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Parental preferences, production technologies, and provision for progeny[☆]

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ABSTRACT

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This paper theoretically explores the implications of the recent developments in the study of human capital production technologies (Cunha and Heckman, 2007) in intrahousehold human capital investment in children (Becker and Tomes, 1976; Behrman et al., 1982). When credit constraints are not binding, parents adopt a reinforcing intrahousehold investment strategy. When credit constraints are binding, the trade-off between the degree of parental aversion to inequality and the degree of complementarity between pre-natal endowments and family investments determines the parental strategy. The observed investment pattern of reinforcement or compensation does not necessarily reveal the underlying preference or technological parameters. Finally, we discuss empirical methods that may separately identify the preference and technological parameters and discuss the econometric challenges associated with these methods. *Journal of Comparative Economics* **45** (2017) 261–270. Department of Public Finance, School of Economics, Wang Yanan Institute for Studies in Economics, MOE Key Laboratory of Econometrics, and Fujian Key Laboratory of Statistical Science, Xiamen University, Xiamen 361005, Fujian, China; Department of Economics, Faculty of Arts & Social Sciences, National University of Singapore, AS2 Level 6, 1 Arts Link, Singapore 117570, Singapore.

1. Introduction

Family is important in fostering children's human capital and affecting their later life-cycle outcomes (Heckman, 2008). But the role of intrahousehold resource allocation in affecting within-family inequality is less clear, although the importance

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of inequality within families has been noticed as early as Sheshinski and Weiss (1982).[1] The seminal work of Becker and Tomes (1976) theoretically pioneers the economic research on intrahousehold compensation and reinforcement of differences among children.[2] Assuming the cost of adding to quality is negatively related to the endowment, Becker and Tomes conjecture that parents take a reinforcement strategy by investing more (less) in the more (less) able child. Behrman et al. (1982) extend Becker and Tomes' research and develop a general preference model for analyzing parental allocations of resources among their children. They further empirically test a particular version of the preference model – the separable earning-bequest model – against a pure investment model. They find evidence supporting the preference model. Parents compensate for children's earning inequality by providing more (fewer) resources to the less (more) able. Since Becker and Tomes (1976) and Behrman et al. (1982), the intrahousehold compensation versus reinforcement investment strategy regarding children's human capital has been one of the core research topics in the field of household economics (Becker, 1991). As more and more household survey data sets have become available, numerous empirical studies have investigated the intrahousehold human capital investment strategies in the past three decades.

The economic literature, however, has not yet achieved a consensus on whether parents take a reinforcement or compensation strategy regarding child human capital investment. Whereas some studies have found evidence of reinforcement behavior (see, e.g., Behrman et al., 1994; Rosenzweig and Wolpin, 1988; Rosenzweig and Zhang, 2009), other studies have found empirical support for parents adopting a compensation strategy (see, e.g., Behrman et al., 1982; Pitt et al., 1990).[3]

This paper aims to interpret the empirical results of the traditional literature on intrahousehold human capital investments in children by drawing implications from the recent literature on human capital production technologies (Cunha and Heckman, 2007; Cunha et al., 2010). The literature on intrahousehold human capital investments may have one major limitation. On one hand, the literature emphasizes the role of parental preferences in the intrahousehold resource-allocation process. For example, Behrman et al. (1982) state that in their preference model, parental aversion to inequality in the distribution of their children's earnings plays a crucial role. Therefore, the authors use a constant elasticity of substitution (CES) utility function to characterize parental aversion to inequality. On the other hand, the role of production technology in intrahousehold human capital investment is minimized. For example, Becker and Tomes (1976), Behrman et al. (1982), and Pitt et al. (1990) use either a linear or Cobb–Douglas (CD) form of the human capital production function. In these cases, they interpret the observed intrahousehold compensation (reinforcement) investment behavior as the evidence of parental (non-) aversion to inequalities.

The recent literature on human capital formation finds technology is important in analyzing the human capital production process (Cunha and Heckman, 2007; Cunha et al., 2010). Estimation results show that a linear or CD form is inappropriate in capturing the human capital production process. The life-cycle human capital production technology in Cunha and Heckman (2007) and Cunha et al. (2010) features strong dynamic complementarity between the initial stock of skills before each period and the human capital investment during the period. Thus, the pre-natal endowment and post-natal investments are complementary inputs in the production of human capital.[4] However, this literature focuses on the production technology by assuming only one child in each household. Thus, it neglects the intrahousehold resource-allocation process among multiple siblings.[5]

This paper theoretically combines the two strands of literature for the first time. We show that three factors determine the intrahousehold human capital investment strategy: credit constraints, parental preferences, and human capital production technologies. When credit constraints are not binding, parents adopt a reinforcing intrahousehold investment strategy on their children as long as investments and endowments are complementary inputs in the child human capital production function, as found empirically in Cunha et al. (2010). When credit constraints are binding, the trade-off between the degree of parental aversion to inequality and the degree of complementarity between pre-natal endowments and family investments determines the parental strategy. Aversion to inequality leads parents to exercise a compensatory intrahousehold investment strategy, whereas the complementarity between investments and endowments in the human capital production function leads to a reinforcing strategy. Therefore, the observed pattern of reinforcement or compensation does not necessarily reveal the underlying preference or technological parameters. Finally, we propose some potential methods to separately identify the preference and production technological parameters in empirical analysis and discuss the econometric challenges associated with each method.

Understanding the preference and production technology parameters separately in determining intrahousehold human capital investment is important. First, separating the production technology parameters from parental preference parameters is necessary to understand the production technology in multiple-child families. The literature on production technol-

[1] Becker and Tomes (1976) conceptually discuss the implications of intrahousehold compensation versus reinforcement of differences among children in three other scenarios: (1) the evaluation of compensatory education policies, (2) biases in the estimates of return to education, and (3) biases in the estimates of the family background effect on child earnings. Griliches (1979) further statistically explores the implications of the intrahousehold investment strategy in using the sibling model to estimate the return to education.

[2] Becker and Tomes (1979),1986) pioneer the study on intrahousehold human capital, inequality, and intergenerational mobility. Please see a review of Becker's methodology in economic research and its application to the household economics in Heckman (2015).

[3] Griliches (1979) speculates that families act as income equalizers.

[4] The other important finding in the recent literature on skill formation technology is the multiple dimensionality of human capital, which implication in intrahousehold human capital investment is explored in Yi et al. (2015).

[5] A notable exception is Aizer and Cunha (2015).

ogy estimation assumes one child in each family. For example, Cunha et al. (2010) randomly choose one child per family when they estimate the skill-formation technology. Second, separating parental preference parameters from the production technology parameters is necessary to understand parental preferences. In his Nobel lecture, Becker (1993) states, "The interactions between husbands, wives, parents, and children are more likely to be motivated by love, obligation, guilt, and a sense of duty than by self-interest narrowly interpreted." Li et al. (2010) empirically show the effects of altruism, favoritism, and guilt on the allocation of family resources. Third, understanding the preference and production technology parameters separately may help us reconcile the conflicting empirical findings on the intrahousehold reinforcement versus compensation investment strategies. Thus, our study calls for cross-country comparative studies of household resource allocation and human capital production.

The remainder of the paper is organized as follows. Section 2 theoretically studies parental preferences, production technologies, and intrahousehold human capital investments. Section 3 discusses the empirical strategies. Section 4 concludes.

2. Parental preferences, production technologies, and intrahousehold human capital investments

2.1. Model setup

We study the intrahousehold human capital investment in children by parents who care about inter-sibling inequality. Each household has a utility function in the following form:

$$U = U(c_p, c_1, \ldots, c_n), \tag{1}$$

where c_p is the parents' own consumption, and c_τ is the consumption of child τ ($\tau = 1, \ldots, n$).[6] Child τ's consumption is determined by her earnings E_τ and the transfer Rb_τ from her parents[7]:

$$c_\tau = E_\tau + Rb_\tau, \tag{2}$$

where R is the interest rate in the capital market, and b_τ is the money parents save as the transfer for child τ. The transfer is nonnegative, so $b_\tau \geq 0$. The market wage w and the child's human capital h_τ determine her earnings. The latter is a function of her pre-natal endowments e_τ and the family's investment I_τ in her. The child's earning function is therefore written as

$$E_\tau = wh(e_\tau, I_\tau). \tag{3}$$

The recent study on the technology of skill formation empirically demonstrates that endowments and investments are complementary inputs in fostering children's human capital (Cunha et al., 2010). Hence, $h_{eI} > 0$.

Following Becker and Tomes (1976), we further assume the parental utility function has the separability property:

$$U_{c_i} \lesseqqgtr U_{c_j} \quad \text{if } c_i \gtreqqless c_j, \tag{4}$$

where $i, j = 1, \ldots, n$. This property states that parents are averse to inequality among their children.[8]

If parents are inequality neutral, the utility function (Eq. (1)) degenerates to[9]

$$U = U\left(c_p, \sum_\tau c_\tau\right). \tag{5}$$

It implies parents care only about the total consumption of their children, and that child consumptions are perfect substitutes for each other. That is, $U_{c_i} = U_{c_j}$ regardless of whether $c_i \geq c_j$ or $c_i \leq c_j$.

Finally, the household budget constraint is

$$\sum_\tau I_\tau + pc_p + \sum_\tau b_\tau = Y,$$

where p is the price for parental consumption. We normalize the price of human capital investment to be 1. Y is the family income, which we assume to be exogenous in the analysis.

2.2. The definition of parental investment strategies

Following Behrman et al. (1994), we define parental reinforcing and compensatory investment strategies.

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[6] Because this paper focuses on the resource-allocation process among children, following Becker and Tomes (1976), we assume the number of children to be exogenous.

[7] The transfer includes both bequests and inter vivos gifts.

[8] Other dimensions of parental preference, such as guilt, may also affect the intrahousehold resource-allocation process (Li et al., 2010). This paper focuses on parental aversion to inequality among their children.

[9] For simplicity, we assume the number of children is predetermined. Thus, the utility function can be interpreted as conditional on the number of children.

Definition 1. Parents adopt a reinforcing (compensatory) strategy in intrahousehold human capital investments if $\frac{\partial I_i}{\partial e_i} > 0$ and $\frac{\partial I_i}{\partial e_j} < 0$ ($\frac{\partial I_i}{\partial e_i} < 0$ and $\frac{\partial I_i}{\partial e_j} > 0$).

If parents adopt a compensatory strategy, they invest less in the better-endowed child and more in the other child. Therefore, under this strategy, family investments reduce the within-family inequality in the children's pre-natal endowments. To deal with cross-household heterogeneity, the empirical analysis based on sibling or twin data in the literature has focused on the estimation of $\frac{\partial I_i}{\partial e_i} - \frac{\partial I_i}{\partial e_j}$ (Rosenzweig and Zhang, 2009). So, under a compensatory (reinforcing) strategy, $\frac{\partial I_i}{\partial e_i} - \frac{\partial I_i}{\partial e_j} < 0$ ($\frac{\partial I_i}{\partial e_i} - \frac{\partial I_i}{\partial e_j} > 0$).

The definition of reinforcing or compensatory strategy does not presume any specific model on intrahousehold resource allocation. The parameters determining whether parents adopt a reinforcing or compensatory strategy, however, depend on the specific model employed. Specifically, the parental investment strategy depends on household credit constraints, parental preferences, and human capital production technologies. We show that when credit constraints are not binding, the human capital production technology uniquely determines parental strategy. When credit constraints are binding, the trade-off between the degree of parental aversion to inequality and the degree of complementarity between pre-natal endowments and family investments determines the parental strategy.

2.3. Intrahousehold human capital investment when credit constraints are not binding

We first consider a scenario in which credit constraints are not binding, such that $b_\tau > 0$. The intrahousehold human capital investment is determined by the equilibrium condition that the marginal benefit of human capital investment is equal to the marginal cost,

$$wh_{I_\tau} = R. \tag{6}$$

The left-hand side is the marginal benefit from one unit of investment in child τ. The right-hand side is the marginal cost, which is equal to the interest rate in the capital market. Eq. (6) implies the intrahousehold human capital investment in children is independent of parental preferences.

Meanwhile, in equilibrium the marginal transfer will generate the same utility for different children:

$$U_{c_i} = U_{c_j}, \tag{7}$$

where $i, j = 1, ..., n$. When parents are averse to inequality among children, we can get $c_i = c_j$. Here, parents maximize efficiency when they make decisions about children's human capital investments, and establish consumption equality among children by transferring a higher amount to a worse-endowed child.

In this case, the result with a general utility function (Eq. (1)) is equal to the one with a special utility function (Eq. (5)) in the absence of parental aversion to inequality. Becker and Tomes (1976) first found this separability property. Because $h_{eI} > 0$, as empirically established by Cunha et al. (2010), parents always adopt a reinforcing strategy when credit constraints are not binding. We summarize this result in the following proposition:

Proposition 1. *If credit constraints are not binding, the marginal benefit of human capital investments in each child is equal to the interest rate in the capital market. The intrahousehold human capital investment in children is independent of parental preferences. Parents adopt a reinforcing investment strategy. Parental aversion to inequality affects children's consumption via the allocation of transfers among children.*

2.4. Intrahousehold human capital investment when credit constraints are binding

Next, we assume credit constraints are binding and $b_\tau = 0$. The child's consumption is thus equal to her earnings in the labor market, $c_\tau = E_\tau$. Using the first-order conditions, the following equilibrium condition would determine the parental human capital investment in each child:

$$U_{c_i} h_{I_i} = U_{c_j} h_{I_j}. \tag{8}$$

The equilibrium condition states the marginal utility of the human capital investment in each child should be the same. Eq. (8) implies the return to intrahousehold human capital investment is lower than the return when parents do not avert inequality. To see this property, we assume $e_i > e_j$ without loss of generality. Thus, $c_i > c_j$ if parents do not exhibit infinite inequalty aversion (i.e., the parental utility function is not a Leontif case).[10] Rearranging Eq. (8), we have

$$\frac{h_{I_i}}{h_{I_j}} = \frac{U_{c_j}}{U_{c_i}}. \tag{9}$$

[10] The property of Eq. (4) dictates this prediction. The parents would never compensate the worse-endowed child to be as good as the better-endowed one.

Because of the separable property of Eq. (4), $U_{c_j} > U_{c_i}$. Thus,

$$h_{I_i} > h_{I_j}. \tag{10}$$

The marginal productivity of the human capital investment in the better-endowed child *i* is higher than that in child *j*. Therefore, parents could gain a higher return to intrahousehold human capital investment by reallocating resources from child *j* to child *i*. They do not choose this high-efficiency strategy, because their utility would lose more when the gap in consumption between these two children increases.

If parents are inequality neutral and do not care about the number of children, that is, if they have a utility function such as Eq. (5), the intrahousehold human capital investment would follow the equilibrium condition:

$$h_{I_i} = h_{I_j}. \tag{11}$$

Eq. (11) implies the children's total consumption $(\Sigma_\tau c_\tau)$ is maximized. Compared with the case in which parents avert inequality, Eq. (11) suggests more resources are allocated to the better-endowed child *i*. But the gap in consumption between the two children is larger than that in the case of inequality aversion. Therefore, an efficiency versus equality trade-off occurs in the intrahousehold human capital investments when parents avert inequality across their children and credit constraints are binding.

When credit constraints are binding, we do not know whether $\frac{\partial I_i}{\partial e_i} > 0$ or $\frac{\partial I_i}{\partial e_i} < 0$ at the equilibrium. From Eq. (8), on one hand, we find that the stronger the complementarity between endowments and investments, the more likely parents are to have an incentive to invest more in the gifted child *i*, and thus they are more likely to adopt a reinforcing investment strategy. On the other hand, the stronger the parental aversion to inequality, the more likely parents are to have an incentive to invest more in the less gifted child *j*, and thus they are more likely to adopt a compensatory strategy.

Here, we propose our general model, which incorporates two past special cases derived from Behrman et al. (1982), where the preference parameter of the degree of parental aversion to inequality in the utility function unambiguously determines the reinforcing or compensatory investment strategy, and from Almond and Currie (2011), where the technological parameters measuring the degree of complementarity between endowments and family investments in the human capital production function unambiguously determines the investment strategy. In our general model, a combination of parameters from the parental utility function and the human capital production function determines the investment strategy.

For analytical convenience, we omit parental consumption in the parental utility function. We further assume each household has only two children, and both the parental utility function and human capital production function are of CES form. In this case, the problem parents face is to

$$\begin{aligned} \max\ & U = [\alpha c_i^\rho + (1-\alpha)c_j^\rho]^{\frac{1}{\rho}}, \\ \text{s.t.}\ & c_\iota = wh_\iota, \qquad \iota = i, j \\ & h_\iota = [\beta e_\iota^\sigma + (1-\beta)I_\iota^\sigma]^{\frac{1}{\sigma}}, \\ & I = I_i + I_j, \end{aligned}$$

where $\rho \le 1$ and $\sigma \le 1$. As discussed in Behrman et al. (1982), an excellent feature of the CES representation of the parental utility function is that ρ measures the degree of parental inequality aversion across siblings. For example, if $\rho = 1$, parents are inequality neutral. This case boils down to a situation in which parents simply maximize the children's total consumption. In the limit as σ approaches $-\infty$, parents exhibit infinite inequality aversion, when their utility function has the Rawlsian form $U = [\min(\alpha c_i, (1-\alpha)c_j)]$. Cunha and Heckman show that a nice feature of the CES representation of the production function is that σ measures the degree of complementarity or substitutability between endowments and family investments in producing children's human capital. For example, if $\sigma = 1$, the endowments and family investments are perfect substitutes for each other. In the limit as σ approaches $-\infty$, the two are perfectly complementary inputs in the human capital production function.[11]

The first-order condition implies

$$\left(\frac{I_i}{I_j}\right)^{1-\sigma} = \frac{\alpha}{1-\alpha} \cdot \left(\frac{\beta e_i^\sigma + (1-\beta)I_i^\sigma}{\beta e_j^\sigma + (1-\beta)I_j^\sigma}\right)^{\frac{\rho}{\sigma}-1}.$$

From this equilibrium condition, we find the preference parameter ρ or the production technological parameter σ no longer unambiguously determine the parental investment strategy. Rather, the trade-off between the degree of parental aversion to inequality and the degree of complementarity between the endowments and investments in the child human capital production function determines it. When ρ is smaller, parents are more averse to inequality. Thus, they are more likely to adopt a compensatory investment strategy. By contrast, when σ is smaller, the complementarity is stronger between

[11] One of the major features of the human capital production function in Cunha and Heckman (2007) is dynamic complementarity. That is, the human capital stock at the beginning of each period and the investment during the period are complementary inputs in the production function, generating the dynamic multiplier of human capital investment. Our CES production function above is static. But it can also be interpreted as dynamic if e is regarded as the pre-natal endowment (the human capital stock at birth) and I is the post-natal investment. This formulation captures the essential feature of Cunha and Heckman (2007) that endowments and investments are complementary in the human capital production function.

investments and endowments in the child human capital production. Parents are more likely to adopt a reinforcing strategy. We formally summarize the above discussion in the following proposition.

Proposition 2. *When parents' utility function and human capital production function are both of CES form, the sign of $\rho - \sigma$ determines the parental investment strategy. Specifically, when $\rho - \sigma > 0$, parents adopt a reinforcing strategy; when $\rho - \sigma < 0$, parents adopt a compensatory strategy.*

We prove the proposition in the Appendix.

From our model, we can get two prior special cases that we summarize into two propositions as follows.

Proposition 3. *When parents' utility function is a CES form and the human capital production function is a CD form, the parental investment strategy is unambiguously determined by the preference parameter ρ in the utility function. Specifically, when $\rho > 0$, parents adopt a reinforcing strategy; when $\rho < 0$, parents adopt a compensatory strategy.*

Proposition 4. *When parents' utility function is a CD form and the human capital production function is a CES form, the production technology parameter σ unambiguously determines the parental investment strategy. Specifically, when $\sigma < 0$, parents adopt a reinforcing strategy; when $\sigma > 0$, parents adopt a compensatory strategy.*

The proofs of the two propositions above are in the Appendix. Proposition 2 has important implications in interpreting the empirical results in the literature. The traditional literature of household economics usually attributes the observed pattern of intrahousehold human capital investments to parental preferences by assuming a CD form production function. Propositions 2–4 demonstrate that the observed pattern of reinforcement or compensation reveals the underlying preference or technological parameters when the parental utility function or the human capital production function is a CD form; however, in more general cases (e.g., the case in Proposition 2), this claim may not necessarily hold.[12] Recent literature usually observed a reinforcing pattern (Rosenzweig and Zhang, 2009), which could be driven by the complementarity between endowments and investments.

3. Empirical strategies

Separately identifying the preference and production technological parameters, which drive the intrahousehold resource-allocation process, has important implications in not only academic research, but also public policy. So, is the identification possible? And how is it achieved? Guided by the theoretical analysis, we discuss this issue in terms of both the structural and reduced-form approaches below.

3.1. The structural approach

We first consider nesting a CES production function into a CES parental utility function as given in Section 2.4. One may be able to structurally estimate the model to separately identify the preference and technological parameters (ρ and σ). However, this structural method has several econometric challenges. First, the cross-household heterogeneity is generically non-additive in this model.[13] Based on sibling or twin data, empirical studies on intrahousehold resource allocation usually use the fixed-effect (FE) method to deal with cross-household heterogeneity. The FE specification is essentially based on the theoretical model with a CES utility function and a CD production function as in Behrman et al. (1982). When both the utility function and the human capital production function are of CES form, the structural approach has to deal with the non-additive cross-household fixed effects.[14]

Second, the structural approach needs exogenous variations that induce the change in human capital investments to carry out the identification. Guided by the theoretical model illustrated in Section 2.4, we can use two types of exogenous variables. The first is the price of the human capital investment, which we normalize to 1 in the analysis. The second is the wage rate w. Although the price of human capital investments is observable, the wage rate for the child is unobservable in cross-sectional data when the child is young. In this case, parental wage rates could be used to proxy for the children's expected wage rate.

3.2. The reduced-form approach

We may also use the reduced-form approach to separately identify the preference and technological parameters. Guided by the theoretical analysis above, the reduced-form approach relies heavily on the separability property derived in Proposition 1. This method is very similar to Davies and Zhang (1995) separating the pure gender preference from the

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[12] In the class of CES function forms when the elasticity of substitution is constant, we are be able to back up the preference (production technology) parameters when we have prior knowledge about the production technology (preference) parameters, by observing the reinforcement or compensation behavior. The CD function form is a special case in which the elasticity of substitution is 0.

[13] See Rosenzweig and Zhang (2009) for the issue of cross-household heterogeneity in the empirical analysis on intrahousehold resource allocation.

[14] With non-additive across-household fixed effects, the structural MZ-DZ method developed by Behrman et al. (1994) requires modification.

observed gender discrimination in the household human capital investments. Assume two groups of households. Credit constraints are not binding for the first group. In this case, the observed parental investment strategy reflects only the production technology. Thus, we can identify the production technology by using this group of households. For the second group, credit constraints are binding. The observed parental investment strategy reflects not only the production technology, but also the parental preference. Therefore, the comparison of the investment strategies between the two groups yields information about parental preferences. However, caution is required in this kind of comparison because it assumes households in these two groups have identical parental preference and child human capital production technology. In other words, the credit constraints are exogenously imposed. Admittedly, this assumption is strong.

When all households have binding credit constraints, is it still possible to separate the technological parameters from parental preferences using the reduced-form approach? The answer is yes, but in this case we need to introduce other ingredients into the basic model. For example, Yi (2015) extends the theoretical framework of intrahousehold altruism by Stark and Zhang (2002) and Becker et al. (2016), and finds the elasticity of the ratio of human capital investment between the two children ($\frac{I_i}{I_j}$) with respect to the ratio of endowments ($\frac{e_i}{e_j}$) reflects only the production technology when the author controls for the degree of altruism. The intuition is simple. With sibling altruism and inter-sibling transfer, the two children act as pooling their earnings. This property is an application of Becker (1974). Thus, conditional on the degree of altruism, parents simply maximize the total earnings of their children. Therefore, by introducing sibling altruism, Yi (2015) separately identifies the production technological parameters from preference parameters.

4. Conclusion

This paper discusses the entangling roles of parental preferences and production technologies in determining the intrahousehold human capital investments in children. With binding credit constraints, parental aversion to inequality leads to a compensatory strategy, whereas the complementarity between pre-natal endowments and family investments leads to a reinforcing strategy. Therefore, the observed pattern of family investments on children does not reveal the underlying preference or technological parameters. Finally, from the perspectives of both the structural and reduced-form estimation, we discuss the potential methods to empirically disentangle these two types of parameters.

Family investments are important not only in affecting the human capital accumulation and economic growth, but also in affecting inequality. Therefore, understanding the intrahousehold behavioral rule in investing among children is very important. Inspired by the recent literature emphasizing the human capital production technology, this paper theoretically challenges the traditional literature on inferring parental preference from the observed pattern of intrahousehold human capital investments. Further studies that quantitatively identify the relative importance of parental preference and production technology in driving the intrahousehold resource-allocation process would be worthwhile.

Appendix. Mathematical proofs

A1. Proof of Proposition 2

The parents' problem is to

$$\begin{aligned} \max\ & U = [\alpha c_i^{\rho} + (1-\alpha) c_j^{\rho}]^{\frac{1}{\rho}}, \\ \text{s.t. } & c_\iota = w h_\iota, \qquad \iota = i, j \\ & h_\iota = [\beta e_\iota^{\sigma} + (1-\beta) I_\iota^{\sigma}]^{\frac{1}{\sigma}}, \\ & I = I_i + I_j. \end{aligned}$$

The first-order condition implies

$$\left(\frac{I_i}{I_j}\right)^{1-\sigma} = \frac{\alpha}{1-\alpha} \cdot \left(\frac{A_i}{A_j}\right)^{\frac{\rho}{\sigma}-1},$$

where

$$A_\iota = h_\iota^{\sigma} = \beta e_\iota^{\sigma} + (1-\beta) I_\iota^{\sigma}.$$

Log-linearizing the equation,

$$(1-\sigma)(\ln I_i - \ln I_j) = \ln\left(\frac{\alpha}{1-\alpha}\right) + \left(\frac{\rho}{\sigma} - 1\right)(\ln A_i - \ln A_j).$$

Totally differentiating w.r.t. e_i,

$$(1-\sigma)\left(\frac{1}{I_i} + \frac{1}{I_j}\right)\frac{dI_i}{de_i} = (\rho - \sigma)\left[\frac{1}{A_i}\beta e_i^{\sigma-1} + \frac{1}{A_i}(1-\beta) I_i^{\sigma-1}\frac{dI_i}{de_i} + \frac{1}{A_j}(1-\beta) I_j^{\sigma-1}\frac{dI_i}{dei}\right].$$

Rearranging the equation, we have

$$\frac{dI_i}{de_i} = \frac{(\rho-\sigma)\frac{1}{A_i}\beta e_i^{\sigma-1}}{(1-\sigma)(\frac{1}{I_i}+\frac{1}{I_j}) - (\rho-\sigma)[\frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}]}.$$

Thus,

$$\frac{dI_i}{de_j} = -\frac{dI_j}{de_j} = \frac{-(\rho-\sigma)\frac{1}{A_j}\beta e_j^{\sigma-1}}{(1-\sigma)(\frac{1}{I_i}+\frac{1}{I_j}) - (\rho-\sigma)[\frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}]}.$$

We note that

$$(1-\sigma)\left(\frac{1}{I_i}+\frac{1}{I_j}\right) - (\rho-\sigma)\left[\frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}\right] > 0,$$

because $1-\sigma > \rho-\sigma$ $(0 < \rho, \sigma < 1)$ and $\frac{1}{I_i}+\frac{1}{I_j} > \frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}$. The last inequality holds because

$$\frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1} = \pi_i\frac{1}{I_j} + \pi_j\frac{1}{I_j},$$

where

$$\pi_\iota = \frac{(1-\beta)I_\iota^\sigma}{A_\iota}.$$

So, $0 < \pi_\iota < 1$. Thus, we derive that

$$\frac{dI_i}{de_i} - \frac{dI_i}{de_j} = \frac{(\rho-\sigma)\beta[\frac{1}{A_i}e_i^{\sigma-1} + \frac{1}{A_j}e_j^{\sigma-1}]}{(1-\sigma)(\frac{1}{I_i}+\frac{1}{I_j}) - (\rho-\sigma)[\frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}]},$$

and

$$signum\left[\frac{dI_i}{de_i}\right] = signum[\rho-\sigma].$$
$$signum\left[\frac{dI_i}{de_j}\right] = signum[-\rho+\sigma].$$
$$signum\left[\frac{dI_i}{de_i} - \frac{dI_i}{de_j}\right] = signum[\rho-\sigma].$$

A2. Proof of Proposition 3

The parents' problem is to

$$\max\ U = [\alpha c_i^\rho + (1-\alpha)c_j^\rho]^{\frac{1}{\rho}},$$
$$\text{s.t. } c_\iota = wh_\iota, \quad \iota = i, j$$
$$h_\iota = e_\iota^\beta I_\iota^{1-\beta},$$
$$I = I_i + I_j,$$

where $\iota = i, j$. The parental investment in each child is determined by the following equilibrium condition:

$$\frac{I_i}{I_j} = \left(\frac{h_i}{h_j}\right)^\rho \frac{\alpha}{(1-\alpha)}.$$

Log-linearizing the equation,

$$\ln I_i - \ln I_j = \rho[\beta\ln e_i + (1-\beta)\ln I_i - \beta\ln e_j - (1-\beta)\ln I_j] + \ln\left(\frac{\alpha}{1-\alpha}\right).$$

Totally differentiating w.r.t. e_i,

$$\left(\frac{1}{I_i}+\frac{1}{I_j}\right)\frac{dI_i}{de_i} = \rho\beta\frac{1}{e_i} + \rho(1-\beta)\left(\frac{1}{I_i}+\frac{1}{I_j}\right)\frac{dI_i}{de_i}.$$

Rearranging the equation, we arrive at

$$\frac{dI_i}{de_i} = \frac{\rho\beta\frac{1}{e_i}}{[1-\rho(1-\beta)](\frac{1}{I_i}+\frac{1}{I_j})}.$$

Thus,

$$\frac{dI_i}{de_j} = -\frac{dI_j}{de_j} = \frac{-\rho\beta\frac{1}{e_j}}{[1-\rho(1-\beta)](\frac{1}{I_i}+\frac{1}{I_j})}.$$

Then we have

$$\frac{dI_i}{de_i} - \frac{dI_i}{de_j} = \frac{\rho\beta(\frac{1}{e_i}+\frac{1}{e_j})}{[1-\rho(1-\beta)](\frac{1}{I_i}+\frac{1}{I_j})}.$$

Because $[1-\rho(1-\beta)] > 0$, we have

$$signum\left[\frac{dI_i}{de_j}\right] = signum[\rho]$$

$$signum\left[\frac{dI_i}{de_j}\right] = signum[-\rho]$$

$$signum\left[\frac{dI_i}{de_i} - \frac{dI_i}{de_j}\right] = signum[\rho].$$

A3. Proof of Proposition 4

The parents' problem is to

$$\begin{aligned} \max\ & U = c_1^{\alpha} c_2^{1-\alpha}, \\ \text{s.t. } & c_\iota = wh_\iota, \qquad \iota = i, j \\ & h_\iota = [\beta e_\iota^{\sigma} + (1-\beta) I_\iota^{\sigma}]^{\frac{1}{\sigma}}, \\ & I = I_i + I_j. \end{aligned}$$

The first-order condition implies

$$\left(\frac{I_i}{I_j}\right)^{1-\sigma} = \left(\frac{h_i}{h_j}\right)^{-\sigma} \frac{\alpha}{(1-\alpha)}.$$

Log-linearizing the equation,

$$(1-\sigma)(\ln I_i - \ln I_j) = -(\ln A_i - \ln A_j) + \ln\left(\frac{\alpha}{1-\alpha}\right),$$

where

$$A_\iota = h_\iota^{\sigma} = \beta e_\iota^{\sigma} + (1-\beta) I_\iota^{\sigma}.$$

Totally differentiating w.r.t. e_i,

$$(1-\sigma)\left(\frac{1}{I_i}+\frac{1}{I_j}\right)\frac{dI_i}{de_i} = -\sigma\left[\frac{1}{A_i}\beta e_\iota^{\sigma-1} + \frac{1}{A_i}(1-\beta)I_i^{\sigma-1}\frac{dI_i}{de_i} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}\frac{dI_i}{de_i}\right].$$

Rearranging the equation, we have

$$\frac{dI_i}{de_i} = \frac{-\sigma\frac{1}{A_i}\beta e_i^{\sigma-1}}{(1-\sigma)(\frac{1}{I_i}+\frac{1}{I_j}) + \sigma[\frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}]}.$$

Thus,

$$\frac{dI_i}{de_j} = -\frac{dI_j}{de_j} = \frac{\sigma\frac{1}{A_j}\beta e_j^{\sigma-1}}{(1-\sigma)(\frac{1}{I_i}+\frac{1}{I_j}) + \sigma[\frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}]}.$$

We note that

$$(1-\sigma)\left(\frac{1}{I_i}+\frac{1}{I_j}\right) + \sigma\left[\frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}\right] > 0.$$

$$\frac{dI_i}{de_i} - \frac{dI_i}{de_j} = \frac{-\sigma\beta(\frac{1}{A_i}e_i^{\sigma-1} + \frac{1}{A_j}e_j^{\sigma-1})}{(1-\sigma)(\frac{1}{I_i}+\frac{1}{I_j}) + \sigma[\frac{1}{A_i}(1-\beta)I_i^{\sigma-1} + \frac{1}{A_j}(1-\beta)I_j^{\sigma-1}]}$$

Therefore, we have

$$signum\left[\frac{dI_i}{de_i}\right] = signum[-\sigma].$$

$$signum\left[\frac{dI_i}{de_j}\right] = signum[\sigma].$$

$$signum\left[\frac{dI_i}{de_i} - \frac{dI_i}{de_j}\right] = signum[-\sigma].$$

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