in time, and since the positive impact of higher education on saving only comes through in later stages of life rather than at young ages. We therefore expect a greater impact of the education and income channel in the future years.

Thus, when moving from one to two children per household, compositional effects account for a 1.7% difference in aggregate saving. Again, this number might seem small in the first instance, but the effect will become more significant in the near future as the generation of only child age and account for a larger share of aggregate income and saving at the age of 40—around 10 years time.

Micro-channels.

Expenditure and Transfers. Third, the imputed increase in expenditures associated with having an additional child is used to quantify the expenditure channel effect. Taking first education expenditures, we give all households with one child under 15 years of age in the sample now a 6.1% higher expenditure in education (as a share of household income) on compulsory education, relying on the estimates from 6 (Column 3). For households with a child above 15 years of age, we assign an additional non-compulsory education expenditure that is lower since the quantity-quality trade-off is at work: from the estimate in Column 3, we find a 1.8% increase for an additional child above 15.[26] The overall effect of lower education expenditures lead to a fall of 2.7% of aggregate savings rate.

One can proceed by the same methodology to calculate the additional food expenditures and other expenditures, remarking though that these effects kick in mostly during later stage of adulthood (see Table 5). We impute to all parents with financially dependent children (i.e below 18 or below 25 and still students) a 1.7% higher food expenditure when under 45, a 4.2% higher food expenditure and a 8.2% higher other expenditures when above 45.

Taken all together, the incremental education, food and other expenditures lead to an additional 4.11% (= 2.68% + 1.32% + 1.11%) drop in aggregate saving (see Table 9). Note that apart from education expenditures that are clearly devoted to children, the change in other expenditures (food and other) when moving from one to two children is partly driven by the 'expenditure channel' and partly by the 'transfer channel'. One cannot fully disentangle the two using existing data, but we nevertheless believe that the impact on older parents' 'other expenditures' very likely operates through the transfer channel.

A caveat is that older parents (in their late 40s and 50s) that were subject to the policy should also be affected by the 'transfer channel', even though their only child has left the household. This effect cannot be measured in the data since one can no longer observe whether parents had an only child or twins when the children no longer live in the household. But if 'other consumption expenditures' for parents above 45 (in Table 5) is used as a proxy for the increase in overall expenditures, households in their late 40s to 50s (before retirement) with two children should have an 8.2% (of household income) additional expenditure, and an even higher one if one considers some of the impact found on food expenditures. This channel is less precisely estimated from the data, and calls for a sensitivity analysis using more conservative estimates: assuming that additional expenditures are instead 4% higher (resp. 8%) for older parents (without children below 21 in the household), aggregate saving rate falls by an additional 1.1% (resp. 2.1 %).

[26]Since this estimate is less precise and not significantly different from zero, we also consider the case in which the fall in quality exactly offsets the rise in quantity— corresponding to constant overall budgets for children above 15. In that case, the fall in aggregate saving associated with education expenditures is 2.35% (compared to 2.7% in our benchmark).

The combined effect of these channels indicate that aggregate saving rate would have been between 7.8% to 8.9% lower in China had a (binding) 'two-child' policy been put in place—or, if the natural rate of fertility after 1977 were simply two children per household. These estimates correspond to roughly 35-45% of the 20% increase in aggregate savings rate in China since the implementation of the policy.

Table 9: Empirical counterfactuals using estimates from twins regressions: aggregate effect under a two children scenario.

	Aggregate savings rate	**Additional effect**
Aggregate savings rate 2009 (Census corrected)	29.74%	
Macro channels		
Age composition	28.28%	-1.45%
Education and income composition (22 to 33y)	28.06%	-0.23%
Micro channels		
Education (ie. below/over15y)	25.38%	-2.68%
Food (ie. below/over 45y)	24.06%	-1.32%
Other expenditures (for parents above 45)	22.95%	-1.11%
Additional transfer channel		
4% scenario	21.89%	-1.06%
8% scenario	20.83%	-2.12%
Total effect (4% scenario)	-7.85%	
Total effect (8% scenario)	-8.91%	

Notes: Counterfactual are run using estimates from the twins regressions. Macro (composition) channels are computed by multiplying the number of individuals born after 1982 by 2 (and 1.5 between 1978-1981), at the same time imputing them lower incomes/education attainment as predicted by Table 7. Micro-channels are calculated using the response of expenditures of households at various ages of the children (for educ. exp.) and various ages of the parents (for food and other) from Tables 5 and 6.

Empirical counterfactual versus Model counterfactual. The counterfactual estimate as measured from the data can be used to gauge the success of our quantitative model, which turns out to generate a fairly close quantitative effect of the policy on aggregate household saving rate. Based on a constant natural fertility rate of 3 children per household, the policy can explain about 55% of the increase in aggregate saving to the one child policy. However, if we run the same counterfactual in our quantitative model as in the empirical counterfactual–that is, assuming a natural fertility rate of 2 rather than 3— the quantitative model predicts that having two children starting 1977 lowers the aggregate saving rate by 6.6% in 2009— explaining roughly 30% of the increase observed in the data, not to far from the 35% in our conservative empirical estimates. This number is perhaps unsurprising since the micro-economic impact as predicted by the model and our simulated age-saving profiles for the young and middle-aged households are fairly close to the data. In a nutshell, if the natural fertility rate of China hovered around 2 to 3 over this period—a very reasonable scenario– one can argue that the one child policy may have contributed to at least 30% (and potentially up to 55%) of the 20% increase in aggregate household saving over the period 1980-2010.

5 A Quantitative OLG Model

We extend the baseline model to a multi-period setting that can capture a finer and more realistic age saving profile. The advantage of the quantitative model is that the distinct implications on the changes in saving behavior and human capital accumulation across generations can be quantitatively evaluated, and compared to the data. So far, the macro-approach in the literature has largely ignored these micro-level predictions. The goal of this section is three-fold. First, a reasonably parameterized model can assess the quantitative impact of the one child policy on aggregate saving over the period 1980-2010. Second, important implications on the predictions of the age saving profile—both in terms of its changes in levels and shape—are confronted with their data counterparts. Third, we quantify the impact of the micro-channel and compare it to data estimates provided in Section 4.

5.1 Set-up and model dynamics

Timing. The structure of the life cycle is the same as before, except that more periods are included to allow for a more elaborate timing of various events that take place over the life cycle. Agents now live for 8 periods, so that eight generations ($\gamma = \{1; 2...; 8\}$) coexist in the economy in each period. The agent is a young child/adult for the first two periods, accumulating human capital in the second period. A young worker in the third period, the agent then becomes a parent in between periods 4-6, rearing and educating children while making transfers to his now elderly parents. Upon becoming old in periods 7 and 8, the individual finances consumption from previous saving and support from his children, and dies with certainty at the end of period 8, leaving no bequests for his children.

Preferences. Let $c^i_{\gamma,t}$ denote the consumption of cohort γ in period t, with $\gamma \in \{3, 4, ..., 8\}$. The lifetime utility of an agent born at $t-2$ and who enters the labour market at date t is

$$U_t = v \log(n_t) + \sum_{\gamma=3}^{8} \beta^{\gamma} \log(c_{\gamma,t+\gamma-3}),$$

where n_t is the number of children the individual decides at the end of period 3 to bear (children per agent); as before, $0 < \beta < 1$ and $v > 0$.

Budget Constraints. The functional form of transfers and the costs of rearing and educating children are the same as before, although the timing of the outlays of these expenditures are more elaborate. Consider an agent entering the labour market at date t. Without loss of generality, the agent is assumed to bear these costs and transfers only in middle-age.[27] Motivated by the data from

[27] This is also in line with the average age of parents giving first births at 28 (average over the period 1975-2005 from UHS).

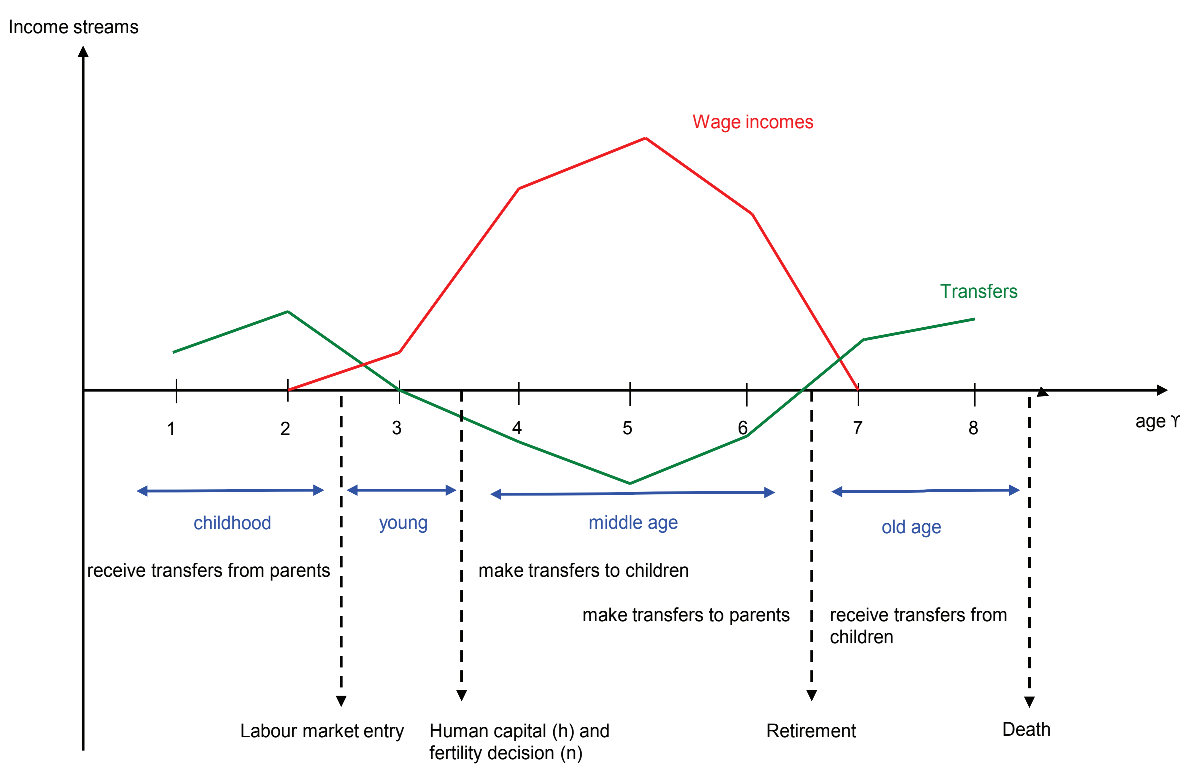
which we observe the timing and scale of the outlays of these expenditures and transfers, we assume that the compulsory education costs are paid during $\gamma = \{4, 5\}$—and is a fraction ϕ_γ of the agent's wage income, per child (per head); the discretionary education costs are born only in period $\gamma = \{5\}$ and is $\phi_h h_{t+1} w_{5,t+2}$ per child (per head). This corresponds to the data, which reveals that the bulk of 'non-compulsory' education costs is paid when the child is between the ages of 15 and 25— right before entering the labor market. Transfers made to the individuals' parents occur only in periods 5 and 6. Net transfers of an individual born in $t-2$ over his lifetime are thus:

$$T_{4,t+1} = -\phi_4 w_{4,t+1} n_t \quad T_{5,t+2} = -\left[(\phi_5 + \phi_h h_{t+1})n_t + \psi \frac{n_{t-1}^{\varpi-1}}{\varpi}\right] w_{5,t+2}$$

$$T_{6,t+3} = -\psi \frac{n_{t-1}^{\varpi-1}}{\varpi} w_{6,t+3} \quad T_{7,t+4} = \psi \frac{n_t^{\varpi}}{\varpi} w_{5,t+4} \quad T_{8,t+5} = \psi \frac{n_t^{\varpi}}{\varpi} w_{6,t+5}.$$

Figure 8 summarizes the timing and patterns of income flows, costs and transfers—collectively denoted as $T_{\gamma,t+\gamma-3}$ ($\gamma = \{3..., 8\}$) in each period of the agent's life. Wages are modeled as previously: an individual entering at date t in the labour market with human capital h_t earns $w_{\gamma,t+\gamma-3} = e_{\gamma,t+\gamma-3} z_{t+\gamma-3} h_t^{\alpha}$ for $\gamma = \{3..., 8\}$; the age effect embedded in the age-income profile is captured by $e_{\gamma,t}$—which is potentially time-varying if growth is biased towards certain age-groups; $z_{t+\gamma-3}$ represents aggregate productivity at a given date, and for simplicity, is assumed to be growing at a constant rate of $z_{t+1}/z_t = 1 + g_z$.

Figure 8: Timing of Lifetime Events: Quantitative OLG Model



Optimal Consumption/Saving. The assumption that agents can only borrow up to a fraction θ of the present value of their future labor income is retained from before:

$$a_{\gamma,t+g-3} \geq -\theta \frac{w_{\gamma+1,t+\gamma-2}}{R} \text{ for } \gamma = \{3; ...; 8\}.$$

where $a_{\gamma,t}$ denotes total asset accumulation by the end of period t for generation $\gamma = \{3; ...; 8\}$. The gross interest rate R is still taken to be exogenous and constant over time. Here, we assume that the parameters of the age-income profile $e_{\gamma,t}$, productivity growth g_z, interest rate and discount factor (β and R), make the constraint binding only in the first period of working age ($\gamma = 3$). We verify that this condition is satisfied at every point along the equilibrium path in the simulations.

The sequence of budget constraints, for an individual born at $t-2$ (and entering labour market at date t), are then:

$$\begin{aligned}
c_{3,t} &= w_{3,t} + \theta \frac{w_{4,t+1}}{R} \\
c_{4,t+1} + a_{4,t+1} &= w_{4,t+1}(1-\theta) + T_{4,t+1} \\
c_{\gamma,t+\gamma-3} + a_{\gamma,t+\gamma-3} &= w_{\gamma,t+\gamma-3} + T_{\gamma,t+\gamma-3} + Ra_{\gamma-1,t+\gamma-4} \qquad \text{for } \gamma = \{5; 6; 7\} \\
c_{8,t+5} &= T_{8,t+5} + Ra_{7,t+4}
\end{aligned}$$

The intertemporal budget constraint when combining the period constraints of $\gamma = 4$ to 8 gives

$$\sum_{\gamma=4}^{8} \frac{c_{\gamma,t+\gamma-3}}{R^{\gamma-4}} = \sum_{\gamma=4}^{8} \frac{w_{\gamma,t+\gamma-3} + T_{\gamma,t+\gamma-3}}{R^{\gamma-4}} - \theta w_{4,t+1}, \tag{20}$$

which, along with the budget constraint for $\gamma = 3$ and the Euler equations, for $\gamma \geq 4$:

$$c_{\gamma+1,t+\gamma-2} = \beta R c_{\gamma,t+\gamma-3}, \tag{21}$$

yields optimal consumption and saving decisions in each period, given $\{n_t; h_{t+1}\}$.

Fertility and human capital. The quantitative model, despite being more complex, yields a similar set of equations capturing the dynamics of fertility and human capital accumulation as in the simple model:

$$n_t = \left(\frac{1}{1 + \Pi(\beta, v)} \right) \frac{(1-\theta) + \mu(1+\mu) - \varphi \frac{n_{t-1}^{\varpi-1}}{\varpi} \mu (1+\mu)}{\phi_0 + \mu \phi_h h_{t+1} \left(1 - \frac{\varpi}{\alpha}(1+\mu)\right)} \tag{22}$$

$$h_t^{\alpha} h_{t+1}^{1-\alpha} = \left(\frac{\varphi \alpha}{\varpi} \frac{\mu^2}{\phi_h} \right) n_t^{\varpi-1}, \tag{23}$$

where $\Pi(\beta, v) \equiv \frac{\beta}{v}(1 + \beta + ...\beta^8)$, $\mu \equiv \frac{(1+g_z)}{R}$, and $\phi_0 = \phi_4 + \mu\phi_5$. We relegate the exposition of fertility and human capital accumulation dynamics to Appendix A. The unique steady state $\{n_{ss}; h_{ss}\}$ can be characterized analytically and is analogous to that of the four-period model. The main difference, however, is that the quantitative model gives rise to a finer age saving profile, which, in the absence of possible analytical characterizations, is explored next using numerical simulations.

5.2 Data and Calibration

Table 10: Calibration of Model Parameters

Parameter	Value	Target (Data source)
β (annual basis)	0.99	/
R (annual basis)	5.15%	Agg. household saving rate in 1981-1983
g_z (annual basis)	7%	Output growth per worker over 1980-2010 (PWT)
v	0.001	Fertility in 1966-1970 $n_{ss} = 3/2$ (Census)
θ	2%	Av. saving rate of under 25 in 1986 (UHS)
α	0.45	Mankiw, Romer and Weil (1992)
ω	0.66	Transfer to elderly wrt the number of siblings (CHARLS)
$\{\phi_4; \phi_5; \phi_h\}$	$\{0.125\%; 0.07; 0.35\}$	Educ. exp. at ages 30-50 in 2006-08 (UHS/RUMICI)
ψ	12%	Savings rate of age 50-58 in 1986 (UHS)
$(e_\gamma/e_5)_{\gamma=\{3;4;6\}}$	$\{65\%; 90\%; 57\%\}$	Wage income profile in 1992 (UHS)
Alternative calibrations		
Low transfers		
ψ	4%	Observed transfers to elderly (CHARLS)
R (annual basis)	3.5%	Agg. household saving rate in 1981-1983
v	0.19	Fertility in 1966-1970 $n_{ss} = 3/2$ (Census)
Time-varying income profile		
$(e_{\gamma,t}/e_5)_{\gamma=\{3;4;6\}}$ for $t \leq 1998$	$\{65\%; 90\%; 57\%\}$	Wage income profile in 1992 (UHS)
for $1998 < t \leq 2004$	$\{65\%; 94\%; 57\%\}$	Wage income profile in 2000 (UHS)
for $t > 2004$	$\{65\%; 101\%; 56\%\}$	Wage income profile in 2009 (UHS)

Parameter values. In an 8-period model, a period corresponds roughly to 10 years. Endogenous variables prior to 1972 are assumed to be at a steady-state characterized by optimal fertility and human capital $\{n_{ss}; h_{ss}\}$. Data used in the calibration procedure is described in Appendix B.

Preferences and Technology

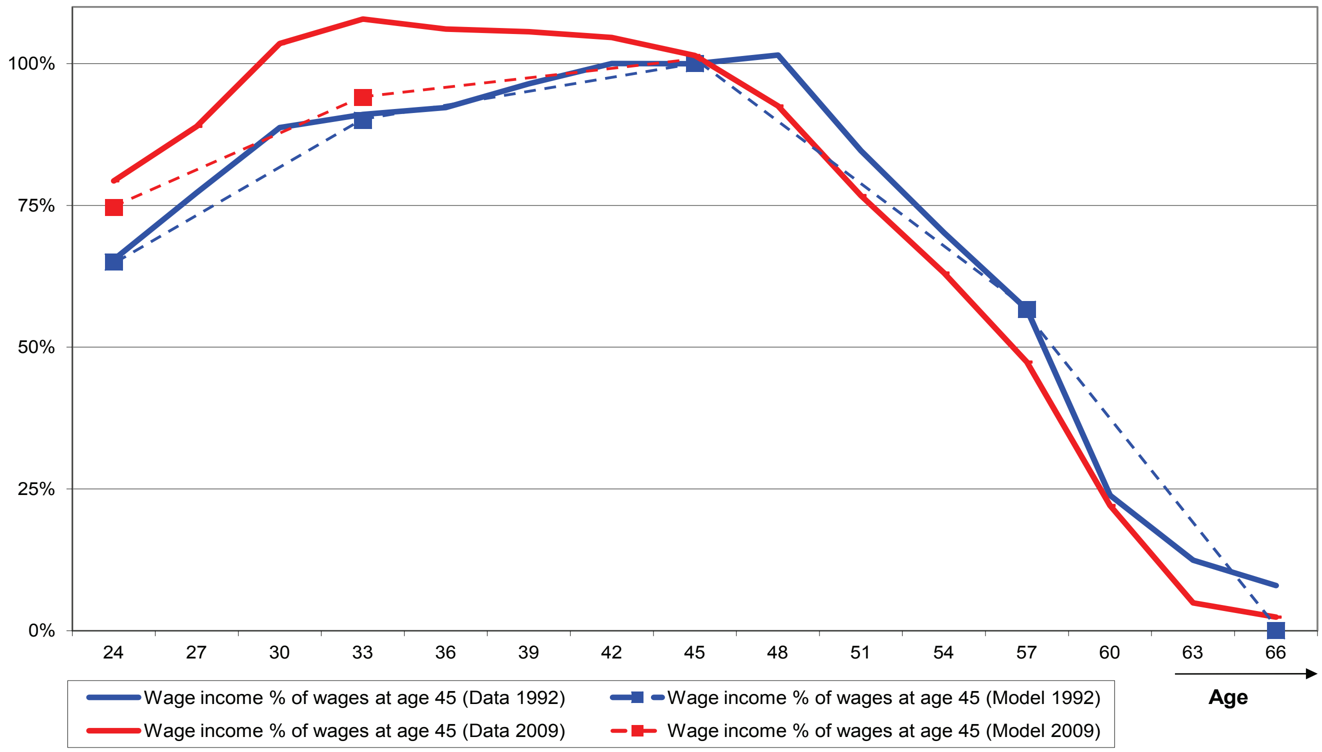
We set $\beta = 0.99$ on an annual basis. The real growth rate of output per worker averages at a high rate of 8.2% over the period 1980-2010 in China (Penn World Tables). Rapid growth as implied by the model occurs partly endogenously—through human capital accumulation—and hence make the growth rate 8.2% an upper-bound for g_z. To generate a real output growth per worker of about 8% in the model, we set the constant exogenous growth rate to be $g_z = 7\%$. The decreasing marginal returns to education α is set to 0.37— in line with the empirical growth literature (see Mankiw, Romer and Weil (1992)).

Age-Income profile

We calibrate the efficiency parameters $\{e_\gamma\}_{3\leq\gamma\leq 6}$ to income by age group, provided by UHS data. The first available year for which individual income information is available is 1992.[28] Calibrating

[28] UHS data for 1986 is available but does not provide individual income for multigenerational households— thus making it

Figure 9: Age Income Profiles (1992 and 2009)



Notes: Data source: UHS, 1992 and 2009. Wages includes wages plus self-business incomes.

the initial steady state to 1992 data is still sensible for the reason that human capital levels of the working-age population has not yet been affected by fertility control policies —- chosen by parents unrestricted by any form of restrictions on fertility. The age-income profile as extrapolated from the data in 1992 is displayed in Figure 9. The benchmark case considers time-invariant efficient parameters in order to zero-in on the impact of the one child policy. In an extension, we allow for a "time-varying income profile", in order to replicate the full flattening of the profile for adults below 45 over the period 1992-2009, as observed in Figure 9. It is important to recognize that part of this flattening arises *endogenously* from the model: the quantity-quality tradeoff induces rapidly rising income for the young only children as a consequence of human capital accumulation.[29]

Fertility, demographic structure and policy implementation

The initial fertility rate n_{ss} is key for determining the quantitative impact of the one child policy on saving. In the benchmark scenario, it is taken to be the fertility rate of urban households prior to 1972—when families were entirely unconstrained. Census data gives $n_{ss} = n_{t<1972} = \frac{3}{2}$ per adult.[30]

difficult to estimate individual age-income profiles. One could alternatively apply the method developed by Chesher (1998) to estimate individual life income profiles as is done for individual consumption and saving profiles (see below). The resulting estimates are very close to the one directly observed for 1992 from UHS.

[29]In the *"Time Varying Income Profiles"* experiment, we take the benchmark values $e_{\gamma,t}$ for $t \leq 1998$, and slightly modified values for $t > 1998$ to match the cross-section of wages across age-groups over 1999-2009 (see Table 10).

[30]The Census data provides information on the number of siblings associated with each observed adult born between the periods of 1966-1971 in the sample. The result is a bit above 3 children per couple. But since the number of children under

We therefore select the preference parameter for children, v, to match $n_{ss} = n_{t<1972} = \frac{3}{2}$. It is possible that the natural rate of fertility may have changed after 1972 in China, and in the later section (see Section 4.5) we allow for a time-varying natural fertility rate. Given initial fertility, the initial population distribution—the share of each age group (0-10; 10-20, ..., 60-70 and above 70) in 1965 —can then be calibrated to its empirical counterpart provided in the United Nations data.[31]

While the one-child policy appeared to be nearly fully-binding in 1980 and fully-binding from 1982 onwards, according to Census data, earlier endeavors to curb population growth were already under way and most likely account for the fall in fertility over the period 1972-1980 (see Figure 1 in section 2). The policy is thus assumed to be implemented progressively during the $70s$—–with the first reduction in fertility occurring in the mid-70s. We take cohorts to be born every 4 years, and allow fertility to vary according to $n_{1971-1972} = \frac{2.7}{2}$, $n_{1975-1976} = \frac{2.25}{2}$and $n_{1979-1980} = \frac{1.3}{2}$, according to fertility data for urban households (see Figure 1).[32] For any date after 1982, fertility is constrained such that $n_{\max} = \frac{1}{2}$.

Transfers

Data from UHS (2006) and RUMICI (2008) show that for children of ages 0-15, the costs of education (as a fraction of total household expenditures) are in between 2% and 12% for an only child (see Figure 4).[33] Thus, we select $\phi_4 = 0.125$ so that 6.25% of total household income is devoted to compulsory education of a child of ages 15 and younger. For children between 15-21, total education expenditures constitute an average of $15\% - 25\%$ of total expenditures (see Fig. 4). A reasonable target is setting $\phi_5 + \phi_h h_{2008-2009}$ to be on the order of 20%.[34] Since compulsory education costs for this age group as revealed by CHIP (2002) constitute 2% to 5% of total household expenditures for a child of ages 15 - 20: a reasonable choice thus selects $\phi_5 = 0.07$— corresponding to 3.5% of household income per child. The remaining non-compulsory eduation costs captured by ϕ_h is then $\phi_h = 0.35$ (for $\phi_5 = 7\%$).[35] It is important to note, however, that these estimates based on education expenditures only represent a lower bound of the total cost associated with a child since other transfers (food, co-residence...) are likely sizeable, although omitted in this model.[36]

Two parameters govern transfers to parents, ψ and ϖ. The first captures the degree of altruism towards one's parents—in terms of the overall amount of transfers one wishes to confer; the latter captures the propensity to free-ride on the transfers provided by one's siblings. Empirical estimates

the one-child policy policy is also slightly above 1, we take 3 to obtain the appropriate change in fertility after the policy change.

[31]One would in principle prefer to take only the demographics data for Chinese urban households rather than that for the entire population, but such Census data are available only starting from 1980. We check, however, that the future distribution of population by age implied by our imputed fertility rates (see below) is broadly in line with urban population data in the 1980s.

[32]We calibrate ν to match these fertility statistics, as ν does not exert any intrinsic impact on the model except through its influence on fertility n.

[33]CHARLS (2008) provides comprehensive data on income and transfers, from parents to children, and from children to parents in 2008. For children below 15, transfers amount to an average of 10.6% of total household income, slightly above the counterpart in UHS (2006) and RUMICI (2008). But since the sample contains only adults above the age of 45, most children are in between the ages of 10-15—thus making this value likely an upper bound.

[34]Similar values are obtained if examining transfers towards children of the same age in CHARLS.

[35]These values of ϕ_h and ϕ_5 generate a share of non-compulsory education costs for children of $15 - 20$ broadly in line with the data (CHIP, 2002).

[36]These other types of expenditures are difficult to break down from total household expenditures to amounts that are attributed solely to the children, unlike education costs.

in Table 8 gives us direct measurements of the elasticity of transfers to the number of children, $\varpi - 1$, where $\varpi = 0.66$.

The direct measurement of ψ based solely on monetary transfers in the data is likely to be underestimated, as it does not include other forms of 'indirect transfers'—in-kind benefits such as coresidence and healthcare. In Section 2.3 we have documented how coresidence with children is a primary form of living arrangement for the elderly. Any forms of transfers that essentially provide insurance benefits to the elderly should in principle be taken into account— as they importantly determine saving decisions for adults in their 40's and 50's. Purely financial transfers amount to about 4%-7% of the wage income $42 - 54$ year olds, from CHARLS (2008),[37] thus yielding a low value of $\psi = 4\%$. However, it is likely that CHARLS' data on transfers is notably underestimated–as the Census data reports that more than half of the elderly's income derives from family support (Figure 2).[38]

Our preferred strategy, given the difficulty in accurately measuring ψ from the data, is to calibrate it to match the initial age saving profile. It is important to point out, however, that the choice of ψ turns out to have little quantitative bearing on the aggregate saving rate, for reasons that will become clear.

Matching Initial Age Saving Profile and Aggregate Saving Rate.

Our main calibration strategy is to choose the remaining parameters to match the initial age-saving profile— its level and shape—and in turn, the initial aggregate saving rate. Replicating the initial saving profile is important for accurately assessing the ability of the model to explain the *change* in aggregate and micro-level saving over time. The first available year to obtain an age saving profile from the data is 1986, displayed in Figure 10.[39] The profile estimated at this point in time is a valid proxy for the initial steady-state profile applicable to pre-policy implementation era, for the reason that the sole cohort (of adults) that would have been subjected to the policy are those in their early 30's in 1986.[40] The model would then slightly underestimate their saving rate by assuming that they are 'untreated'. In reality, within that group, there is likely a sizeable population that had children earlier than the age of 28 and would have therefore been unaffected. Thus, the 1986 age saving profile is a reasonable approximation of the initial age saving profile.

There are three parameters, jointly determined, to match three targets–the levels of the age saving profile, its shape, and the aggregate saving rate. The parameter θ largely determines the first point on the age-saving profile—that is, the level of saving rate of 20-year olds in 1986. The resulting value is $\theta = 2\%$.[41] The value of ψ is important for matching the saving rate of those in their 50's in 1986. The

[37] Wages of children are not observed in CHARLS but can be imputed based on observed children's characteristics (education, age, parental incomes...). See Appendix B and Section 4.4 for a more detailed description of data treatment.

[38] As a result of high growth rates, these transfers amount to sizeable fractions of the old's income.

[39] Estimating the individual age-saving profile in the presence of multigenerational households (more than 50% of the observations) is a complex task, and the standard approach based on using household head information is flawed—as demonstrated in Coeurdacier et al (2012). A technical appendix shows how individual age-saving can be recovered from household-level data following a method initially proposed by Chesher (1998). The method relies on estimating individual consumption from household level consumption data using variations in the family composition as an identification strategy. Individual saving are then calculated using these individual consumption estimates in conjunction to the observed individual income data (see Appendix B and Coeurdacier, Guibaud and Jin (2012) for more details).

[40] The younger cohorts are subject to the credit constraint and therefore unaffected by fertility policies.

[41] The lack of consumer credit and mortgage markets, as well as the very low levels of household debt in China (less than 10% of GDP in 2008) warrants a choice of a low θ to strongly limit the ability of young households to borrow against future

resulting value is $\psi = 12\%$. This parameter is the main determinant of the shape of the age saving profile. As Figure 10 shows, taking $\psi = 4\%$ from direct estimates significantly distorts the profile. Lower transfers to the elderly will tend to underestimate the saving rate of the young and overestimate that of the middle-aged—as lower receipts of transfers from children bid the middle-aged to save more, and the young to save less due to mitigated parental obligations. This larger wealth accumulation also leads to significantly larger dissavings of the old. This choice is in line with Banerjee et al. (2010), which adopts higher shares of transfers—of 13-20 percent of children's income, and also in line with Curtis et al. (2011).

Even with $\psi = 12\%$, the young's saving rate (those between 26-30) still falls slightly short of data estimates. Yet, this discrepancy, is if anything, consistent with the theory, since these individuals are the first to be affected by the policy change in 1986 and therefore, should accordingly see a higher saving rate (data estimate) than their counterparts before the policy change (model predictions). The rate of return R, given $\beta = 0.99$, to match the average aggregate saving rate of 10.4% between 1981-1983. The values of R hover around reasonable orders of magnitude of $3 - 5\%$.

A unique combination of the three parameters gives us a very close fit of the model-implied initial age saving profile with the data in 1986, matching well the saving rate of the young and the middle-aged, as well as the dissaving of the old.[42]

5.3 The Impact of the One-Child Policy

We next study the transitory dynamics of the model following the implementation of the one child policy, starting from an unconstrained steady-state characterized by $\{n_{ss}; h_{ss}\} = \{n_{t_0-1}; h_{t_0+1}\}$ and an initial age-saving profile $\{s_{\gamma,t_0}\}_{\gamma=\{3;...8\}}$. The policy is implemented at date $t_0 = 1982$ and is assumed to be binding (with the exception of twin births).[43] Since analytical solutions are cumbersome, we resort to a numerical simulation of the model's dynamics following the policy (see Table 10 for the parametrization of the model).

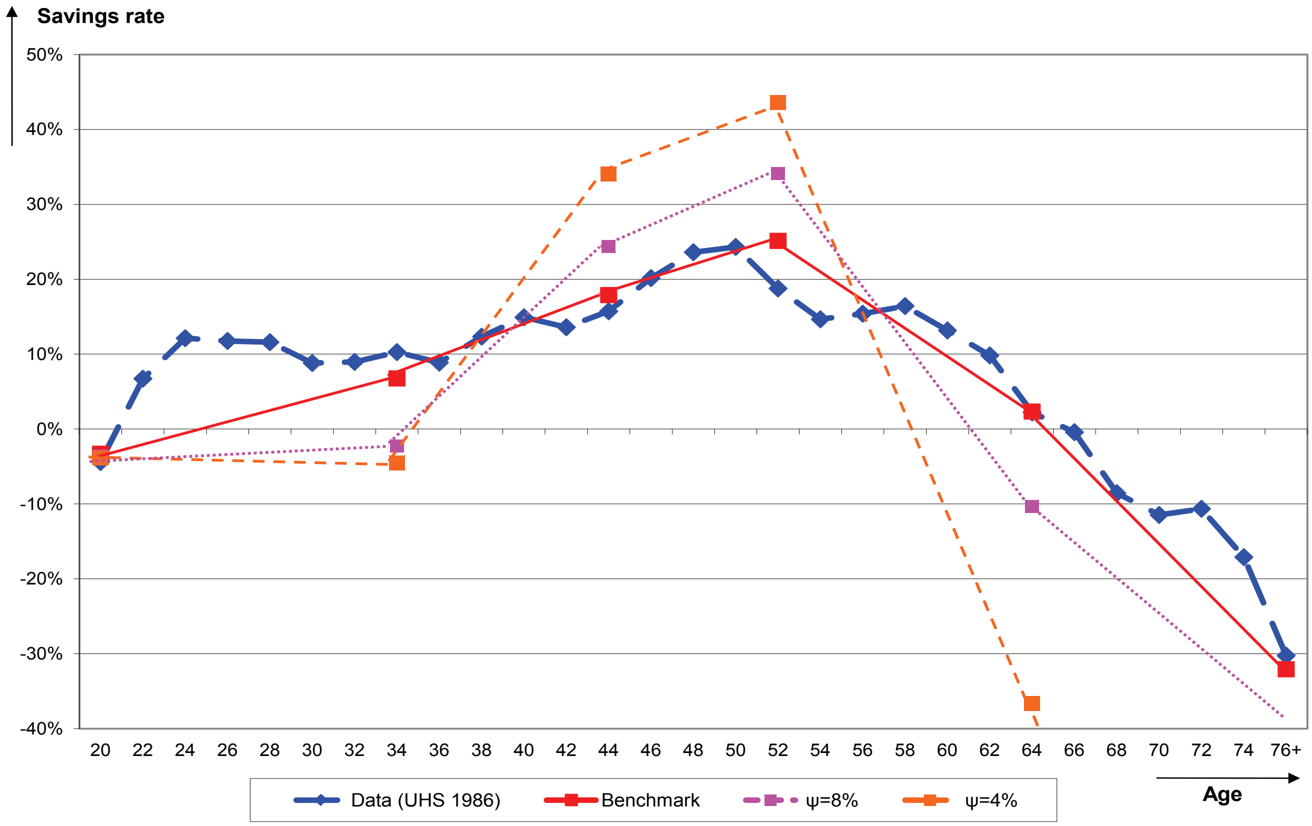
Transitory dynamics. The maximization problem is the same as in the case with unconstrained fertility, except that fertility is subject to the binding constraint $n \leq n_{\max}$. After t_0, the equation governing the evolution of human capital is is described by Eq. 23, except that $n_{\max}$ now replaces n. Given initial human capital h_{t_0} and the dynamics of human capital h_t for $t \geq t_0 + 1$, the consumption/saving decisions at $t \geq t_0 + 1$ can be readily backed out for each age group, using the appropriate intertemporal budget constraint (equation (20)) and the Euler equation (21). Aggregate saving and age-saving profile immediately follow.

income. The choice of $\theta = 2\%$ allows the model to reach reasonable estimates for the young's saving rate in 1986, and similar estimates would have been obtained if using the subsequent years of the survey. Results are not very sensitive to θ as long as it is fairly close to zero.

[42]The saving rate of the very old (which are very large dissavers) reaching age $\gamma = 8$ in the case of $\psi = 4\%$ is omitted since it is of little relevance to our purpose at hand and affects significantly the scale of the graph.

[43]Note that $h_{t_0+1} = h_{t_0}$, since those with human capital of h_{t_0+1} are born in $t_0 - 1$— before the policy implementation.

Figure 10: Initial Age-Saving Profile: Model vs. Data



Notes: Data source: UHS (1986), to construct individual profiles according to the methodology in Chesher (1998) (see technical appendix in Coeurdacier et al. (2013)). Steady-state age-saving profiles as implied by the model take $n_{ss} = \frac{3}{2}$. For different values of ψ, the real interest rate R is chosen to keep aggregate saving constant to their 1985 value.

5.3.1 Aggregate saving

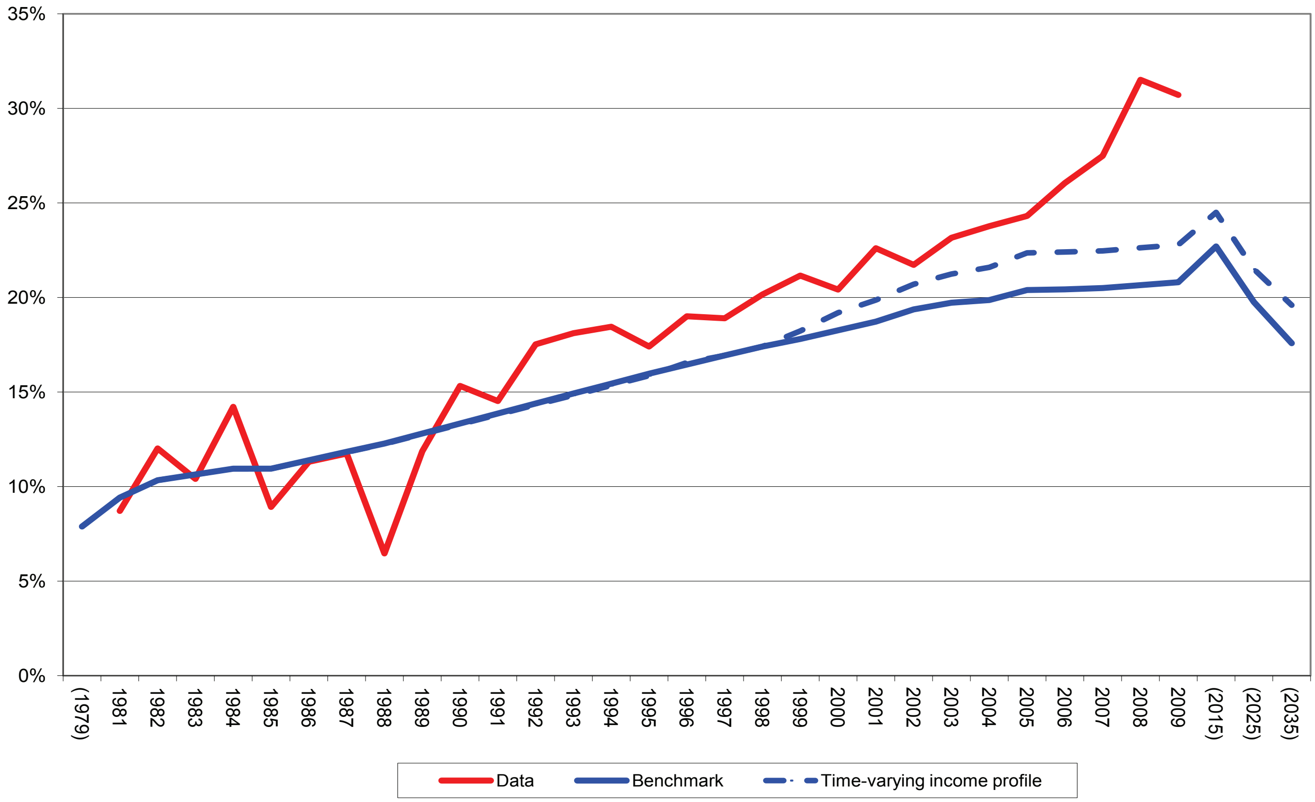
Figure 11 displays aggregate saving as a share of labour income in the years following the policy as per the benchmark calibration, compared to the data. Model estimates are linearly interpolated at the various dates (1979, 1989, ..., 2009). Our model generates roughly $50 - 60\%$ of the total increase in aggregate saving over the last thirty years.

Interestingly, calibrations for different values of ψ produce similar patterns in aggregate saving dynamics—a 11.4% rise over the period 1981-2009 in the benchmark case compared to a 8.3% rise in the case of low transfers ($\psi = 4\%$)–against the 20.4% rise in the data.[44] The reason for which aggregate saving prediction are so similar albeit under different parameter selections for transfers is that the two main channels governing aggregate saving turns out to be more or less offsetting: a higher value of ψ, as in the benchmark calibration, makes the 'micro-channel' stronger as the fall in transfers becomes more important; the 'macro-channel', however, is dampened as a result of a flatter age-saving profiles (Figure 10)—since demographic and income compositional changes are stronger when differences among various age groups are more distinct. Conversely, lower values of ψ imply a stronger 'macro-economic channel' and a weaker 'micro-economic channel'. The predicted rise in

[44] Household saving rates are slightly noisy in the beginning of the sample, and as such, we average the first 3 years (1981-1983) when calculating its overall increase.

aggregate saving is thus comparable— even though the age saving profile differs.

Figure 11: Aggregate Household Saving Rate: Model vs. Data



Notes: Data source: To be done

The experiment with *time-varying income profiles*, displayed in Figure 11, replicates the full flattening of the income profile for those between 30-45 and pushes the model predictions even closer to the data. The result derives from a stronger incentive to save in one's 30s. As the cohort of thirty-year-olds comprises a significant fraction of the population in 2009, the aggregate saving rises by even more under this scenario.

5.3.2 Age-saving profiles

The data reveals a marked evolution in the age-saving profile between 1986 to 2006. These changes are easily visualized by comparing the Model SS (which matches well with initial age saving profile in 1986 by our calibration) and Data (2009). In particular, there has been an upward *shift* in the age-saving profile over this period, as well as a change in the *shape* of the profile–characterized by two distinct features: a significant flattening of the saving profile for the middle-aged (30-60) as compared to the more conventional hump-shaped pattern in 1986—and a noticeable dip in the saving rate of those in their late 30's. We investigate to what extent our model captures these particularities, and, at the same time demonstrate the failure of a standard OLG model in accounting for these changes when intergenerational transfers are absent.

The oldest cohort in the model is born in 1940, with subsequent cohorts born every 4 years.[45] The age at which individuals have their first children corresponds to the average age of first-births in the data over the last 30 years (age 28). While individuals optimize over a 10 year period, we assume that they have the same saving rate over the age brackets: [22-26], [30-38], [42-50] and [54-60] (corresponding to $\gamma = 3, .., 5$)—in order to generate a smoother age saving profile. It is important to note that individuals from different age groups coexisting in the years of interest, 1986 and 2009, may be differently affected by fertility control policies. For instance, those born after the policy implementation (born after 1980) contrast with those who were partially affected (1972-1980), and with those who were entirely unaffected (born before 1972). A 30 year old in 2009, for example, is different from a 38 year old in 2009: the former is only allowed one child and was at the same time born during a period in which the policy was basically fully-implemented (in 1980). Those who are 38 are also subject to the one child policy but on the the other hand, have siblings themselves (born in 1971 before the policy implementation). Table 11 summarizes the information of coexisting cohorts in terms of the number of children and siblings they have in these two years.

Figure 12 presents the predicted age-saving profile $\{s_{\gamma,t}\}_{\gamma=\{3;...8\}}$ for $2009 - 2010$ and their data counterparts. The profiles under the benchmark calibration and under the *time-varying income profile* calibration are juxtaposed. The initial age-saving profile (before the policy) is displayed for comparison,[46] (with its closely-corresponding data counterpart omitted). One can mark that, first, the model can generate the upward *shift* of the profile over the period; this shift is the result of both a fall in expenditures on children and a rise in saving throughout the lifecycle in response to the expected fall in future receipts of transfers. The model also captures well two aspects of the change in the shape of the profile. The first is a significant flattening of the curve for the middle-aged (30-60): in 1986, the peak of the saving rate occurred around age 50 in the model—as in the data. After the policy, saving rates flattened for the age groups of 30s to 50s. The implication is that the saving rate rose fastest for those in their 30s—consistent with this well-marked pattern in the Chinese data (see also Chamon and Prasad (2010) and Song and Yang (2010).[47]

The model predict this pattern for the following reason: the cohorts around age 30 in 2009 were most impacted by the policy–both because they were the subject of the one child policy and therefore take on the brunt of the burden of supporting their parents, and also because they are subject to the one child policy themselves and expect to receive less transfers from their only child. Both effects raise substantially their saving rate. Cohorts in their late 30s-50s in 2009 are only partially affected by the policies, and to varying degrees: although they are allowed only one child, those in their 50's had more siblings than those in their late late 30s and early 40s to share the burden of parental transfers. The eldest cohorts, on the other hand, were entirely unaffected by the policy. Table 11 shows the differential impact of fertility on each contemporaneous cohort in both 1986 and 2009.

Comparison with a standard OLG Model. These changes in the levels and shape of the age-saving profile become apparent when examining the change in the saving rate across cohorts over the last three

[45]Note that an individual agent maximizes over a 10-year period, but in order to obtain finer age-saving profiles, we let cohorts be born every 4 years.

[46]Profiles in the case of "Low transfers" are not displayed as the patterns are known to be inconsistent with the data.

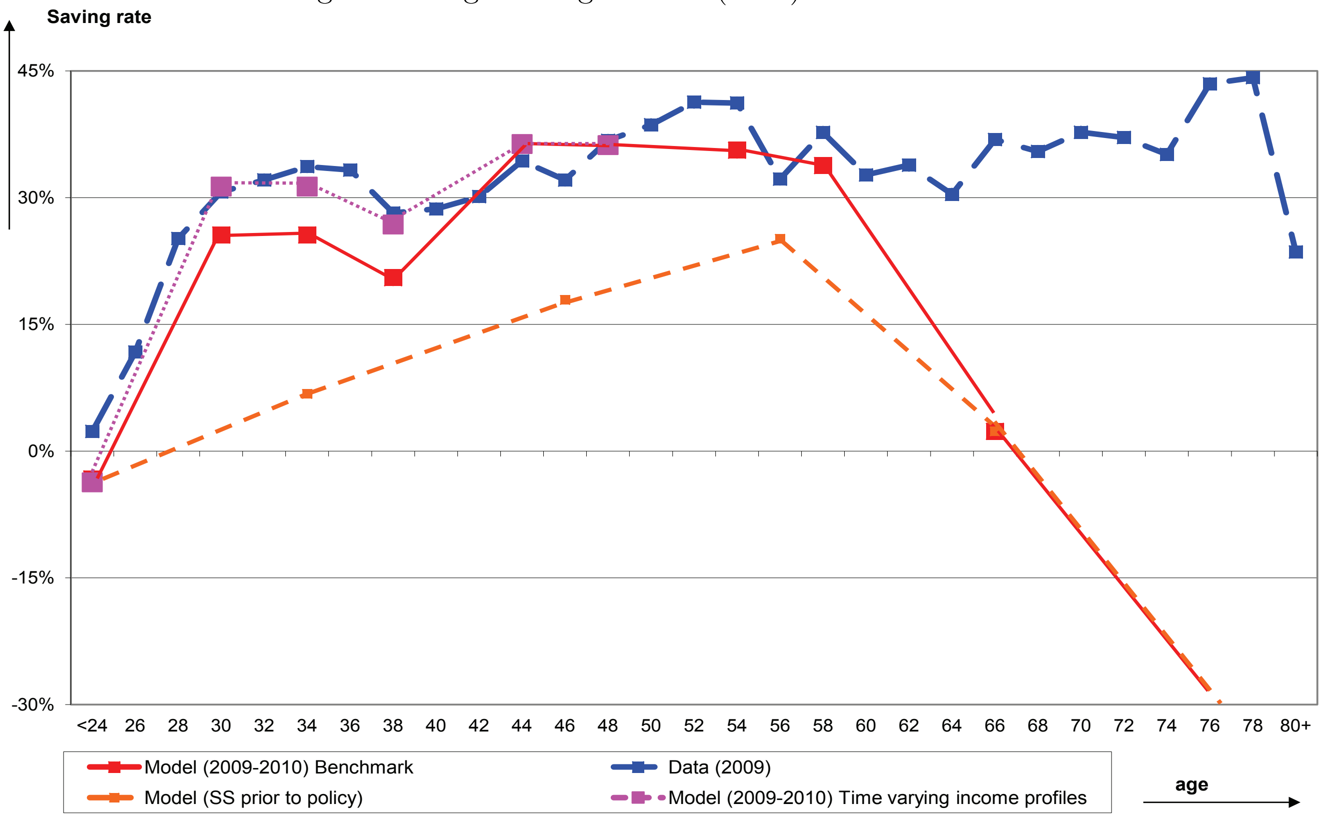
[47]An important difference between our saving profiles as estimated from the data and those of Chamon and Prasad (2010) and Song and Yang (2010) is that young (childless) adults did not see a rise in saving rates. The difference comes from our correction for the biases associated with multigenerational households (see Coeurdacier, Guibaud and Jin (2013)).

Table 11: Number of Siblings/Children by Cohort (1986 and 2009)

	1986			2009	
Age	No. Sibling (Birth Year)	No. Children (Fertility Year)	Age	No. Sibling (Birth Year)	No. Children (Fertility Year)
30	3 (1956)	1 (1984)	30	1 (1980)	1 (2008)
35	3 (1951)	$1.5-2$ (1979)	35	1.5-2 (1975)	1 (2003)
45	3 (1941)	$1.5-2$ (1969)	45	1.5-2 (1965)	1 (1993)
55	3 (1931)	3 (1959)	55	n_{ss} (1955)	1 (1983)
65	3 (1921)	3 (1949)	65	n_{ss} (1945)	1.5-2 (1973)
75	3 (1911)	3 (1939)	75	n_{ss} (1935)	3 (1963)

Notes: The number of children and siblings (including the individual) attributed to an individual belonging to a particular cohort in the year 1986 and 2009—by year in which they and their children were, respectively, born. This shows that contemporaneous cohorts in each of these two years were differentially affected by fertility control policies.

Figure 12: Age-Saving Profiles (2009): Model vs. Data



Notes: Data source: UHS (2009), to construct individual age-saving profile following the Chesher method (1998).

decades. Figure 13 juxtaposes the predicted growth rates in the benchmark model (and its extension) with that of the standard OLG model in which only the "expenditure channel" is operative.[48] In the absence of transfers, the standard OLG model falls significantly short of predicting the growth in saving rate across all ages. But the largest discrepancy arises for the cohort above 50. The standard model predicts a fall in saving rate for this age group after the one child policy.[49] The reason is that lower expenditures on children released more resources for consumption after the departure of their children. In contrast, in our model, the rise in saving for this age group is precisely due to the 'transfer channel'—as at this stage of parenthood, children have already departed and the expenditure channel is no longer relevant. Indeed, the canonical OLG model cannot explain this noteworthy and somewhat puzzling rise in saving rate for the more elderly. The transfer channel as demonstrated by the quantitative model, in conjunction with the indirect evidence from consumption behaviors of twin-parents in their 40s, strongly suggest the existence and impact of the transfer channel in linking fertility changes to saving.

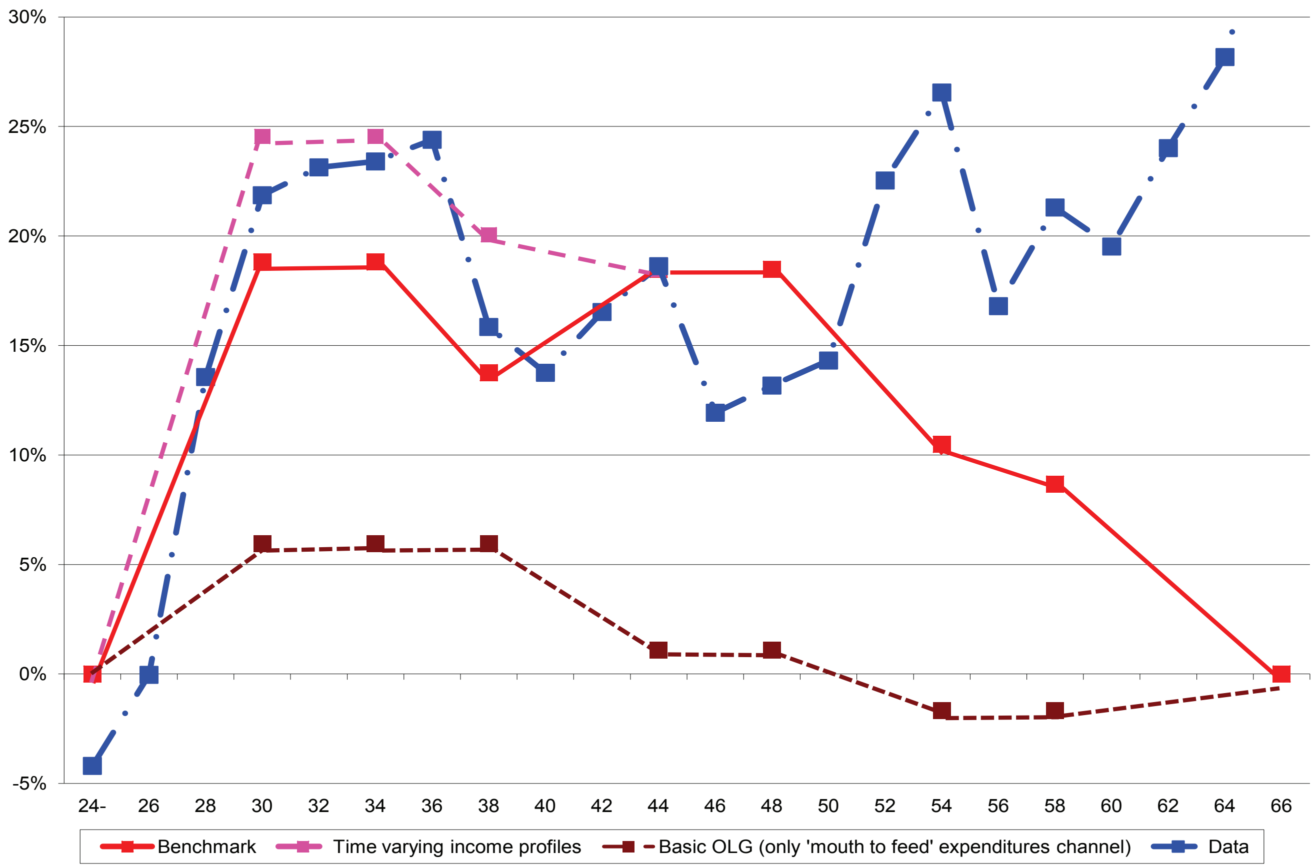
Still, one can mark that our benchmark model falls short of explaining the sharp increase in saving

[48] Fixed costs per child ("mouth-to-feed expenditure" due to ϕ_γ) are kept at the same values but human capital is fixed and transfers to elderly are set to zero. Similar patterns emerge if old age transfers are independent of the number of children.

[49] By construction, it can predict at most a rise in saving equivalent to the (small) fall in the expenditures on children—spread over time owing to consumption smoothing.

rate of retirees over this period and falls somewhat short of explaining the overall increase in saving of younger adults (in their 30s). Allowing for “time-varying life income profiles” can remedy the latter issue: as the life-income profile flattens in recent years, younger adults in their 30s have greater incentives to save (see Song and Yang (2010) and Guo and Perri (2013) for a similar point).

Figure 13: Change in saving rates across age between the initial steady-state and 2009. Model Predictions.



Notes: This figure plots the model-implied change in saving rate between the initial period to 2009. The three cases considered are the benchmark calibration, the “time-varying income profile” calibration, and the standard OLG model in which transfers and human capital accumulation are absent. Cohorts in the quantitative model are born every four years starting from 1940. Parameter values are provided in Table 10.

5.4 Human capital accumulation

The inclusion of human capital accumulation, absent in the standard lifecycle model, is critical. First, it can generate *endogenously* a portion of the flattening of the income profile observed in the data (see Fig. 9). Thus, rather than relying on the assumption that growth was entirely biased towards the young cohorts as is typically done,[50] we show that it is a byproduct of the one child policy: the quantity-quality trade-off generates higher levels of human capital for the younger generations. Quantitatively, the level of human capital of an only child is 45% higher than the level of their parents (with two siblings). This translates to a wage increase of 14% of the recent generation of only childs

[50]See Song and Yang (2010) and Chamon and Prasad (2010).

(born after 1980) compared to their parents. The distribution of income across age groups therefore changes and thus in turn impact aggregate saving (the income composition channel). It is important to mention that this effect will only increase in magnitude in the coming years when this generation of at-most 30 year olds in 2009-2010 exerts a greater impact in the economy–in terms of their higher income and saving. Finally, an additional prediction is that the share of education expenditure spent on each child rises as a consequence of the policy—a prediction confirmed later in the data.

5.5 Identifying the Micro-Channel through 'Twins'

Lastly, we examine the simulated results for individuals giving birth to twins at a date $t > t_0$, under the binding constraint that $n_{max} = 2$. Even though education expenditures are calibrated to those of an only child in the data, our predicted expenditures for discretionary education expenditures for twins are extremely close to the data. We also show that the predicted differences in saving rates between a twin-household and an only-child-household match well with empirical estimates shown in Section 4.

Table 12 reports the saving rate at various ages for an individual with twins under the benchmark calibration, and contrasts it with that of an individual with an only child. The predicted saving rate at $\gamma = 4$ and $\gamma = 5$ are respectively 7.0% and 8.8% lower in households with twins than in households with an only child in 2009. These predictions are close to the estimates on twins found in the data and shown in Section 4. When examining expenditure differences (as a share of total expenditures), we observe that households with twins have 6.5% (resp. 8.4%) higher expenditures devoted to children at age $\gamma = 4$ (resp. $\gamma = 5$)— again a similar order of magnitude to what is found in the data in Section 4. In terms of non-compulsory education, parents of twins tend to reduce their children's quality as compared to their counterparts with an only child— by about 3.7% in education spending per child (for children above 15, $\gamma = 5$)—again broadly in line with our later empirical estimates. As a consequence, our calibrated model suggests a 21% difference in human capital attainment between a twin and an only child.

6 Conclusion

We show in this paper that exogenous fertility restrictions in China may have lead to a rise in household saving rate—by altering saving decisions at the household level, and demographic and income compositions at the aggregate level. We explore the quantitative implications of these channels in a simple model linking fertility and saving through intergenerational transfers that depend on the quantity and quality of offspring. Predictions on the age- saving profile become richer and more subtle than that of the standard lifecycle model—where both human capital investment and intergenerational transfers are absent. We show that where our quantitative framework can generate both a micro and macro effect on saving that is close to the data, the standard OLG model falls short on both fronts.

From our empirical estimates based on identification through households with twins, we find that the 'one-child policy' can account for about 35-45 percent of the rise in the aggregate household saving rate since its enforcement in 1980. We show how one can decompose the overall effect to the contributions of various channels and find that the micro channel accounts for the majority of the

Table 12: Twin Experiment: Quantitative Predictions

	Model			Data
Saving rate	Only child	Twins	Difference	Difference
$\gamma = 4$ (30–40)	21.3%	14.3%	7.0%	$5.74 - 6.6\%$
$\gamma = 5$ (40–50)	36.2%	27.4%	8.8%	
Expenditures				
(% total exp.)				
$\gamma = 4$ (30–40)	7.8%	14.3%	6.5%	$6.06\% - 7.02\%$
$\gamma = 5$ (40–50)	15.9%	24.3%	8.4%	
Education expenditures per child				
(% total exp.)				
$\gamma = 5$ (40–50)	16.0%	12.3%	−3.7%	−3.13%
Human capital	Only child	Twins	% Difference	
$(h_{2009} - h_{ss})/h_{ss}$	45%	15%	$\left(\frac{h_{only}-h_{twin}}{h_{only}}\right) = 21\%$	

Notes: This table compares the saving rate, expenditures devoted to children and children's human capital attainment for households with twins and those with an only child in 2009, under the benchmark calibration, and in the data (where relevant). Education (and 'mouth to feed') expenditures (% total exp.) are $(\phi_4 n)/(c_{4,2009} + \phi_4 n)$ at age $\gamma = 4$, $\frac{(\phi_5 n + \phi_h n h_{2009})}{(c_{5,2009} + \phi_5 n + \phi_h n h_{2009})}$ at age $\gamma = 5$. Education expenditures per child (% total exp.) are $\frac{\phi_5 + \phi_h h_{2009}}{(c_{5,2009} + \phi_5 n + \phi_h n h_{2009})}$ at age $\gamma = 5$.

effect. This contrasts with the standard lifecycle hypothesis which conventionally focuses only on the macro channel of shifting demographic compositions. We link these empirical estimates to our quantitative predictions and find that the model fares well both on its micro-level and macro-level predictions.

This paper demonstrates that shifts in demographics as understood through the lens of a lifecycle model remains to be a powerful factor in accounting for the high and rising national saving rate in China—when augmented with important features capturing the realities of its households, and particularly when buttressed by compatible micro-level evidence. The tacit implication—on a broader scale—is that the one-child policy provides a natural experiment for understanding the link between fertility and saving behavior in any developing economies. The quantitative impact on the policy is still evolving as the generation of more-educated only childs grow older and exert a greater impact on the economy —both in human capital and demographic weight. We may therefore well expect a greater impact of the policy on aggregate saving in years to come.

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A Theory

Proof of Proposition 1

Proof of uniquess:

If $\{n_{ss}; h_{ss}\}$ exists, then it must satisfy the steady-state system of equations:

$$\begin{aligned}\frac{n_{ss}}{1-\theta-\psi\frac{n_{ss}^{\varpi-1}}{\varpi}} &= \left(\frac{v}{\beta(1+\beta)+v}\right)\left(\frac{1}{\phi_0+\phi_h\left(1-\frac{\omega}{\alpha}\right)h_{ss}}\right)\\ h_{ss} &= \left(\frac{\alpha\psi\left(1+g_z\right)}{\phi_h R}\right)\frac{n_{ss}^{\varpi-1}}{\varpi},\end{aligned}$$

which, combined, yields:

$$\frac{n_{ss}}{1-\theta-\psi\frac{n_{ss}^{\varpi-1}}{\varpi}} = \left(\frac{v}{\beta(1+\beta)+v}\right)\left(\frac{1}{\phi_0+\left(\frac{\alpha}{\omega}-1\right)\left(\frac{\psi(1+g_z)}{R}\right)n_{ss}^{\varpi-1}}\right).$$

Let $N_{ss} = n_{ss}^{\varpi-1}$, and rewriting the above equation yields

$$N_{ss}^{-1/(1-\omega)} - \left(\frac{v}{\beta(1+\beta)+v}\right)\left(\frac{1-\theta-\frac{\psi}{\omega}N_{ss}}{\phi_0+(\alpha-\omega)\frac{(1+g_z)}{R}\frac{\psi}{\omega}N_{ss}}\right) = 0$$

Define the function $G(x) = x^{-1/(1-\omega)} - \left(\frac{v}{\beta(1+\beta)+v}\right)\left(\frac{1-\theta-\frac{\psi}{\omega}x}{\phi_0+(\alpha-\omega)\frac{(1+g_z)}{R}\frac{\psi}{\omega}x}\right)$ for $x > 0$. Then,

$$\lim_{x\to+\infty} G(x) = \left(\frac{v}{\beta(1+\beta)+v}\right)\frac{\psi/\omega}{\left(\frac{\alpha}{\omega}-1\right)\left(\frac{\psi(1+g_z)}{R}\right)} < 0$$

if $\varpi > \alpha$ and

$$\lim_{x\to 0^+} G(x) = +\infty$$

We know that

$$G'(x) = -\frac{x^{-\omega/(1-\omega)}}{1-\omega} + \frac{v\psi/\omega}{\beta(1+\beta)+v}\frac{\phi_0-(\omega-\alpha)\frac{(1+g_z)}{R}}{\left(\phi_0+\left(\frac{\alpha}{\omega}-1\right)\frac{(1+g_z)}{R}\psi x\right)^2}.$$

Two cases are:

- Case (1): if $\phi_0 - \left(1-\frac{\alpha}{\omega}\right)\frac{(1+g_z)}{R} \leq 0$ then $G(x)$ is monotonically decreasing over $[0; +\infty]$.
- Case (2): $G(x)$ is first decreasing— to a minimum value $x_{\text{min}} > 0$ such that $\frac{x_{\text{min}}^{-\omega/(1-\omega)}}{1-\omega} = \frac{(\omega-\alpha)\frac{(1+g_z)}{R}-\phi_0}{\left(\phi_0+\left(\frac{\alpha}{\omega}-1\right)\frac{(1+g_z)}{R}\psi x_{\text{min}}\right)^2}$ and where $G(x_{\text{min}}) < 0$—and then increasing for $x > x_{\text{min}}$.

In both cases, the intermediate value theorem applies, and there is a unique $N_{ss} > 0$ such that $G(N_{ss}) = 0$—-thus pinning down a unique $\{n_{ss}; h_{ss}\}$ such that both are greater than 0. Moreover, if we define a unique n_0 implictly by

$$\frac{n_0}{1-\theta-\psi\frac{n_0^{\varpi-1}}{\varpi}} = \left(\frac{v}{\beta(1+\beta)+v}\right)\left(\frac{1}{\phi_0}\right),$$

then it immediately follows that $n \geq n_0$ if $\varpi \geq \alpha$.

Proof of Lemma 2: Define aggregate labour income in the economy to be the sum of income of the young and middle-aged workers $Y_{t+1} = (1 + n_t e) N_{m,t+1} w_{m,t+1}$. Population evolves according to $N_{m,t+1} = N_{y,t} = n_{t-1} N_{o,t+1}$, and analogously, $N_{y,t+1} = n_t N_{y,t} = n_t N_{m,t+1}$. Cohort-level saving at date $t+1$ are respectively:

$$\begin{aligned}
S_{y,t+1} &\equiv N_{y,t+1} a_{y,t+1} = -\theta n_t N^m_{t+1} \frac{w_{m,t+2}}{R} \\
S_{m,t+1} &\equiv N_{m,t+1} \left(a_{m,t+1} - a_{y,t} \right) \\
&= N_{m,t+1} \left[\frac{\beta w_{m,t+1}}{1+\beta} \left(1 - \theta - n_t \phi(h_{t+1}) - \frac{\psi n_{t-1}^{\varpi-1}}{\varpi} \right) - \frac{w_{m,t+2}}{R(1+\beta)} \frac{\psi n_t^{\varpi}}{\varpi} + \theta \frac{w_{m,t+1}}{R} \right] \qquad (24) \\
S_{o,t+1} &\equiv -N^o_{t+1} a_{m,t-1} = -\frac{N_{m,t+1}}{n_{t-1}} \left[\frac{\beta w_{m,t}}{1+\beta} \left(1 - \theta - n_{t-1} \phi(h_t) - \frac{\psi n_{t-2}^{\varpi-1}}{\varpi} \right) - \frac{w_{m,t+1}}{R(1+\beta)} \frac{\psi n_{t-1}^{\varpi}}{\varpi} \right]
\end{aligned}$$

Let $S_{t+1} = \sum_\gamma S_{\gamma,t+1}$ (where $\gamma \in \{y, m, o\}$) be aggregate saving at $t+1$, denoted, then the aggregate saving rate $s_{t+1} = S_{t+1}/Y_{t+1}$ can be written as

$$s_{t+1} = \frac{1}{(1+en_t)} \left[\begin{array}{c} -\frac{\theta}{R} n_t \left(\frac{w_{m,t+2}}{w_{m,t+1}} \right) + \frac{\beta}{1+\beta} \left(1 - \theta - n_t \phi(h_{t+1}) - \frac{\psi n_{t-1}^{\varpi-1}}{\varpi} \right) - \frac{\psi}{R(1+\beta)} \frac{n_t^{\varpi}}{\varpi} \left(\frac{w_{m,t+2}}{w_{m,t+1}} \right) + \frac{\theta}{R} \\ -\frac{1}{(1+\beta) n_{t-1}} \left(\frac{\beta}{1+g_z} \left(1 - \theta - n_{t-1} \phi(h_t) - \frac{\psi n_{t-2}^{\varpi-1}}{\varpi} \right) - \frac{\psi}{R} \frac{n_{t-1}^{\varpi}}{\varpi} \right) \end{array} \right] . \qquad (25)$$

The aggregate saving rate in t_0+1, after the policy implemented in t_0, is obtained by replacing $t+1$ by t_0+1 in Eq. 25 and n_t by n_{max}. Using the optimal relationship between fertility and human capital along the transition path: $\phi_h n_{\max} h_{t_0+1} = \left(\frac{\alpha\psi}{R} (1+g_z) \left(\frac{h_{t_0+1}}{h_{t_0}} \right)^{\alpha} \right) \frac{n_{\max}^{\varpi}}{\varpi} = \left(\frac{\alpha\psi}{R} \right) \frac{n_{\max}^{\varpi}}{\varpi} \left(\frac{w_{m,t+2}}{w_{m,t+1}} \right)$, we have

$$s_{t_0+1} = \frac{1}{(1+n_{\max} e)} \left[\begin{array}{c} \frac{\theta}{R} \left(1 - n_{\max} \frac{w_{m,t+2}}{w_{m,t+1}} \right) + \frac{\beta}{1+\beta} (1-\theta) \left(1 - \frac{1}{n_{t_0-1}(1+g_z)} \right) \\ -\frac{\psi}{R(1+\beta)} \frac{n_{\max}^{\varpi}}{\varpi} \left(\frac{w_{m,t+2}}{w_{m,t+1}} \right) (1+\beta\alpha) - \frac{\beta}{1+\beta} \phi_0 \left(n_{\max} - \frac{1}{1+g_z} \right) \\ -\frac{1}{n_{t_0-1}} \frac{\psi}{R(1+\beta)} \frac{n_{t_0-1}^{\varpi}}{\varpi} (1+\beta\alpha) - \frac{\psi\beta}{1+\beta} \left(\frac{n_{t_0-1}^{\varpi-1}}{\varpi} - \frac{1}{n_{t_0-1}(1+g_z)} \frac{n_{t_0-2}^{\varpi-1}}{\varpi} \right) \end{array} \right]$$

The aggregate saving rate s_t in the initial period $t = t_0$ is the steady-state equivalent of the above equation. In order to find the difference $s_{t_0+1} - s_{t_0}$ we first obtain, with some algebraic manipulation:

$$\begin{aligned}
s_{t_0+1} &- \left(1 + \frac{(n_{t_0-1} - n_{\max}) e}{1 + n_{\max} e} \right) s_{t_0} \\
&= \frac{1}{1+n_{\max} e} \left[\begin{array}{c} -\frac{\theta}{R} \left(n_{\max} \left(\frac{w_{m,t+2}}{w_{m,t+1}} \right) - n_{t_0-1} (1+g_z) \right) \\ -\frac{(1+\beta\alpha)}{R(1+\beta)} \frac{\psi}{\varpi} \left(n_{\max}^{\varpi} \left(\frac{w_{m,t+2}}{w_{m,t+1}} \right) - (1+g_z) n_{t_0-1}^{\varpi} \right) - \frac{\beta}{1+\beta} \phi_0 \left(n_{\max} - n_{t_0-1} \right) \end{array} \right] \\
&= \frac{1}{1+n_{\max} e} \left[\begin{array}{c} -\frac{\theta}{R} (1+g_z) \left(n_{\max} \left(\frac{h_{t_0+1}}{h_{t_0}} \right)^{\alpha} - n_{t_0-1} \right) \\ -\frac{(1+\beta\alpha)}{R(1+\beta)} \frac{\psi}{\varpi} (1+g_z) \left(n_{\max}^{\varpi} \left(\frac{h_{t_0+1}}{h_{t_0}} \right)^{\alpha} - n_{t_0-1}^{\varpi} \right) - \frac{\beta}{1+\beta} \phi_0 \left(n_{\max} - n_{t_0-1} \right) \end{array} \right].
\end{aligned}$$

Rearranging,

$$
\begin{aligned}
s_{t_0+1}-s_{t_0} &= \frac{(n_{t_0-1}-n_{\max})\,e}{1+n_{\max}e}s_{t_0}+\frac{1}{1+n_{\max}e}\frac{\theta\,(1+g_z)}{R}\left(n_{t_0-1}-n_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha}\right)\\
&+ \frac{\beta}{(1+\beta)(1+n_{\max}e)}\left[\phi_0\,(n_{t_0-1}-n_{\max})+\frac{(1+\beta\alpha)}{R\beta}\frac{\psi\,(1+g_z)}{\varpi}\left(n^{\omega}_{t_0-1}-n^{\omega}_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha}\right)\right].
\end{aligned}
$$

To prove that $s_{t_0+1}-s_{t_0}>0$, we first use Eq. 9 to determine the human capital level in periods t_0 (in steady-state) and t_0+1:

$$
\begin{aligned}
h_{t_0} &= \left(\frac{\alpha\psi}{\phi_h R}(1+g_z)\right)\frac{(n_{t_0-1})^{\varpi-1}}{\varpi}\\
(h_{t_0+1})^{1-\alpha}h^{\alpha}_{t_0} &= \left(\frac{\alpha\psi}{\phi_h R}(1+g_z)\right)\frac{(n_{\max})^{\varpi-1}}{\varpi}\\
\Rightarrow\left(\frac{h_{t_0+1}}{h_{t_0}}\right) &= \left(\frac{n_{t_0-1}}{n_{\max}}\right)^{\frac{1-\omega}{1-\alpha}}
\end{aligned}
\tag{26}
$$

This implies that if $n_{t_0-1}>n_{\max}$, then

$$
\begin{aligned}
n_{t_0-1}-n_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha} &= n_{t_0-1}\left(1-\left(\frac{n_{\max}}{n_{t_0-1}}\right)^{1-\frac{\alpha(1-\omega)}{1-\alpha}}\right)>0\\
n^{\omega}_{t_0-1}-n^{\omega}_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha} &= n^{\omega}_{t_0-1}\left(1-\left(\frac{n_{\max}}{n_{t_0-1}}\right)^{\frac{\omega-\alpha}{1-\alpha}}\right)>0
\end{aligned}
$$

if $\omega>1/2>\alpha$.

Proof of Lemma 3

The saving rate for a middle-aged agent in period $t+1$ is $s_{m,t+1}\equiv(a_{m,t+1}-a_{y,t})/w_{m,t+1}$. By Eq. 25, we have

$$
s_{m,t_0+1}-s^{twin}_{m,t_0+1}=\frac{\beta}{1+\beta}\left[\phi_0 n_{\max}+\frac{(1+\alpha\beta)}{R\beta}\frac{\psi(1+g_z)}{\varpi}n^{\varpi}_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha}\left(2^{\frac{\varpi-\alpha}{1-\alpha}}-1\right)\right].
$$

The micro-channel on aggregate saving of moving from $n_{t_0-1}=2n_{max}$ to n_{max} in t_0 is,

$$
\begin{aligned}
\Delta s(2n_{\max}) &= \frac{\beta}{1+\beta}\left[\phi_0 n_{\max}+\frac{(1+\beta\alpha)}{R\beta}\frac{\psi(1+g_z)}{\varpi}n^{\omega}_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha}\left(2^{\omega}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{-\alpha}-1\right)\right.\\
&= \frac{\beta}{1+\beta}\left[\phi_0 n_{\max}+\frac{(1+\beta\alpha)}{R\beta}\frac{\psi(1+g_z)}{\varpi}n^{\omega}_{\max}\left(\frac{h_{t_0+1}}{h_{t_0}}\right)^{\alpha}\left(2^{\frac{\varpi-\alpha}{1-\alpha}}-1\right)\right]\\
&= s_{m,t_0+1}-s^{twin}_{m,t_0+1},
\end{aligned}
$$

using Eq. 26.

Derivation of Fertility and Human Capital Relationships in the Quantitative Model. The first order condition with respect to n_t is:

$$\frac{v}{n_t} + \beta^4 \frac{\psi n_t^{\varpi-1} w_{5,t+4}}{c_{7,t+4}} + \beta^5 \frac{\psi n_t^{\varpi-1} w_{6,t+5}}{c_{8,t+5}} = \beta \frac{\phi_4 w_{4,t+1}}{c_{4,t+1}} + \beta^2 \frac{(\phi_5 + \phi_h h_{t+1}) w_{5,t+1}}{c_{5,t+1}},$$

which, using the Euler equation Eq.21, yields

$$\left(\frac{c_{8,t+5}}{w_{4,t+1}}\right) \frac{v}{\beta^5 n_t} = R^3 \left[R\phi_4 + (\phi_5 + \phi_h h_{t+1})(1+g_z)\right] - \left[R + (1+g_z)\right] \psi n_t^{\varpi-1} (1+g_z)^3 \left(\frac{h_{t+1}}{h_t}\right)^{\alpha}. \quad (27)$$

The first-order condition with respect to h_t is:

$$\begin{aligned}
\beta^2 \psi \frac{n_t^{\varpi}}{\varpi} \left[\frac{\beta}{c_{8,t+5}} \frac{\partial w_{6,t+5}}{\partial h_{t+1}} + \frac{1}{c_{7,t+4}} \frac{\partial w_{5,t+4}}{\partial h_{t+1}}\right] &= n_t \phi_h \left(\frac{w_{5,t+2}}{c_{5,t+2}}\right) \\
\beta^2 \psi \frac{n_t^{\varpi}}{\varpi} \alpha h_{t+1}^{\alpha-1} z_{t+4} \left[\beta^{-2} R^{-3} (1+g_z) + (\beta R)^{-2}\right] &= n_t \phi_h z_{t+2} h_t^{\alpha} \\
h_t^{\alpha} h_{t+1}^{1-\alpha} &= \left(\frac{\psi \alpha}{\varpi} \frac{(1+g_z)^2}{R^2 \phi_h}\right) n_t^{\varpi-1}
\end{aligned}$$

or

$$\psi (1+g_z)^2 n_t^{\varpi-1} \left(\frac{h_{t+1}}{h_t}\right)^{\alpha} = \frac{\varpi}{\alpha} R^2 \phi_h h_{t+1}.$$

Plugging the above expression into Eq. (27), and using the Euler equation, we have:

$$\begin{aligned}
\left(\frac{c_{8,t+5}}{w_{4,t+1}}\right) \frac{v}{R^3 \beta^5 n_t} &= \left[R\phi_4 + (\phi_5 + \phi_h h_{t+1})(1+g_z)\right] - \left[R + (1+g_z)\right] \frac{(1+g_z)}{R} \frac{\varpi}{\alpha} \phi_h h_{t+1} \\
\left(\frac{c_{4,t+1}}{w_{4,t+1}}\right) \frac{Rv}{(1+g_z)\beta n_t} &= \frac{\phi_4 R}{1+g_z} + \phi_5 + \phi_h h_{t+1} \left[1 - \frac{\varpi}{\alpha}\left(1 + \frac{1+g_z}{R}\right)\right] \\
\frac{c_{4,t+1}}{w_{4,t+1}} &= \frac{(1+g_z)\beta}{Rv} \left[\left(\frac{\phi_4 R}{1+g_z} + \phi_5\right) n_t + \phi_h n_t h_{t+1} \left(1 - \frac{\varpi}{\alpha}\left(1 + \frac{1+g_z}{R}\right)\right)\right].
\end{aligned}$$

Plugging this into the intertemporal budget constraint Eq. (20):

$$
\begin{aligned}
\left(\sum_{\gamma=4}^{8}\beta^{\gamma-4}\right)\left(\frac{c_{4,t+1}}{w_{4,t+1}}\right) &= \sum_{\gamma=4}^{8}\frac{w_{\gamma,t+\gamma-3}/w_{4,t+1}+T_{\gamma,t+\gamma-3}/w_{4,t+1}}{R^{\gamma-4}}-\theta \\
&= (1-\theta-\phi_4 n_t)-(\phi_5+\phi_h h_{t+1})\frac{(1+g_z)n_t}{R}-\psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\frac{(1+g_z)}{R}\left(1+\frac{(1+g_z)}{R}\right) \\
&\quad +\sum_{\gamma=1}^{2}\frac{(1+g_z)^{\gamma}}{R^{\gamma}}+\sum_{\gamma=7}^{8}\frac{\psi\frac{n_t^{\varpi}}{\varpi}w_{\gamma-2,t+\gamma-3}/w_{4,t+1}}{R^{\gamma-4}} \\
&= (1-\theta-\phi_4 n_t)-(\phi_5+\phi_h h_{t+1})\frac{(1+g_z)n_t}{R}-\psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\frac{(1+g_z)}{R}\left(1+\frac{(1+g_z)}{R}\right) \\
&\quad +\sum_{\gamma=1}^{2}\frac{(1+g_z)^{\gamma}}{R^{\gamma}}+\psi\frac{n_t^{\varpi}}{\varpi}\left(\frac{h_{t+1}}{h_t}\right)^{\alpha}\left(\frac{1+g_z}{R}\right)^{3}\left(1+\frac{(1+g_z)}{R}\right) \\
&= 1-\theta-\phi_4 n_t-(\phi_5+\phi_h h_{t+1})\frac{(1+g_z)n_t}{R}-\psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\frac{(1+g_z)}{R}\left(1+\frac{(1+g_z)}{R}\right) \\
&\quad +\sum_{\gamma=1}^{2}\frac{(1+g_z)^{\gamma}}{R^{\gamma}}+\frac{\varpi}{\alpha}\phi_h n_t h_{t+1}\left(\frac{1+g_z}{R}\right)\left(1+\frac{1+g_z}{R}\right)
\end{aligned}
$$

Denoting $\Pi(\beta,v)\equiv\beta\left(\sum_{\gamma=4}^{8}\beta^{\gamma-4}\right)/v$, we have

$$
\begin{aligned}
&\frac{R(1-\theta)}{1+g_z}+\left(1+\frac{1+g_z}{R}\right)-\left(\frac{\phi_4 R}{1+g_z}+\phi_5\right)n_t-\frac{\psi n_{t-1}^{\varpi-1}}{\varpi}\left(1+\frac{1+g_z}{R}\right)+\phi_h n_t h_{t+1}\left[1-\frac{\varpi}{\alpha}\left(1+\frac{1+g_z}{R}\right)\right] \\
&= \Pi(\beta,v)\left[\left(\frac{\phi_4 R}{1+g_z}+\phi_5\right)n_t+\phi_h n_t h_{t+1}\left(1-\frac{\varpi}{\alpha}\left(1+\frac{1+g_z}{R}\right)\right)\right],
\end{aligned}
$$

or,

$$
\frac{R(1-\theta)}{1+g_z}+\left(1+\frac{1+g_z}{R}\right)-\frac{{}^{\varpi-1}_{t-1}}{\varpi}\left(1+\frac{1+g_z}{R}\right)=(1+\Pi(\beta,v))\,n_t\left[\left(\frac{\phi_4 R}{1+g_z}+\phi_5\right)+\phi_h h_{t+1}\left(1-\frac{\varpi}{\alpha}\left(1+\frac{1+g_z}{R}\right)\right)\right.
$$

$$
\mathrm{n}_t=\frac{(1-\theta)+\left(\frac{1+g_z}{R}+\left(\frac{1+g_z}{R}\right)^2\right)-\psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\left(\frac{(1+g_z)}{R}+\left(\frac{1+g_z}{R}\right)^2\right)}{(1+\Pi(\beta,v))\left[\left(\phi_4+\phi_5\frac{1+g_z}{R}\right)+\frac{(1+g_z)}{R}\phi_h h_{t+1}\left(1-\frac{\varpi}{\alpha}\left(1+\frac{1+g_z}{R}\right)\right)\right]}
$$

Letting $\phi_0=\left(\phi_4+\phi_5\frac{(1+g_z)}{R}\right)=\phi_4+\mu\phi_5$, where $\mu\equiv\frac{(1+g_z)}{R}$, we obtain Eq. 22 and 23:

$$
\begin{aligned}
n_t &= \left(\frac{1}{1+\Pi(\beta,v)}\right)\frac{(1-\theta)+\mu(1+\mu)-\psi\frac{n_{t-1}^{\varpi-1}}{\varpi}\mu(1+\mu)}{\phi_0+\mu\phi_h h_{t+1}\left(1-\frac{\varpi}{\alpha}(1+\mu)\right)} \\
h_t^{\alpha}h_{t+1}^{1-\alpha} &= \left(\frac{\psi\alpha}{\varpi}\frac{\mu^2}{\phi_h}\right)n_t^{\varpi-1}.
\end{aligned}
$$

Steady-State Properties. If $(1+\mu)\varpi\geq\alpha$, there exists a unique steady-state $\{n_{ss};h_{ss}\}$— characterized by $n_{ss}>\left(\frac{1}{1+\Pi(\beta,v)}\right)\left(\frac{(1-\theta)+\mu(1+\mu)}{\phi_0}\right)$ and $h_{ss}>0$— to which the dynamic model defined by Eq. (22) and (23) converges. The modified (NN) and (QQ) curves, describing the steady-state choice of fertility, given human capital accumulation and the quantity-quality trade-off, become:

$$\frac{n_{ss}}{(1-\theta)+\mu(1+\mu)-\psi\frac{n_{ss}^{\varpi-1}}{\varpi}\mu(1+\mu)} = \left(\frac{1/(1+\Pi(\beta,v))}{\phi_0+\mu\phi_h h_{t+1}\left(1-\frac{\varpi}{\alpha}\left(1+\mu\right)\right)}\right) \qquad (NN)$$

$$h_{ss} = \left(\frac{\psi\alpha}{\varpi}\frac{\mu^2}{\phi_h}\right)n_{ss}^{\varpi-1}, \qquad (QQ)$$

where the (NN) and (QQ) curves and the associated comparative statics are analogous to those in the simple four-period model.

B Data

Common Definitions.:

Nuclear household: a household with two parents (head of household and spouse) and either a singleton or twins.

Individual disposable income: annual total income net of tax payments: including salary, private business and property income, as well as private and public transfers income.

Household disposable income: sum of the individual disposable income of all the individuals living in the household.

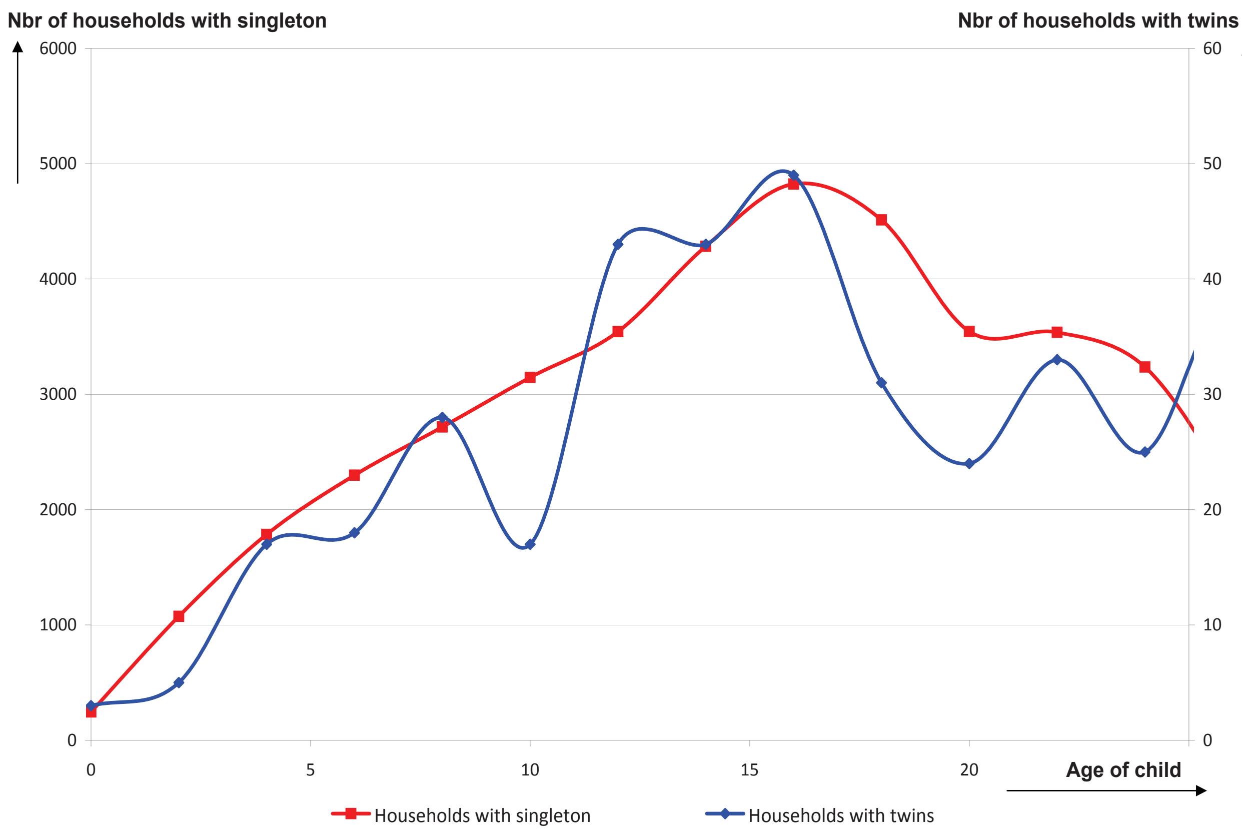
Household consumption expenditures: the sum of consumption expenditures in the household, including food, clothing, health, transportation and communication, education, housing (ie. rent or estimated rent of owned house), and miscellaneous goods and services. Education transfers to children living in another city are available only for UHS 2002 to 2009. Our definition of consumption expenditure does not include interest and loan repayments, transfers and social security spending, nor expenditures related to housing.

Individual consumption expenditures: individual expenditures are not directly observable. The estimation strategy explicated in Appendix B.2 gives age-specific individual expenditures from household aggregates.

Household saving rate: household disposable income less household expenditures as a share of household disposable income.

Individual savings rate: individual disposable income less individual expenditure as a share of disposable income.

Figure 14: Number of observations for twins/singleton nuclear households (2002-2006 average).



Notes: UHS (2002-2006).

B.1 Data Sources and Description

1. Urban Household Survey (UHS)

We use annual data from the Urban Household Survey (UHS), conducted by the National Bureau of Statistics, for 1986 and 1992 to 2009. Households are expected to stay in the survey for 3 years and are chosen randomly based on several stratifications at the provincial, city, county, township, and neighborhood levels. Both income and expenditures data are reported to be collected based on daily records of all items purchased and income received for each day during a full year. No country other than China uses such comprehensive 12-month expenditure records. Households are required by Chinese law to participate in the survey and to respond truthfully, and the Chinese survey privacy law protects illegal rural residents in urban locations (Gruber, 2012 ; Banerjee et al, 2010).

The 1986 survey covers 47,221 individuals in 12,185 households across 31 provinces. Hunan province observations in 1986 are treated as outliers and excluded because of the excessive share of twins households (46 out of 356). For the 1992 to 2009 surveys the sample covers 112 prefectures across 9 representative provinces (Beijing, Liaoning, Zhejiang, Anhui, Hubei, Guangdong, Sichuan, Shaanxi and Gansu). The coverage has been extended over time from roughly 5,500 households in the 1992 to 2001 surveys to nearly 16,000 households in the 2002 to 2009 surveys.

We generally limit the sample of households to those with children of 18 and below (or 21 and below) because older children who still remain in their parents' household most likely are income earners and make independent decisions on consumption (rather than being made by their parents). Children who have departed from their parents' household are no longer observed. As less than 0.5% of surveyed individuals aged 18 to 21 years old are living in uni-generational household (i.e. children studying in another city are still recorded as members of their parents' household), we believe that potential selection biases are rather limited.

Definitions:
Young dependents: all individuals aged below 18 years of age as well as those aged 18 to 25 who are still full-time students. We assume that those individuals, being financially dependent, do not make their own saving and investment decisions.
Twins: we identify a pair of twins as two children under the same household head who are born in the same year, and when available, in the same month. When comparing twins identified using year of birth data as opposed to using both year and month of birth data (available for 2007 to 2009), only 8 households out of 206 with children below 18 years were misidentified as having twins and only 1 nuclear household out of 154 was misidentified. Overall, twins household make up for roughly 1% of all households with young children, which is consistent with the biological rate of twins occurrence.

In Table 7 the following definitions apply:
Higher education: dummy is equal to one if the child has reached post-secondary education.
Academic high school: dummy is equal to one if the child's highest level of education is either an academic high school or an undergraduate/postgraduate degree.
Technical high school: dummy is equal to one if the child's highest level of education is either a technical or vocational high school or a professional school (i.e. junior college).

2. Three cities survey
The Study of Family Life in Urban China, referred to as the "three cities survey", was conducted in three large cities (Shanghai, Wuhan, and Xi'an) in 1999. The survey comprise of two questionnaires: one for respondents younger than 61 years old and one for respondents aged 61 or above. In the current analysis, only data on the elderly sample is used—with 1,696 elderly respondents and information on 5,605 respondent children. The three cities survey provides information on financial transfers between the elderly respondent and each of his children, as well as basic income and demographic data on both the respondent and his children.

Definitions (Table 8):
Transfers: amount of financial help from an adult child to his parents.
Financial level: categorical variable with 4 groups ranging from "not enough" to "very well-off".
Education level: categorical variable with 8 groups ranging from "no formal education" to "graduate school graduate".

3. CHARLS
The China Health and Retirement Longitudinal Study (CHARLS) pilot survey was conducted in 2008 in two provinces—Zhejiang and Gansu. The main respondents are from a random sample of people over the age of 45, and their spouses. Detailed information are provided on their transfer

received/given to each of their children. The urban sample covers 670 households (of which 321 have at least one parent above 60 and at least one adult children above 25).

Definitions:
Gross transfers: sum of regular financial transfer, non-regular financial transfer and non-monetary transfer (i.e. the monetary value of gifts, in-kind etc.) from adult children to elderly parents. Of the 359 urban households in which transfers occurs between children and parents: regular monetary transfers represent 14% of the total value of transfer from children, non-regular monetary transfers represent 42%, and 44% takes in the form of non-monetary support.
Net transfers: gross transfers less the sum of all transfers from parents to children.

In Table 8:
Transfers: the sum of all financial and non-monetary transfers from an individual child to his elderly parents. We focus only on gross transfers because the Poisson estimation does not allow for negative values in the dependent variable. This restriction does not bias the results since negative net transfers between elderly parents and adult children occur in only 4% of the households in CHARLS.
Individual income: CHARLS 2008 does not provide data on children's individual income. Therefore, in order to approximate the share of transfers in children's income we need to use UHS (2008) income data. We compute the average individual income level by province, gender and education level (four groups) for each 3-year age group, in UHS. Then the incomes of these individuals with a certain set of characteristics are taken to be a proxies for the incomes of children with the same set of characteristics in CHARLS.
Education level: categorical variable with 10 groups ranging from "no formal education" to "PhD level".

4. RUMiCI
We use the China sample of the 2008 Rural-Urban Migration in China and Indonesia (RUMiCI) survey. The urban sample covers 4,998 households (of which 2,654 are nuclear households) across 19 cities in 10 provinces. RUMiCI provides data on all children born to the household head (as opposed to UHS where only children registered in the household are reported). Thus we can use RUMiCI as a robustness check on the saving and expenditures profiles, which are in line with those estimated from UHS data (Figure 3).

5. Census
The 1990 Chinese census surveyed 1% of the Chinese population across 31 provinces. The urban sample includes nearly 3 million individual observations. Figure 1 plots the number of surviving children associated with the responding head of household (or spouse) against the average birth cohort of children living in the household. For the calibration and counterfactual analysis we use the 1990 Census age distribution of urban individuals, assuming a zero mortality to compute the aggregate savings rate in different years.

B.2 Individual consumption estimation

The estimation procedure for age-saving profiles in China are explained in detail in the Technical Appendix of Coeurdacier et al. (2013). Here, we briefly describe the main methodology employed to disaggregate household consumption into individual consumption, and thereby estimate individual saving by age. Following the projection method of Chescher (1997), the following model is estimated on the cross-section of households for every year:

$$C_h = \exp(\boldsymbol{\gamma}.\boldsymbol{Z}_h)\left(\sum_{j=19}^{99} c_j N_{h,j}\right) + \epsilon_h,$$

where C_h is the aggregate consumption of household h, $N_{h,j}$ is the number of members of age j in household h, and $\boldsymbol{Z}_h$ denotes a set of household-specific controls. Following Chesher (1997), multiplicative separability is assumed to limit the number of degrees of freedom, and control variables enter in an exponential term. The control variables include:

- Household composition: number of children aged 0-10, number of children 10-18, number of adults, and depending on the specification, the number of old and young dependents. The coefficient associated with the number of children is positive, as children-related expenses are attributed to the parents.
- Household income group: households are grouped into income quintiles. The sign of the control variable (a discrete variable 1-5) is positive: individuals living in richer households consume more.

In the estimation, a roughness penalization term is introduced to guarantee smoothness of the estimated function $c_j = c(j)$. This term is of the form:

$$P = \kappa^2 \int \left[c''(j)\right]^2 dj,$$

where κ is a constant that controls the amount of smoothing (no smoothing when $\kappa = 0$ and forced linearity as $\kappa \to \infty$). The discretized version of P, given that j is an integer in $[19; 99]$, can be written $\kappa^2(\boldsymbol{J}\boldsymbol{c}_j)'(\boldsymbol{J}\boldsymbol{c}_j)$, where the matrix $\boldsymbol{J}$ is the 79×81 band matrix

$$\boldsymbol{J} = \begin{bmatrix} 1 & -2 & 1 & 0 & \dots & 0 & 0 & 0 \\ 0 & 1 & -2 & 1 & \dots & 0 & 0 & 0 \\ 0 & 0 & 1 & -2 & \dots & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \dots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \dots & -2 & 1 & 0 \\ 0 & 0 & 0 & 0 & \dots & 1 & -2 & 1 \end{bmatrix},$$

and $\boldsymbol{c}_j = [c_j]_{j=19,\dots,99}$ is an 81×1 vector. Pre-multiplying $\boldsymbol{c}_j$ by $\boldsymbol{J}$ produces a vector of second differences. We set $\kappa = 10$.

As a robustness check, we use the projection method to estimate individual income distributions by age from household income data, and then confront the estimated distributions to the actual ones—which we observe for the period 1992-2009. The estimated income distributions are very close to the observed ones.[51]

[51] For the year 1986, information on income is available only at the household level. For that year, we therefore use the projection method to estimate both individual income and individual consumption. The estimated age-saving profile for 1986 is then used to construct the average profile over the first three years of observations (1986, 1992, and 1993).