Journal of Comparative Economics 45 (2017) 219–224

Contents lists available at ScienceDirect

Journal of Comparative Economics

journal homepage: www.elsevier.com/locate/jce

Family size, birth order, and tests of the quantity–quality model☆

Rufei Guo[a], Junjian Yi[b], Junsen Zhang[c,*]

[a] Economics and Management School, Wuhan University, 299 Bayi Road, Wuhan, 430072, China
[b] Department of Economics, National University of Singapore, Faculty of Arts & Social Sciences AS2 Level 6, 1 Arts Link, Singapore 117570, Singapore
[c] Department of Economics, The Chinese University of Hong Kong, Shatin, Hong Kong

ARTICLE INFO

Article history:
Available online 21 September 2016

JEL Classification:
C21
J13

Keywords:
Quantity–quality trade-off
Birth order
Family size
Sample truncation

ABSTRACT

Guo, Rufei, Yi, Junjian, and Zhang, Junsen—Family size, birth order, and tests of the quantity–quality model

Recent empirical studies challenge the quantity–quality (Q–Q) trade-off of children modeled by Becker and Lewis. In the ordinary least squares (OLS) estimates, the effect of family size on child outcomes is frequently estimated with birth order controls. In a group of instrumental variable (IV) estimates, the family size effect is estimated only for low-parity children. We show that existing studies using the above two specifications do not identify the family size effect on average child quality and do not contradict the Becker–Lewis Q–Q theory. *Journal of Comparative Economics* **45** (2017) 219–224. Economics and Management School, Wuhan University, 299 Bayi Road, Wuhan, 430072, China; Department of Economics, National University of Singapore, Faculty of Arts & Social Sciences AS2 Level 6, 1 Arts Link, Singapore 117570, Singapore; Department of Economics, The Chinese University of Hong Kong, Shatin, Hong Kong.

1. Introduction

The quantity–quality (Q–Q) theory (Becker, 1960; Becker and Lewis, 1973) is a major contribution in family economics. As the quantity and quality of children multiplicatively enter the household budget constraint, the Q–Q theory predicts that the *average* quality of children is lower in larger families than in smaller ones. This prediction is empirically verified by early studies (e.g., Rosenzweig and Wolpin, 1980; Hanushek, 1992), but challenged by recent studies that aim to identify the causal effect of family size on child outcomes (e.g., Angrist et al., 2010; Åslund and Grönqvist, 2010; Black et al., 2005; 2010; Caceres-Delpiano, 2006; Conley and Glauber, 2006; de Haan, 2010; Li and Zhang, 2016; Li et al., 2008; Liu, 2014; Millimet and Wang, 2011; Qian, 2009; Rosenzweig and Zhang, 2009).

Studies challenging the Q–Q theory can be categorized into two groups. First, in a group of ordinary least squares (OLS) estimates, the family size effect on child outcomes (e.g., educational attainment) are estimated with birth order controls (Black et al., 2005; de Haan, 2010). Second, in a group of instrumental variables (IV) estimates, family size is instrumented

☆ We thank Gary Becker, James Heckman, Mark Rosenzweig, and an anonymous referee for their helpful suggestions. This paper has also benefited from the comments of participants in the Labor Economics Workshop in the Department of Economics at University of Chicago.

* Corresponding author. Fax: +852 26035805.
E-mail addresses: rufei.guo@gmail.com (R. Guo), junjian@nus.edu.sg (J. Yi), jszhang@cuhk.edu.hk (J. Zhang).

http://dx.doi.org/10.1016/j.jce.2016.09.006
0147-5967/© 2016 Association for Comparative Economic Studies. Published by Elsevier Inc. All rights reserved.

by twinning or the sex composition of the first two children to identify the effect on low-parity children.[1] We contend that both groups of studies do not identify the effect of family size on *average* child quality and do not contradict the Becker–Lewis Q–Q theory.

The OLS estimates with birth order controls suggest that the magnitude of the family size effect decreases substantially after controlling for birth order (Black et al., 2005; de Haan, 2010).[2] Subsequently, they claim that the family size effect becomes negligible when controlling for birth order effects.

We show that when the family size effect is estimated with birth order controls, the estimated coefficients on the family size variables are the effects on the *first-born* child. The family size effect is inseparable from the birth order effect, because the family size effect on high-parity children has been partly absorbed by birth order indicators. A negligible or statistically insignificant family size effect on the first-born child does not necessarily contradict the Q–Q model, because the effect of family size on high-parity children can be negative.

We then consider the IV estimates on low-parity children, assuming that the IVs are valid.[3] Some studies find a negatively significant family size effect on child outcomes, and the authors claim that the results are consistent with the prediction of the Q–Q theory (Caceres-Delpiano, 2006; Li and Zhang, 2016; Li et al., 2008). Other studies do not find a significant negative effect, implying a lack of supporting evidence of the Q–Q theory (Angrist et al., 2010; Åslund and Grönqvist, 2010; Black et al., 2005; de Haan, 2010; Qian, 2009). A number of studies find negatively significant family size effect in some specifications but not in others, and the authors report only weak evidence supporting the Q–Q theory, or insist that the Q–Q trade-off is present only under certain circumstances (Black et al., 2010; Conley and Glauber, 2006).

IV estimates on low-parity children suffer from sample truncation: high-parity children have been excluded from the sample.[4] For example, when twinning at the third birth is used as the instrument for family size, only families with three or more children are included in the sample, and children born at or after the third birth are dropped from the sample (e.g., Angrist et al., 2010; Åslund and Grönqvist, 2010; Black et al., 2005; 2010; Caceres-Delpiano, 2006; de Haan, 2010).[5] An insignificant or negligible IV estimate of the family size effect on low-parity children does not predict a negative effect of family size on average child quality. We elaborate in Section 4 why first-born children and those born at lower birth parities are less likely to be negatively affected by family size than children born at higher parities are.

Black et al. (2005) appear to be the first to use the above two specifications to test the Q–Q theory. Black et al. (2005) made a valid contribution by raising the importance of the birth order effects. However, the family size effect identified by Black et al. (2005) and following studies does not test the Q–Q theory.

The rest of this paper proceeds as follows. Section 2 shows that the OLS estimates of family size with birth order controls identify the effects on the first-born child. Section 3 discusses the sample truncation problem in the IV estimates. Section 4 considers the family size and birth order effects in dynamics. Section 5 concludes.

2. Identification of family size effects in specifications with birth order controls

The specification used in the literature is:[6]

$$Edu_{i,j} = \alpha + \sum_{k=2}^{k=N} \beta_k d_j^k + \sum_{l=2}^{l=N} \gamma_l d_{i,j}^l + \varepsilon_{i,j}; \qquad k, l = 1, \ldots, N, \tag{1}$$

where $Edu_{i,j}$ is the educational attainment for child *i* born in family *j*, d_j^k is a family size dummy for family *j*, $d_{i,j}^l$ is a birth order dummy for child *i* in family *j*, *N* is the maximum family size in the population, and $\varepsilon_{i,j}$ is an error term and is assumed to be *i.i.d.*[7] The omitted baseline group for the dummies of family size, d_j^k, comprises families with only one child ($k = 1$). Thus, β_1 is set to zero. Similarly, the omitted baseline group for the dummies of birth order, $d_{i,j}^l$, consists of the group of first-born child ($l = 1$), thus γ_1 is zero.

---

[1] Throughout this paper, by IV estimates we refer exclusively to the IV estimates that instrument for high-parity shocks and include only low-parity children in the sample. We thank the editor and the referee for leading us to this clarification.

[2] When discussing the OLS estimates, we do not consider the endogeneity of family size and focus on whether the OLS estimates can capture the family size effect implied by the Q–Q model.

[3] We are not addressing the issue of whether the instruments are valid. The validity of IVs is irrelevant to the main points about distinguishing the birth order and family size effects. We thank the editor and the referee for pointing this out.

[4] An exception is Rosenzweig and Zhang (2009). They modify the Q–Q model by explicitly incorporating the endowment heterogeneity and intrahousehold resource reallocation. They estimate the upper and lower bounds of the family size effect. Their estimates indicate that an extra child at parity one or at parity two significantly decreases schooling years, the expected college enrollment, grades in school, and the assessed health of all children in families in China.

[5] Conley and Glauber (2006) instrument family size by the gender composition of the first two children, and only include the first two children in the sample of estimation. Li and Zhang (2016) and Qian (2009) mainly examines the family size effect on the first-born child. Some papers have used multiple instrumental variables (Angrist et al., 2010; Black et al., 2010; de Haan, 2010; Qian, 2009). The same problem of sample truncation remains because not all children in large families have been included.

[6] Black et al. (2005, p. 679) use this specification. Other covariates are ignored for simplicity of illustration. In another commonly used specification, family size is treated as a continuous variable. The case of a continuous family size variable with birth order controls can be analyzed analogously.

[7] We focus on what the coefficients (β_ks) identify in this section. Thus, family size (d_j^k) is assumed to be exogenous, and Eq. (1) is assumed to be consistently estimated by OLS, or that family size is validly instrumented. The problem of IV methods in estimating Eq. (1) is discussed in the next section.

Existing empirical studies find that while the estimated $\widehat{\beta}_k$s are negatively significant without the birth order controls ($d^l_{i,j}$), the magnitude of $\widehat{\beta}_k$s (in terms of absolute value) decreases drastically after controlling for $d^l_{i,j}$. The estimated $\widehat{\beta}_k$s even become statistically insignificant in certain cases. These studies have concluded that the family size effect is statistically insignificant or unimportant after controlling for birth order effects; therefore, the Q–Q theory is empirically rejected. However, this conclusion is conceptually incorrect, because the estimated $\widehat{\beta}_k$s do not correspond to the family size effect implied by the Q–Q model (Becker, 1960; Becker and Lewis, 1973).

First, the β_ks in Eq. (1) only measures the effect of family size on the first-born child. Specifically, the expected educational attainment for the child born in a one-child family is

$$E(Edu_{i,j}|k=1, l=1) = \alpha.$$

Likewise, the expected education attainment for the first child born in a two-child family is

$$E(Edu_{i,j}|k=2, l=1) = \alpha + \beta_2.$$

Thus,

$$\beta_2 = E(Edu_{i,j}|k=2, l=1) - E(Edu_{i,j}|k=1, l=1),$$

and it can be generalized as

$$\beta_m = E(Edu_{i,j}|k=m, l=1) - E(Edu_{i,j}|k=1, l=1); \qquad m=2,\ldots,N. \tag{2}$$

Therefore, β_k in Eq. (1) only measures the family size effect on the first-born child when the family size increases from 1 to k, where $k=2,\ldots,N$.

Second, the Q–Q theory predicts that the per child (average) quality rather than the child quality (e.g., educational attainment) at a specific birth order is lower in larger families. To illustrate, we consider Eq. (1). The expected per child educational attainment for family j with family size $k=m$ is

$$E(Edu_{i,j}|k=m) = \alpha + \beta_m + \left(\sum_{l=2}^{l=m} \gamma_l\right)/m. \tag{3}$$

In contrast with Eq. (2), which measures the family size effect on the first-born child when the family size increases from 1 to m, the family size effect implied by the Q–Q theory is

$$E(Edu_{i,j}|k=m) - E(Edu_{i,j}|k=1) = \beta_m + \left(\sum_{l=2}^{l=m} \gamma_l\right)/m. \tag{4}$$

The first term on the right-hand side of Eq. (4) measures the effect of family size on the first-born child (as in Eq. (2)), whereas the second term measures the average of the differences between the family size effect at each parity and the family size effect at the first parity. Thus, it is incorrect to reject the Q–Q theory by merely observing that the estimated $\widehat{\beta}_m$ is not negatively significant or is even positive, because the second term $((\sum_{l=2}^{l=m}\gamma_l)/m)$ can be negative.

To generalize, we consider an increase in family size from $m-1$ to m ($m \geq 2$). The family size effect implied by the Q–Q theory is[8]

$$\begin{aligned} &E(Edu_{i,j}|k=m) - E(Edu_{i,j}|k=m-1) \\ &= (\beta_m - \beta_{m-1}) + \left[\left(\sum_{l=2}^{l=m}\gamma_l\right)\Big/ m - \left(\sum_{l=2}^{l=m-1}\gamma_l\right)\Big/ (m-1)\right] \end{aligned} \tag{5}$$

For example, when family size increases from 1 to 2, the family size effect is

$$E(Edu_{i,j}|k=2) - E(Edu_{i,j}|k=1) = \beta_2 + \frac{\gamma_2}{2};$$

and the family size effect when family size increases from 1 to 3 is

$$E(Edu_{i,j}|k=3) - E(Edu_{i,j}|k=1) = \beta_3 + \frac{\gamma_2}{3} + \frac{\gamma_3}{3}.$$

In Table 1, we use Eq. (3) to tabulate family size and average education of children. The estimated $\widehat{\beta}_k$s and $\widehat{\gamma}_l$s are from Black et al. (2005). The estimated coefficients have been adjusted by controlling for age, sex, mother's age, mother's education, father's age, and father's education. Table 1 shows that the average education of children monotonically decreases when the family size increases from two. On average (for family sizes ranging from 1 to 10), when the family size increases by one unit, the children's education decreases by 0.08 years. In particular, the children's education decreases by 0.13 years on average when the family size increases by one unit in the fertility range of 2–6, which is the most relevant fertility range for developing countries. Thus, the prediction of the Becker–Lewis Q–Q theory holds.

[8] When $m=2$, as noted earlier, $\beta_{m-1} = \beta_1$, which is assumed to be zero in the specification of Eq. (1).

Table 1
Family size and average child education.

Family size	Calculation formula	Average child education
1	0	0
2	0.257+(−0.342)/2	0.086
3	0.270+(−0.342−0.538)/3	−0.023
4	0.195+(−0.342−0.538-0.621)/4	−0.180
5	0.115+(−0.342−0.538−0.621−0.648)/5	−0.345
6	0.034+(−0.342−0.538−0.621−0.648−0.661)/6	−0.434
7	−0.018+(−0.342−0.538−0.621−0.648−0.661−0.709)/7	−0.521
8	−0.039+(−0.342−0.538−0.621−0.648−0.661−0.709−0.605)/8	−0.555
9	−0.037+(−0.342−0.538−0.621−0.648−0.661−0.709−0.605−0.800)/9	−0.584
10	−0.090+(−0.342−0.538−0.621−0.648−0.661−0.709−0.605−0.800−0.981)/10	−0.681

Notes: (1) the estimated coefficients are from the last column of Table IV in Black et al. (2005, p. 679). (2) The calculation formula follows Eq. (3) in the present paper. (3) The average children's education in one-child families is normalized to 0. (4) The estimated coefficients have been adjusted by controlling for age, sex, mother's age, mother's education, father's age, and father's education.

Provided that the γ_ls are not all zero, the β_ks alone can not be taken as the family size effect. The existence of the birth order effect implies that an increase in family size affects children at various birth parities differently. The birth order dummy γ_n captures the difference between the family size effect on the nth-born child and the family size effect on the first-born child.[9] The mechanical correlation between a child's birth order and the number of his or her siblings makes the family size effect inseparable from the birth order effect. In other words, the family size effect implied by the Q–Q theory can generate the birth order effect if an increase in family size has a larger effect on children born at higher parities.

3. IV estimates and sample truncation

Black et al. (2005) appear to be the first influential study that uses the specification of IV estimates on low-parity children. To illustrate, we consider the following equation:

$$Edu_{i,j} = \alpha + \beta n_j + \gamma D_{i,j} + \varepsilon_{i,j}, \tag{6}$$

where n_j is the number of children in family j, and $D_{i,\,j}$ is a dummy indicating whether the child i in family j is born at the second parity.[10] The following practices are found in Black et al. (2005) and followed by many studies: (1) twinning at the third birth is used to instrument for family size n_j;[11] (2) the sample only includes families with three or more children ($n_j \geq 3$); and (3) in those families, only the first-born and second-born children are retained, and children born at higher birth parities are not included in the sample.[12]

Black et al. (2005) discussed why they use the sample truncation specification. For example, consider twinning at the third birth. Children born at the fourth birth in families with third-born twins have four older siblings, while fourth-born children in families without twins only have three older siblings. In this sense, twinning "shifts downwards the birth order of children born after twins (Black et al., 2005, p. 681)".

However, the estimated $\widehat{\beta}$ of Eq. (6) does not correspond to the family size effect implied by the Q–Q theory. $\widehat{\beta}$ in Eq. (6) identifies the average family size effect on the first two children when family size increases by one unit, conditional on family size being equal to or larger than three ($n_j \geq 3$). By contrast, the Q–Q theory predicts that the average quality of all children in a family is lower in larger families than in smaller ones. Thus, Eq. (6) is inappropriate for testing the Q–Q theory.

Angrist et al. (2010, p. 777) further explain why they adopt Black et al. (2005)'s sample truncation specification, "Because twins probably differ from nontwins for reasons both observed and unobserved, we prefer empirical strategies that look at the effects of twins on older siblings. Similarly, when using sex mix as an instrument, we look only at older siblings because the outcomes of the last child born come from an endogenously selected sample if fertility is endogenous."

What "endogenously selected sample" indicates is not clear. Angrist et al. (2010)'s remark would make sense if it means that twinning (the sex composition of the first two children) affects the outcomes of children born before the occurrence of the twin birth (the first two children) exclusively through family size, and twinning affects outcomes of children born after

[9] We consider an increase in family size from 1 to m. The family size effect on the first-born child is $E(Edu_{i,j}|k=m, l=1) - E(Edu_{i,j}|k=1) = \beta_m$ and the family size effect on the nth born child is $E(Edu_{i,j}|k=m, l=n) - E(Edu_{i,j}|k=1) = \beta_m + \gamma_n$. Then the difference between the family size effect on the nth-born child and the family size effect on the first-born child is $[E(Edu_{i,j}|k=m, l=n) - E(Edu_{i,j}|k=1)] - [E(Edu_{i,j}|k=m, l=1) - E(Edu_{i,j}|k=1)] = \gamma_n$.

[10] To conform to the literature, we treat family size as a continuous variable in Eq. (6). The case of treating family size as a discrete variable can be analyzed analogously.

[11] The validity of instrument is not the focus of this paper.

[12] Similarly, if twinning at the second birth is used to instrument for family size (n_j), the sample only includes first-born children in families with two or more children ($n_j \geq 2$). Estimates using other IVs frequently encounter the same sample truncation problem. For example, when the gender composition of the first two children is used to instrument for family size, children born at the third or higher birth orders are not included in the sample. Other studies only examine the family size effect on the first-born children in their IV estimates (de Haan, 2010; Li and Zhang, 2016; Qian, 2009).

the occurrence of twin birth (children born at higher parities) through other channels apart from family size.[13] Under this assumption, the elimination of children born at higher parities from the sample of estimation facilitates the identification of the causal effect of family size on the quality of low-parity children. Unfortunately, the practice of sample truncation actually leads to a worse situation: estimating the family size effect on children born at low parities no longer tests the Becker–Lewis Q–Q theory.

4. Birth order and family size effects in dynamics

Recent empirical studies find that the birth order dummies ($\gamma_l, \forall l = 2, \ldots, n$) in Eq. (1) are not zero and become increasingly negative in higher birth order (e.g., Black et al., 2005; Booth and Kee, 2009). These findings indicate that the magnitude of the negative family size effect is larger on children born at higher birth order. The birth order effect arises because of the sequential nature of childbearing, which makes the decisions on both fertility and investment on children a dynamic process.[14] The estimated family size effect on the quality of low-parity children is actually a downwardly biased (in terms of absolute value) estimate of the family size effect on average child quality.

We now turn to a dynamic context and focus on three factors that can result in the differential family size effects across birth order: birth timing, early childhood development, and intrahousehold resource allocation across birth parities.

4.1. Birth timing

We consider an increase of family size from one to two. The first-born child is only partly affected by the increase in family size, because he or she exclusively shares the resources of his or her parents before the birth of the second child. The second-born child is more affected by family size than the first-born child because he or she has to share the resources with the older sibling. Certain resources (e.g., parental time) cannot be easily transferred inter-temporally; thus, the family size effect should be larger for the second-born child than for the first-born child. Similarly, for an increase of family size from $m-1$ to m, the family size effect is larger for the mth-born child because only the mth-born child is fully affected.

Using data from the American Time Use Survey, Price (2008) finds that parents in two-child families give roughly equal time to each child at any point in a period (when the two children are at different ages) after the birth of the second child; the total amount of parent-caring time decreases with the age of the first-born child. As a result, the parent-caring time received by the first-born child is approximately 40% more than that of the second-born child across ages 4–13.

Birth timing results in differential family size effect across birth order, and the family size effect is more pronounced on the high-parity children.

4.2. Early childhood development

One might perceive child development at ages 4–6 as important as that at ages 0–3. However, the literature on child development and neuroscience suggests otherwise (Shonkoff and Phillips, 2000). Early childhood is a critical stage for child development in multiple dimensions. The first-born child may have undergone the most crucial stage of his or her childhood development before the birth of the second child. Therefore, the importance of early childhood development suggests that further downward bias is introduced if the family size effects on the first-born child are regarded as the family size effect on average child quality.

It is possible that children born at higher parities may be treated better than those born at lower parities. For example, children born at higher parities may be born in a more favorable environment because of the growth of family income over the life cycle. However, empirical studies consistently find a negative correlation between birth order and child outcomes (e.g., Black et al., 2005; Booth and Kee, 2009). This empirical regularity indicates that the benefits from the more favorable environment for children born at higher parities may be outweighed by the negative family size effect, which dilutes family resources. The negative correlation between birth order and child outcomes actually supports the Q–Q model because children at high parities are more likely to be born in large families. Thus, the average quality of children is more likely to be lower in larger families.

4.3. Intrahousehold resource allocation across birth parities

Intrahousehold resource allocation across birth parities can also lead to heterogeneous family size effects across birth orders.[15] As elaborated in Section 4.1, even if children are homogeneous in all aspects except for birth order, the low-parity children can more exclusive share parental resources, and are less affected by family size.

[13] Justifying that twinning affects outcomes of children born before the occurrence of twin births exclusively through family size is difficult. In fact, twinning affects outcomes of all children through other channels apart from family size. Twinning is special primarily because of the lower birth weights of twin children and the associated zero birth spacing. These special features of twinning should affect the intrahousehold resource allocation across the family and the outcomes of *all* children within the household. For example, Rosenzweig and Zhang (2009) empirically demonstrate that parents reallocate resources across all children within the family in response to differences in birth weights between twin children and non-twin children.

[14] For a literature survey on dynamic microeconomic fertility models, see Arroyo and Zhang (1997).

[15] See Behrman (1997) for a survey of the literature on intrahousehold resource allocation.

A more complicated scenario arises if children born in a family are heterogeneous in certain aspects (e.g., endowment) other than birth timing. For example, we consider twinning as an instrument for family size. Rosenzweig and Wolpin (2000) argue that twinning directly affects child outcomes, because the inferior endowment of twins compared with singletons can result in within-family resource reallocation. Furthermore, Rosenzweig and Zhang (2009) demonstrate that parents reinforce the inherent endowment difference between twins and singleton(s) and allocate more resources to singleton(s). Thus, the estimated family size effect on the first-born child, in which family size is instrumented by twinning at the second birth, underestimates the family size effect (in terms of absolute values).

5. Conclusion

Black et al. (2005) raise an important issue of estimating the birth order effect. The OLS and IV specifications used by Black et al. (2005) have been followed by many studies to test the Becker–Lewis Q–Q theory. We show that both specifications do not identify the family size effect on average child quality and do not test the Becker–Lewis Q–Q theory. In the OLS estimates with birth order controls (e.g., Eq. (1)), the coefficients on the family size variables identify the family size effect on the first-born child. In the IV estimates using the truncated sample, the estimated family size effect on low-parity children underestimates the family size effect on average child quality. The sequential nature of child bearing gives rise to the birth order effects, and makes the family size effect more pronounced on high-parity children. Future research should look into the interaction between the birth order and family size effects.

References

Angrist, J., Lavy, V., Schlosser, A., 2010. Multiple experiments for the causal link between the quantity and quality of children. J. Labor Econ. 28 (4), 773–824. doi:10.1086/653830.

Arroyo, C.R., Zhang, J., 1997. Dynamic microeconomic models of fertility choice: a survey. J. Popul. Econ. 10 (1), 23–65. doi:10.1007/s001480050030.

Åslund, O., Grönqvist, H., 2010. Family size and child outcomes: is there really no trade-off? Labor Econ. 17 (1), 130–139. doi:10.1016/j.labeco.2009.05.003.

Becker, G.S., 1960. An economic analysis of fertility. In: Demographic and Economic Change in Developed Countries, vol. I. Columbia University Press, pp. 209–240.

Becker, G.S., Lewis, H.G., 1973. On the interaction between the quantity and quality of children. J. Political Econ. 81 (2), S279–S288.

Behrman, J.R., 1997. Intrahousehold distribution and the family. In: Handbook of Population and Family Economics, vol. 1, pp. 125–187. doi:10.1016/S1574-003X(97)80021-9.

Black, S.E., Devereux, P.J., Salvanes, K.G., 2005. The more the merrier? The effect of family size and birth order on chileducation. Q. J. Econ. 120 (2), 669–700.

Black, S.E., Devereux, P.J., Salvanes, K.G., 2010. Small family, smart family? Family size and the IQ scores of young men. J. Hum. Resour. 45 (1), 33–58. doi:10.1353/jhr.2010.0001.

Booth, A.L., Kee, H.J., 2009. Birth order matters: the effect of family size and birth order on educational attainment. J. Popul. Econ. 22 (2), 367–397. doi:10.1007/s00148-007-0181-4.

Caceres-Delpiano, J., 2006. The impacts of family size on investment in child quality. J. Hum. Resour. 41 (4), 738–754.

Conley, D., Glauber, R., 2006. Parental educational investment and children's academic risk: estimates of the impact of sibship size and birth order from exogenous variation in fertility. J. Hum. Resour. 41 (4), 722–737. doi:10.3368/jhr.XLI.4.722.

de Haan, M., 2010. Birth order, family size and educational attainment. Econ. Educ. Rev. 29 (4), 576–588. doi:10.1016/j.econedurev.2009.10.012.

Hanushek, E.A., 1992. The trade-off between child quantity and quality. J. Political Econ. 100 (1), 84. doi:10.1086/261808.

Li, B., Zhang, H., 2016. Does population control lead to better child quality? Evidence from China's one-child policy enforcement. J.Comp. Econ. in this issue.

Li, H., Zhang, J., Zhu, Y., 2008. The quantity–quality trade-off of children in a developing country: identification using Chinese twins. Demography 45 (1), 223–243.

Liu, H., 2014. The quality–quantity trade-off: evidence from the relaxation of China's one-child policy. J. Popul. Econ. 27 (2), 565–602. doi:10.1007/s00148-013-0478-4.

Millimet, D.L., Wang, L., 2011. Is the quantity–quality trade-off a trade-off for all, none, or some? Econ. Dev. Cultural Ch. 60 (11), 155–195. doi:10.1086/661216.

Price, J., 2008. Parent–child quality time. J. Hum. Resour. 43 (1), 240–265. doi:10.3368/jhr.43.1.240.

Qian, N., 2009. Quantity–Quality and The One Child Policy: The Only-Child Disadvantage in School Enrollment in Rural China. Technical Report. National Bureau of Economic Research, Cambridge, MA doi:10.3386/w14973.

Rosenzweig, M.R., Wolpin, K.I., 1980. Testing the quantity–quality fertility model: the use of twins as a natural experiment. Econometrica 48 (1), 227. doi:10.2307/1912026.

Rosenzweig, M.R., Wolpin, K.I., 2000. Natural "Natural Experiments" in economics. J. Econ. Lit. 38 (4), 827–874. doi:10.1257/jel.38.4.827.

Rosenzweig, M.R., Zhang, J., 2009. Do population control policies induce more human capital investment? Twins, birth weight and China's one-child policy. Rev. Econ. Stud. 76 (3), 1149–1174. doi:10.1111/j.1467-937X.2009.00563.x.

Shonkoff, J.P., Phillips, D.A., 2000. From Neurons to Neighborhoods: The Science of Early Childhood Development. National Academies Press, Washington, DC.