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Identifying non-cooperative behavior among spouses: Child outcomes in migrant-sending households ☆

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ABSTRACT

I propose a model of household decision-making under asymmetric information and show that resulting allocations may not be fully cooperative. The model yields a simple test for cooperative decision-making, which I apply to data from China. I find that, when the father migrates without his family, children spend more time in household production, while mothers spend less time in both household production and income-generating activities. This is not consistent with standard cooperative models of the household: simply reallocating time to compensate for the father's absence would cause an increase in household labor for both children and mothers and, if migration occurs in response to a negative shock, we should observe an increase in mothers' time in income-generating activities rather than a reduction. The results also do not appear to be driven by an increase in mothers' bargaining power, as children's human capital is not affected by migration, controlling for income.

1. Introduction

Economic studies of the household have increasingly moved toward collective models in which decision-makers have heterogeneous preferences, and thus both the value and the ownership of income streams are important. When household members bargain over decisions and control over resources affects their allocation, we must consider whether and how individuals may behave strategically in order to increase their own utility. I examine an information problem that permits an individual to conceal expenditures and/or allocations from his/her spouse. This may lead to non-cooperative behavior, as intra-household allocations can only be coordinated to the extent that they can be enforced. Migration presents a clear opportunity for such behavior: the migrant has limited ability to observe expenditure and allocation decisions made by the spouse remaining at home but may also be able to conceal his own expenditures by determining the amount of money that will be remitted to the household.

The economic literature on the impact of remittances on migrant-sending households (see Yang, 2011 for a survey) has largely neglected a key feature of such income: the difficulty inherent in monitoring the disbursement and allocation of remittances (for exceptions, see Ashraf et al., 2011; Chami et al., 2003; Chen, 2006). With rising trends in both rural-urban and international migration, it is essential to understand the implications of such an information problem in order to assess the ultimate impact on origin households and communities. The existence of non-cooperative behavior among household members would suggest that expanding opportunities for migration will have different effects than simply increasing the amount of income received by the household. Non-cooperative behavior would also have important implications for policy and program design because it implies that the channel through which income is received can have important spillover effects. For example, direct subsidies are easily observed by other household members, whereas the proceeds of micro-credit enterprises could be concealed and used to finance expenditures that otherwise would not be undertaken.

I introduce asymmetric information into a model of household decision-making such that the migrant has imperfect information about the actions taken by his spouse. If the migrant also has incomplete information about his spouse's preferences, it is possible to have an equilibrium in which the migrant behaves cooperatively but his

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spouse does not. If the migrant does have complete information about his spouse's preferences, he can design a fully incentive-compatible contract to elicit cooperative behavior, but intra-household allocations will still shift in favor of the non-migrant, who has the advantage of complete and perfect information. Data are drawn from the China Health and Nutrition Survey (CHNS). The panel aspect of these data allow me to account for both unobservable child and household fixed effects as well as time-varying local economic shocks that may be correlated with the migration decision. Because data on the migrant's remittances and private expenditures are not available, the potential for non-cooperative behavior on the part of the migrant is left to future research.

Results indicate that non-cooperative behavior, whether realized or simply invoked as a threat, affects intra-household allocations in a surprising way. Children's schooling and health exhibit no significant change with the father's migration, controlling for income. This is not consistent with a case in which migration increases mother's bargaining power, given existing evidence that mothers tend to invest more heavily in these goods. In contrast, time spent in household chores does change; girls engage in more housework while mothers reduce their time in both housework and income-generating activities. The *simultaneous* increase in child labor and reduction in mother's labor cannot be explained with a cooperative model of household decision-making: as long as fathers derive (weakly) greater disutility from child labor than from mothers' labor, their absence from the household should not lead to an increase in child labor without an accompanying increase in mother's household labor. Moreover, this pattern is not evident among households in which the migrant happens to be home at the time of the survey, which suggests that it is the physical absence of the father – and not self-selection into migration – that is driving the results.

The following section presents a framework for modeling the effect of migration on intra-household allocation and compares equilibria with and without asymmetric information. Section 3 describes the key empirical distinctions between cooperative and non-cooperative formulations of the model and shows that the data are inconsistent with standard cooperative models of the household. Several robustness checks are provided in Section 4 to ensure that the results are not driven by the assumptions of the model or the limitations of the empirical strategy, and Section 5 concludes.

2. Migration with asymmetric information

Migration introduces imperfect information, increasing transaction costs associated with enforcing cooperative bargaining agreements. In some cases, the cooperative outcome may become unsustainable, as evidenced by a growing body of literature. Dubois and Ligon (2004) find that, where there is asymmetric information about activities, the allocation of calories among household members is used both to create incentives for individuals and as a form of investment. Ashraf (2009) finds that, in an experimental setting, spouses attempt to conceal expenditures from each other when presented with the opportunity, and de Laat (2005) finds that migrants living in Nairobi invest in costly monitoring technologies to mitigate moral hazard on the part of their spouses in rural villages. Recent work by Ashraf et al. (2011) and Chin et al. (2011) suggest that migrants are concerned about the degree of control they possess over remittances, providing indirect evidence of information asymmetries and non-cooperation. Improving migrants' control (reducing the potential for non-cooperative behavior) is found to increase savings and income, suggesting improvements in both static and dynamic efficiency.

Lundberg and Pollak (1993) provide the first theoretical framework for non-cooperative behavior within marriage. In a non-cooperative equilibrium, individuals do not coordinate their actions or pool their resources. Rather, each spouse maximizes his/her own welfare, given the behavior of his/her spouse. Warr, 1983 and Bergstrom et al., 1986 show that, when all players make strictly positive contributions, control over resources will not affect provision of the public good or the equilibrium utilities of the individuals, even if the individuals do not coordinate. However, if the provision of household public goods is organized along "separate spheres", as in Lundberg and Pollak (1993), such that at least one spouse makes zero contributions to some public good, control over resources and the degree of cooperation will affect the equilibrium outcome.[1] Migration gives the non-migrant spouse de facto control over the provision of all household public goods, essentially forcing allocations into separate spheres.

Here, intra-household allocation is modeled as a contracting problem, allowing for both incomplete and imperfect information. Note that, although cooperative equilibria exist, the model is non-cooperative in nature. Because the CHNS provides data only on sending households, I consider only imperfect monitoring of the non-migrant's actions. A more complete dynamic model in which wives update beliefs about husbands' wage realizations is left to future research.

2.1. Description of game

Consider a household with two adults, a migrant (m) and a non-migrant (n), and one child (k). Adults may engage in wage and household labor, while children engage only in household labor. Each adult has preferences over own private consumption (x_i), own labor (t_i), child labor (t_k) and child quality (z). For ease of notation, I allow time spent in productive activities (wage and household) to provide some disutility, rather than specifying a utility of leisure.

$$U_i(x_i, t_i, t_k, z) \text{ with } t_i = t_i^w + t_i^h \text{ for } i = m, n. \quad (1)$$

Note that, for simplicity, I have assumed that neither the migrant nor the non-migrant cares about the labor hours of his/her spouse. However, the theoretical implications discussed below will hold as long as each adult cares more about the child's labor than about his/her spouse's labor.[2] Child quality is produced with a household good (y), and child labor detracts from child quality.

$$z = \tilde{z}(y, t_k) \quad (2)$$

The household good, in turn, is produced with child and adult household labor according to person-specific productivities (τ)

$$y = y\left(t_m^h, t_n^h, t_k; \tau_m, \tau_n, \tau_k\right). \quad (3)$$

For simplicity, we can then rewrite the production function for child quality as

$$z = z\left(t_k, t_m^h, t_n^h; \tau_m, \tau_n, \tau_k\right). \quad (4)$$

Note, however, that $\partial z / \partial t_k$ is not strictly the marginal product of child labor for child quality; rather, it reflects both the negative effect of own labor on child quality and the offsetting positive effect via production of the household good. To close the model, I assume that total private consumption must be equal to total earnings

$$x_m + x_n = w_m t_m^w + w_n t_n^w. \quad (5)$$

[1] This holds as long as spouses face different implicit prices, even if both make positive contributions.

[2] This assumption has strong foundations in Hamilton's (1964) rule, which suggests that altruism is a function of genetic preservation. Because parents and children share a large amount of genetic material while spouses share none, each parent should be willing to sacrifice his/her spouse for their shared child, in order to preserve a greater proportion of the parent's own genetic material. See Cox (2007) for additional discussion of Hamilton's rule in economic models of the household.

In the event of migration, allocations move into separate spheres. The migrant can contract with his spouse for a set of allocations to be implemented in his absence, but he may only be able to imperfectly monitor her actions. The contract also stipulates a transfer (s) to be made to the wife upon the migrant's return, and the value of this transfer may be contingent upon the outcome of a monitoring process.

Definition. The non-migrant's action space includes own private consumption $x_n \in [0, w_n t_n^w]$ (equivalently, own market labor $t_n^w \in [0,T]$), own household labor, $t_n^h \in [0,T]$ and the child's household labor, $t_k \in [0,T]$. The migrant cannot contribute to household production ($t_m^h = 0$), so his action space is limited to the choice of market labor hours $t_m^w \in [0,T]$ and a contingent contract $\{t_n^{h^c}, t_k^c, s^c, s^{nc}\}$ that includes a transfer to his wife, $s \in [0, w_m t_m^w]$ expressed in units of x, where s^c is the transfer if the contracted allocations are observed, and s^{nc} is the transfer otherwise.

Transfers from the migrant to his spouse are bounded from below by zero, analogous to a participation constraint. Because the migrant cannot contribute to household production, a contract specifying t_n^h and t_k also implicitly specifies y (the public good) and therefore z (child quality) as well. Note that, unlike the classic principal-agent model, here the migrant has preferences over both the outcome and the inputs to production. Therefore, he cannot simply "sell" the production of child quality to his spouse; he must also stipulate and monitor the household labor of both mother and child.

The migrant's strategy consists of a contingent contract, and the non-migrant's strategies are to either play *cooperate* and choose the contracted allocations or disregard the contract and play *don't cooperate*. The game then proceeds as follows. First, player m, the migrant, offers a contingent contract to his spouse, player n, that specifies all intra-household allocations and the transfer the non-migrant spouse will receive contingent on the outcome of the monitoring process. Both players then choose the allocations associated with their respective spheres. Player n's choices are monitored, and a transfer is made from player m to player n contingent on the outcome. I assume that player m's actions are perfectly monitored by player n and that player m cannot renege on the contract.[3] If player n plays *cooperate*, the contracted allocations are revealed with probability one; otherwise, monitoring reveals player n's actions with probability $0 \le q \le 1$ and the contracted allocations with probability $(1-q)$. The probability of detection (q) depends on the actions of both players as well as an exogenous parameter ω_q, and both players have complete information regarding the structure of this q-function (see Technical appendix for complete definition).

Given concavity of the utility function and convexity in the probability of detection (q), there exists a unique best response associated with *don't cooperate* for each value of ω_q and thus a unique value of q. Payoffs are

$$V_m = U_m(t_m^w, z^c, t_k^c, x_m - s^c) \text{ and } V_n = U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, t_k^c, x_n^c + s^c\right)$$

if player n chooses the contracted allocations, and

$$V_m = (1-q^*)U_m(t_m^w, z, t_k, x_m - s^c) + q^* U_m(t_m^w, z, t_k, x_m - s^{nc}) \text{ and}$$
$$V_n = (1-q^*)U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^c\right) + q^* U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^{nc}\right)$$

otherwise, where q^* is the probability of detection associated with player n's best response. For simplicity, I have assumed that the migrant's payoff is dependent on the allocations that are chosen in equilibrium, irrespective of the outcome of monitoring. Allowing the migrant's payoff to depend on the outcome of monitoring (*i.e.*, when monitoring does not reveal non-cooperative behavior, the migrant believes that the contracted allocations have been chosen and, therefore, receives a payoff consistent with cooperative behavior) will increase the range of parameter values over which non-cooperative behavior may occur in equilibrium, since the contracted allocations always provide the migrant with greater utility than the non-cooperative allocations.

2.2. Asymmetric information

I now consider the case of imperfect information, in which the migrant is unable to perfectly observe the actions of his spouse. Additionally, he may have incomplete information about her preferences. Specifically, suppose player n may be one of two types, A and B, drawn exogenously with probability p and $(1-p)$, respectively, with p taken as fixed. Type A has payoffs as defined above, but Type B incurs a fixed cost (c) when she chooses to play *don't cooperate*.[4] Payoffs for player n are thus

$$V_n^A = V_n^B = U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, t_k{}^c, x_n{}^c + s^c\right)$$

when playing *cooperate*, and

$$V_n^A = (1-q^*)U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^c\right) + q^* U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^{nc}\right)$$
$$V_n^B = (1-q^*)U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^c\right) + q^* U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^{nc}\right) - c$$

when playing *don't cooperate*. When both types play the same strategy, player m's payoffs are as defined above, otherwise player m's expected payoff is

$$V_m = (1-p)U_m(t_m^w, z, t_k, x_m - s^c) + p[(1-q^*)U_m(t_m^w, z, t_k, x_m - s^c) + q^* U_m(t_m^w, z, t_k, x_m - s^{nc})]$$

when type A plays *don't cooperate* and type B plays *cooperate* and

$$V_m = pU_m(t_m^w, z, t_k, x_m - s^c) + (1-p)[(1-q^*)U_m(t_m^w, z, t_k, x_m - s^c) + q^* U_m(t_m^w, z, t_k, x_m - s^{nc})]$$

when type B plays *don't cooperate* and type A plays *cooperate*.

Proposition 1. *For $\omega_q \ge \overline{\omega_q}$, the allocations that would be obtained with perfect monitoring are feasible and will be obtained in equilibrium. For $\underline{\omega_q} \le \omega_q < \overline{\omega_q}$, the equilibrium payoff for player n is weakly greater than the payoff she would obtain under perfect monitoring and conversely for player m; however, whether or not the contracted allocations are obtained in equilibrium depends on the probability that player n is type A. For $\omega_q < \underline{\underline{\omega_q}}$, the non-pooling allocations will prevail. That is, the migrant and his spouse will not pool resources, but the resultant allocations are equivalent to the contracted allocations. For $\underline{\underline{\omega_q}}' \le \omega_q < \underline{\omega_q}$, the contracted allocations will be chosen in equilibrium by type B but not by type A and, for $\underline{\underline{\omega_q}} \le \omega_q < \omega_q'$, the non-pooling allocations will also prevail, where the cutoff point ω_q' depends on the value of p.*

Proof. When the probability of detection is very high, even small deviations from the cooperative allocations will be discovered, so player n cannot increase her utility by deviating from the contracted allocations. Thus, for $\omega_q \ge \overline{\omega_q}$, the optimal actions associated with player n's *don't cooperate* strategy are equivalent to the actions associated with *cooperate*, and the fully cooperative allocations (*i.e.*, the allocations that would be obtained under perfect monitoring), denoted $\{t_n^{w^*}, z^*, t_n^{h^*}, t_k^*, t_m^{w^*}, s^*\}$, can be enforced even when monitoring is imperfect. Furthermore,

[3] More formally, enforcement of the contract could occur through repeated interaction between spouses; this extension is discussed below.

[4] This assumption ensures that, for any given contract, the payoff functions for types A and B cross only at the value of ω_q at which the *don't cooperate* strategy yields a higher payoff than the *cooperate* strategy for type A. Alternative formulations for player heterogeneity are discussed below.

because these are the allocations that would be obtained when $q = 1$, the value of q^* associated with $\overline{\omega_q}$ must be strictly less than one. And, with a fixed cost for type B, whenever type A finds it optimal to play *cooperate*, type B will also find it optimal to play *cooperate*.

For $\omega_q < \overline{\omega_q}$, the fully cooperative allocations cannot be enforced because the payoff to *don't cooperate* exceeds the payoff to *cooperate* for both possible types of player n. The migrant can incentivize both types to behave cooperatively, *i.e.* choose the contracted allocations, by offering a contract that provides type A with higher utility than playing *don't cooperate* and thus also higher utility than she would obtain under perfect monitoring. This contract will be determined as follows:

$$\max_{t_m^w, t_n^{h^c}, t_k^c, s^c, s^{nc}} V_m = U_m\left(t_m^w, z^c, t_k^c, x_m - s^c\right) \text{ subject to } x_m = w_m t_m^w - s^c \text{ and}$$
$$U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, t_k^c, x_n^c + s^c\right) \geq (1-q^*) U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^c\right) + q^* U_n\left(t_n^w, z, t_n^h, t_k, x_n\right).$$

The migrant is willing to do this as long as he can extract some of the gains from cooperation,

$$U_m\left(t_m^w, z^c, t_k^c, x_m - s^c\right) \geq U_m\left(t_m^{w\prime}, z', t_k', x_m' - s'\right)$$

where $'$ denotes the non-pooling allocations, *i.e.* the allocations that would be chosen if each individual maximized his/her own utility, taking the other player's actions and $q = 1$ as given. The right-hand side of the former inequality is inversely related to ω_q; the payoff to *don't cooperate* increases for player n as ω_q decreases and thus the migrant must offer increasingly more favorable contracts to induce cooperation. Alternatively, the migrant can offer a contract that induces cooperation only from type B. This will be optimal if the probability of type A is sufficiently low (see Condition 1, Technical appendix). In this case, player m offers a contract that cannot always be enforced. This contract provides type B with weakly higher utility than she would obtain under perfect monitoring.[5] Type A also receives higher utility because, for a given contract, payoffs for type A are always weakly greater than for type B.

However, if ω_q falls below some minimum threshold $\underline{\underline{\omega}}_q$, the only contracts that induce either type of player n to choose the contracted allocations provide player m with less utility than the fully non-cooperative allocations, and thus the optimal contract is $\{t_n^h{}', t_k', s', s'\}$. Resources will not be pooled, but the contracted allocations will be chosen by both types of player n in equilibrium. Since the migrant knows with certainty the allocations that his spouse will choose in equilibrium, he offers s' irrespective of the outcome of monitoring. And, because type A receives a weakly higher payoff from playing *don't cooperate* than type B, it must be the case that $\underline{\underline{\omega}}_q < \underline{\omega}_q$. That is, the contract that induces type A to cooperate when $\omega_q = \underline{\omega}_q$ will induce type B to cooperate for $\omega_q < \underline{\omega}_q$. Finally, for $\underline{\underline{\omega}}_q \leq \omega_q < \underline{\omega}_q$, there exists a contract that induces type B to cooperate and, conditional on player n being type B, yields higher utility for player m than the fully non-cooperative allocations. And, for a fixed value of p, there exists a cutoff point $\underline{\underline{\omega}}_q'$ at which it becomes optimal for the migrant to offer a contract specifying the fully non-cooperative allocations rather than a contract that is incentive-compatible only for type B (see Condition 2, Technical appendix). Again, when the probability that player n is type A is sufficiently small, the contracted allocations will not always be chosen in equilibrium. □

When the probability of a type A spouse is sufficiently low, the migrant offers contracts that are not always incentive compatible, and non-cooperative behavior may occur in equilibrium.

The case of complete but imperfect information is nested within this framework. In this case, $p = 1$ and the migrant can always design fully incentive-compatible contracts, even though resources are not always pooled. However, even when the equilibrium is cooperative, there is still a difference between the contracted allocations and those that would be obtained under perfect information, and this difference provides an indication of the extent of the incentive problem. And, from Proposition 1, we can gain additional insight into exactly how the pattern of intra-household allocation will change once imperfect monitoring is introduced.

Corollary 1. *For* $\underline{\underline{\omega}}_q' \leq \omega_q < \overline{\omega_q}$, *the optimal contract offered by player m is such that* $t_n^{h^c} \leq t_n^{h*}$, $t_k^c \geq t_k^*$, $s^c \geq s^*$, *with at least one strict inequality. That is, player n is allowed to reduce her own household labor and increase child labor, as well as receive a larger transfer, relative to the case of perfect monitoring.*

Proof. See Technical appendix, Part B. □

2.3. Extensions

A variety of extensions to the above model will be discussed briefly here, with more rigorous treatment left to future research. First, allowing the migrant to offer a menu of contracts to his spouse does not affect the main results. The assumption that payoffs for types A and B differ only by a fixed cost associated with non-cooperative behavior ensures that any contract that induces type A to cooperate will also induce type B to cooperate and, because the payoffs are identical for types A and B conditional on playing *cooperate*, both types will have identical preferences for any such contracts. If, however, both players are risk averse, the migrant can induce type A and B to separate by offering one contract that induces cooperation only from type B and a second contract that is identical but has a smaller spread between s^c and s^{nc}. Type A will prefer the second contract, but non-cooperative behavior will still be her dominant strategy. If only one player is risk averse, a separating equilibrium can still occur with the risk-averse player paying a premium to reduce the spread between s^c and s^{nc}. The ability to offer a menu of contracts can increase the payoff for the migrant provided that at least one player is risk-averse, but it does not eliminate the range of parameter values for which non-cooperative behavior can occur in equilibrium.

Introducing heterogeneity in a different form will not affect the main results provided that the payoff to playing *don't cooperate* is always weakly greater for type A. As long as this assumption holds, the migrant cannot utilize separate contracts to simultaneously induce cooperation from both types, and thus non-cooperative behavior will occur in equilibrium for certain parameter values. For example, heterogeneity could be characterized as differences in the efficacy of the monitoring technology – the wife may be “good” or “bad” at hiding allocations from her spouse, or the husband may enlist members of his social network to monitor his spouse's actions without knowing ex ante whether they are “good” or “bad” monitors – without eliminating the range of parameter values for which non-cooperative behavior will occur in equilibrium. Alternatively, if types A and B have different preferences such that *don't cooperate* is, under some contracts, a dominant strategy for type B but not for type A (*e.g.*, type B has stronger preferences for the household public good and is willing to trade a smaller amount of child labor for a large reduction in private consumption), there can exist a separating equilibrium in which both types cooperate but under different contracts. However, this type of heterogeneity likely would have been observed prior to migration such that the migrant would not have any uncertainty about his spouse's type.

Extending the game to multiple periods will provide the migrant with more latitude in designing incentive-compatible contracts to

[5] For $\overline{\omega_q}' \leq \omega_q < \overline{\omega_q}$ where $\overline{\omega_q}'$ is the value of ω_q at which type B is just indifferent between the *cooperate* and *don't cooperate* strategies, the probability of detection is sufficiently high that type B cannot increase her own utility by deviating from the cooperative allocations. That is, she will find it optimal to cooperate when offered a contract that specifies the fully cooperative allocations and a zero transfer conditional upon discovery of non-cooperative behavior.

elicit cooperative behavior. If migration occurs over multiple periods, the migrant may be willing to accept a lower payoff in the first period in order to implement contracts that will enable him to separate types A and B. An infinitely repeated version of the above stage game would be a better framework for describing intra-household allocation, as spouses typically interact over long periods of time and external enforcement of contracts is often infeasible. With multiple periods, the migrant would be able to impose more stringent punishments when non-cooperative behavior is detected, and non-cooperative behavior could only occur in equilibrium if such punishments have some lower bound, *e.g.* as imposed by social norms. A dynamic model would also raise issues related to limited commitment, as in Ligon (2002), such that the wife cannot commit to cooperate in subsequent periods when facing multiple periods of punishment for prior non-cooperative behavior.

3. Testing for asymmetric information

In the presence of asymmetric information, the non-migrant spouse will be able to decrease her own household labor and increase child labor, even if allocations are fully cooperative. However, migration affects the household in several ways, in addition to introducing asymmetric information. There is a reduction in the amount of time available for household production, a change in father's wages and, potentially, a change in the distribution of bargaining power between spouses. The appropriate counterfactual for identifying non-cooperative behavior is, then, the set of allocations that would be chosen, conditional on these changes, if spouses could costlessly commit to cooperation. Using the framework outlined in the previous section, note that, for ω_q sufficiently high, the game can be treated as one of perfect information. That is, for $\omega_q \geq \overline{\overline{\omega_q}}$, the probability of detection is equal to one for all actions taken by either player; the migrant can perfectly observe any deviations from the contract, irrespective of the specific values stipulated by the contract. If the migrant also has complete information about his wife's preferences, the game is equivalent to a standard collective, and cooperative, model of the household in which the couple *jointly* maximizes a weighted sum of their utility functions

$$\lambda U_m(x_m, z, t_m, t_k) + (1-\lambda) U_n(x_n, z, t_n, t_k), \tag{6}$$

and the bargaining weights $(\lambda, 1-\lambda)$ are a function of the individuals' threat points (the maximum utility he/she could expect to attain in the absence of a cooperative agreement; see Lundberg and Pollak, 1993; Manser and Brown, 1980; McElroy and Horney, 1981).

Under full information, comparative statics (see Technical appendix, Part A) indicate the following: A reduction in father's household labor, holding income constant, reduces mother's time in income-generating activities, increases her time in household production and has an ambiguous effect on child labor. This is because, for a compensated increase in wages, fathers increase market labor supply and reduce household labor supply. With a utility function concave in x and z, total household utility can be increased by reallocating mother's labor from the wage sector to the household. The effect on child labor is ambiguous because an increase in child labor has both a direct negative effect on parents' utility and an indirect positive effect through the increase in y. An increase in father's wages, holding his household labor fixed, will also lead to a reduction in mother's work hours and increase in her household work. That is, mothers will shift time from market to household work because fathers are able to purchase a larger quantity of private goods with the same quantity of market labor hours. Conversely, the same increase in father's wages will unambiguously reduce child labor, as long as child leisure is normal good. In both cases, the net effect on mothers' leisure will depend on the elasticity of substitution between public and private goods. Finally, an increase in father's bargaining power, holding his wage and household labor fixed, reduces child labor and causes mothers to shift time away from income-generating activities into household production.

	Child's Hh labor	Mother's Hh labor	Mother's income generating work
Reduction in time available for household production	+/−	+	−
Increase in household income	−	+	−
Increase in father's bargaining power	−	+	−

Note that, because child labor enters each parent's utility function directly, the reduction in time available for household production will generate an increase in child labor if, and only if, it is accompanied by an increase in mothers' household labor. Thus, a reduction in mother's household labor coupled with an increase in child labor can only be consistent with a cooperative model of the household if migration is associated with lower income and/or greater bargaining power for mothers. Migration can increase the mother's bargaining power if her threat point is defined by a non-cooperative outcome within marriage because, while away, husbands must rely on their wives for provision of child quality. Alternatively, if migration occurs in response to a negative shock, father's wages may be lower during the migration episode, even though migration leads to higher wages compared to the counterfactual of not migrating. In the absence of saving/borrowing, the household may also have to absorb some fixed costs associated with migration, necessitating a reallocation of time among mothers and children. Zhao (1999) computes the average explicit costs of migration in 1995 as 721.7 yuan, based on a survey of migrant workers conducted by China's Ministry of Labor.[6] This is equivalent to roughly 6.5% of average nominal household income for CHNS households in 1997 and 12.5% of average nominal household income in 1993.

However, in all cases, we should also observe an increase in mother's time in income-generating activities (see Technical appendix, Part A). And, in the case of an increase in mothers' bargaining power, we should also observe increased consumption of other goods favored by the mother, such as children's human capital.[7] Qian (2008) finds that, among farm households in China, an exogenous increase in the share of female income has a significant positive effect on educational attainment for all children, whereas increasing the share of male income reduces educational attainment for girls. Chen (2012) finds that girls' school enrollment increases relative to boys' when mothers have increased bargaining power, and Duflo (2003) and Thomas (1990) find that an increase in female income improves health outcomes for all children, with a disproportionate effect on girls.[8] In contrast, the non-cooperative model indicates that allocations chosen by the mother will be constrained by the probability that her actions are detected. Thus, because changes in human capital are easy to detect, the mother will not alter her overall consumption of these goods, even though doing so would increase her utility (but not her expected payoff).

3.1. Data and empirical specification

Data are drawn from the China Health and Nutrition Survey (CHNS), which includes roughly 4000 households (15,000 individuals), drawn from nine diverse provinces. The sample of interest is

[6] Includes average transportation costs of 498.6 yuan, and registration fees (obtaining various certificates and cards) of 223.1 yuan.

[7] These two claims are not inconsistent; they simply imply that, while mothers have higher disutility for own labor than for child labor, they are still willing to substitute own consumption of market goods for investments in children's human capital.

[8] While it remains unclear whether these findings are indicative of preferences for children's human capital *per se* (*e.g.*, because children's human capital also serves as an investment and women typically have longer horizons), we can conclude that, when given the opportunity, and where saving and retirement options are limited, women prefer to spend more on children's human capital.

households with at least one child between the ages of 6 and 16 in which both spouses are typically co-resident. Households were first surveyed in 1989, with follow-ups in 1991, 1993, 1997 and 2000. The timing of the survey is well-suited for the study of migration, as the 1990s were a period of rapid growth in intra-national labor migration. Using population surveys, Liang and Ma (2004) find that the number of inter-county migrants in China increased from 20 million in 1990 to 45 million in 1995 and 79 million in 2000. This was, in large part, due to a relaxation of migration restrictions in 1988, which allowed individuals to obtain legal temporary residence in other localities. Increased openness and marketization in the 1990s also spurred economic growth, which increased the demand for construction and service workers in urban areas (de Brauw and Giles, 2006).

Migrants are defined as individuals living away from the household for at least one full month during the previous year. The sample of migrant-sending households is further limited to those in which the father was away for all seven days in the week prior to enumeration, because most outcomes of interest are defined over the previous week. Descriptive statistics are presented in Tables 1 through 3, with observations at the person-year or household-year level. Differences in observable characteristics between migrant and non-migrant households are minor, both prior to and during the migration episode. Note that we do not observe all migrant households prior to migration because some episodes occur in the first survey for the household (1989 or 1997/2000 for newly added households), and roughly half of the migrant sample reports being away in multiple surveys but only one "pre" period is included. Daughters in migrant households are somewhat more likely to be enrolled in school and have slightly lower calorie and protein intake. The migrants themselves appear to be somewhat positively selected on schooling, as are their spouses, although this may reflect increasing migration rates among younger cohorts. And, as would be expected, migrant households have higher household income and wages but hold less value in productive assets, on average. Interestingly, fathers are less

Table 1
Characteristics of children aged 6–16 by gender and migrant status.

	Father never migrates		Before migration		Father currently away	
	Sons	Daughters	Sons	Daughters	Sons	Daughters
Age	11.28	11.40	11.39	10.69 *	11.63	11.50
	(3.093)	(3.074)	(3.265)	(3.165)	(3.131)	(3.121)
School enrollment	0.861	0.827	0.877	0.822	0.893	0.884 **
	(0.346)	(0.378)	(0.331)	(0.385)	(0.310)	(0.321)
Do laundry for the Hh	0.073	0.187	0.075	0.147	0.084	0.173
	(0.259)	(0.390)	(0.265)	(0.357)	(0.278)	(0.379)
Prepare food for the Hh	0.057	0.117	0.062	0.099	0.087	0.130
	(0.231)	(0.321)	(0.242)	(0.300)	(0.283)	(0.338)
Buy food for the Hh	0.024	0.032	0.000 ***	0.081	0.021	0.041
	(0.153)	(0.176)	(0.000)	(0.275)	(0.143)	(0.198)
Do any chores (buy/prep food or laundry)	0.115	0.228	0.065	0.088	0.125	0.209
	(0.319)	(0.420)	(0.248)	(0.284)	(0.332)	(0.408)
Engage in other work	0.063	0.077	0.096	0.230	0.043	0.068
	(0.243)	(0.267)	(0.297)	(0.424)	(0.203)	(0.252)
Body mass index	17.41	17.58	17.29	17.18	17.20	18.01
	(2.667)	(2.761)	(2.408)	(3.090)	(2.459)	(2.686)
Daily calorie intake	1841	1706	1751	1660	1838	1621 *
	(603.7)	(535.5)	(663.4)	(466.4)	(551.3)	(534.0)
Daily protein intake	62.07	57.84	57.88	55.12	63.85	53.60 **
	(22.92)	(20.95)	(23.52)	(18.88)	(21.77)	(18.16)
Months away in the year					6.681	6.340
					(3.908)	(3.923)
Number of observations	4474	4116	92	80	210	162

Notes: standard deviations reported in parentheses. (*) indicates significant difference from column [1] or column [2] at the 10%, (**) 5% or (***) 1% level. Observations at the person-year level.

Table 2
Characteristics of households by father's migrant status.

	Never migrates	Before migration	Currently away
Household size	4.31	4.30	4.11 ***
	(1.11)	(0.94)	(0.97)
Number of children	2.11	2.15	2.00 *
	(0.938)	(0.897)	(0.923)
Sex ratio of children	0.543	0.529	0.577
	(0.358)	(0.359)	(0.361)
% with only one child	0.278	0.250	0.318
	(0.448)	(0.435)	(0.467)
Mother's age	38.32	37.72	38.20
	(6.38)	(6.18)	(6.07)
Father's age	40.24	39.39	39.95
	(7.02)	(5.95)	(6.60)
Mother's schooling	5.65	5.35	6.20 **
	(4.13)	(3.88)	(3.74)
Father's schooling	7.54	7.52	7.90 *
	(3.50)	(2.97)	(3.03)
Mother's wage	9.09	7.11 ***	9.15
	(12.79)	(5.54)	(9.44)
Father's wage	11.83	12.09	15.24 ***
	(21.40)	(16.85)	(15.55)
Area of owned home	66.77	74.41	66.20
	(55.26)	(58.66)	(51.87)
Farm land	3.64	3.04 **	3.12
	(8.80)	(3.01)	(6.66)
Value of business equip.	227.5	114.1	58.77 ***
	(2588)	(555)	(388)
Adj. per capita Hh income	1344	1429	1590 ***
	(1053)	(1121)	(1052)
Months away in the year			6.61
			(3.88)
Number of observations	5625	116	262

Notes: standard deviations reported in parentheses. (*) indicates significant difference from column [1] at the 10%, (**) 5% or (***) 1% level.
Observations at the household-year level.

Table 3
Parents' outcomes of interest by migrant status.

	Never migrates	Before migration	Currently away
Mothers			
Total work hours (excl. household chores)	44.80	50.32 *	45.45
	(27.52)	(29.42)	(29.24)
Do laundry for the Hh	0.914	0.948	0.935
	(0.280)	(0.222)	(0.247)
Prepare food for the Hh	0.912	0.922	0.939 *
	(0.284)	(0.269)	(0.240)
Buy food for the Hh	0.615	0.623	0.760 ***
	(0.487)	(0.487)	(0.428)
Do any chores (buy/prep food or laundry)	0.974	0.966	0.973
	(0.158)	(0.183)	(0.162)
Body mass index	22.41	22.29	22.31
	(2.96)	(2.67)	(2.84)
Daily calorie intake	2110	2205	2034 *
	(595)	(632)	(626)
Daily protein intake	70.55	71.48	68.29
	(22.01)	(21.49)	(22.05)
Fathers			
Do laundry for the Hh	0.142	0.119	
	(0.349)	(0.326)	
Prepare food for the Hh	0.240	0.133 ***	
	(0.427)	(0.341)	
Buy food for the Hh	0.408	0.381	N/A
	(0.491)	(0.488)	
Do any chores (buy/prep food or laundry)	0.500	0.425	
	(0.500)	(0.497)	
Number of observations	5625	116	262

Notes: standard deviations reported in parentheses. (*) indicates significant difference from column [1] at the 10%, (**) 5% or (***) 1% level.
Observations at the person-year level.

likely to be engaged in household chores prior to migration, while mothers are more likely to be buying and preparing food when the father is absent.

Attrition at the household level is less than 5% between waves, and new households were added in 1997 and 2000, to replace both households and communities no longer participating. Raw attrition rates for individuals are somewhat higher, and notably more so for those in migrant households; roughly 8% of children in non-migrant households attrite in the following wave, compared to 18% of those in migrant households. However, controlling for observable characteristics (age; sex; parents' ages, schooling and wages; household size; value of assets owned; adjusted per capita household income; survey month and year) as well as unobserved community-year fixed effects, neither migration nor the duration of migration episodes exhibits a statistically significant relationship with attrition in the following wave (see Table A1).

I first estimate reduced-form demand equations for household labor. For individual i in household j in community k at time t, the demand for labor in activity y can be expressed as

$$y_{ijkt} = \alpha + \beta \cdot h_{jkt} + \phi \cdot c_{ijkt} + \delta \cdot away_{jkt} + \rho \cdot f\left(months\ \ away_{jkt}\right) + \pi_t + \xi_{ijkt} \tag{5}$$

where $\xi_{ijkt} = \upsilon_{ijk} + \eta_{kt} + \varepsilon_{ijkt}$. The error term consists of three components — a person-specific effect that is fixed over time (υ), a community-level effect that varies across periods (η), and a mean-zero i.i.d. disturbance (ε). h is a vector of time-varying household characteristics, c is a vector of individual covariates, and π is a period effect. Migration is also allowed to affect boys and girls differentially, with $\delta = \delta_0 + (Girl_{ijk} {}^* \delta_g)$ and $\rho = \rho_0 + (Girl_{ijk} {}^* \rho_g)$. The panel nature of the data allows for inclusion of individual and community-year fixed effects to account for unobserved time-invariant characteristics of the household and/or child as well as unmeasured local economic shocks that may influence the migration decision.

Additional control variables include a quadratic in age, parents' ages (for child-level regressions), parents' wages,[9] assets owned (farm land, farming equipment, value of small business capital and area of owned home),[10] household size, number of children (number of siblings for child-level regressions), the sex composition of children (siblings), as well as month of survey. Parents' schooling attainment changes very little over time and is therefore subsumed into the fixed effect. A quadratic in the months the father is away is included because the allocation of household labor may require some time to adjust. For example, where learning is required, there may be fixed costs involved with reallocating labor. Second, the wage variables reflect labor market opportunities available at the time of the survey. If migrants earn higher wages only while living away from home, including higher-order measures of the duration of migration episodes will better control for changes in total household income. Additionally, the duration of the migration episode may affect the scope for or cost of monitoring.

[9] Wages for migrants are reported by spouses and may, therefore, reflect non-cooperative behavior on the part of the migrant in the form of hidden income. In this case, the empirical specification estimates the *net* effect of asymmetric information, including both proactive and reactive non-cooperative behavior on the part of the non-migrant.

[10] Although individual-level fixed effects (mother-level fixed effects, in the case of mothers' outcomes) are included, asset holdings may still be endogenous if they reflect a response to household-specific, time-varying shocks. Using the lagged value of the asset variables does not affect the main results (not reported).

Table 4
Time allocation for children aged 6–16, child-fixed effects estimates.
(Source: China Health and Nutrition Survey, 1989–2000, UNC Carolina Population Center.)

	I	II	III	IV
	Do laundry	Prepare food	Buy food	Other work[a]
Father away	0.149	0.151	−0.036	−0.025
	(0.116)	(0.106)	(0.034)	(0.063)
Months father away	−0.067	−0.044	0.027	0.014
	(0.044)	(0.043)	(0.018)	(0.022)
Months away squared	0.005	0.003	−0.002	−0.002
	(0.003)	(0.003)	(0.001)	(0.002)
Relative effect for girls				
Father away	−0.312 **	−0.202	−0.077	0.207
	(0.146)	(0.124)	(0.080)	(0.131)
Months father away	0.169 **	0.051	0.001	−0.067
	(0.066)	(0.055)	(0.042)	(0.043)
Months away squared	−0.013 **	−0.002	0.000	0.005
	(0.005)	(0.004)	(0.003)	(0.003)
Marginal effects for boys				
3 months away	−0.003	0.043	0.027	0.001
6 months away	−0.060	−0.015	0.058 *	−0.005
10 months away	0.012	−0.016	0.048 **	−0.062 *
Marginal effects for girls				
3 months away	0.070	−0.024	−0.050	0.049
6 months away	0.156 *	0.016	−0.028	−0.034
10 months away	0.043	0.091	−0.061	−0.065 *
Number of observations	8329	8476	8723	9794

Notes: robust standard errors reported in parentheses. (*) indicates significance at the 10%, 5% (**) or 1% (***) level. Includes controls for age of parents, assets owned, household size, parents' wages, month and year of survey, and community-year fixed effects.
[a] Includes work on the family farm or garden, livestock care, fishing and handicrafts.

3.2. Main results

Table 4 presents the child-fixed effects estimates of the effect of migration on the probability of doing household chores (purchasing food, preparing food, or doing laundry) for children aged 6 to 16. Unfortunately, more detailed data on the amount of time spent on each household chore was collected inconsistently across waves and thus cannot be used in this analysis. For laundry and food preparation, the "level" effect of having a migrant father is positive, but the length of time the father is away has the opposite effect. That is, when the father initially leaves the household, children must take on more chores. When the father remains away for a longer period of time, they are relieved of some of these tasks as total demand for household production falls. However, relative effects for girls are opposite in sign; girls are initially less likely to do chores when the father is away but, if the father is away for at least four months, the probability of doing chores is significantly greater for girls with migrant fathers than for boys. Point estimates are significant only for girls' laundry (see also Chen, 2006) but are quite large in magnitude — if the father is away for six months, the probability that daughters do laundry is 15.6 percentage points higher, compared to the baseline in which approximately 18.7% of girls do laundry. I also find positive and significant marginal effects for boys in food purchase, although the estimated coefficients are not statistically significant. Again, the marginal effects are quite large — an increase of 5.8 percentage points compared to the baseline in which only 2.4% of boys report buying food for the household.

Additionally, I look at the probability that children engage in "other" work (gardening, household farming, livestock care, fishing, handicrafts), to check for offsetting changes in time allocation (Table 4, Column IV). None of the coefficients in this specification are statistically significant, although they are opposite in sign to those for girls' laundry and boys' food purchase, exactly the chores

Table 5
Mothers' time allocation, mother-fixed effects estimates.
(Source: China Health and Nutrition Survey, 1989–2000, UNC Carolina Population Center.)

	I	II	III	IV
	Do laundry	Prepare food	Buy food	Work hours[a]
Father away	0.067	0.105 **	0.125	12.19 *
	(0.049)	(0.050)	(0.132)	(7.295)
Months father away	−0.041 *	−0.045 **	−0.033	−5.579 **
	(0.023)	(0.021)	(0.046)	(2.810)
Months away squared	0.003	0.003 **	0.003	0.459 **
	(0.002)	(0.002)	(0.003)	(0.218)
Marginal effects				
3 months away	−0.029	−0.002	0.051	−0.424
6 months away	−0.074 **	−0.054	0.028	−4.780
10 months away	−0.054 *	−0.037	0.074	2.258
Number of observations	6436	6430	6440	5996

Notes: robust standard errors reported in parentheses. (*) indicates significance at the 10%, 5% (**) or 1% (***) level. Includes controls for own and husband's age and wages, assets owned, household size, month and year of survey, and community-year fixed effects.

[a] Includes work for wages, on the family farm/garden, livestock care, fishing and handicrafts.

for which significant increases are evident. And marginal effects are significant at the 10% level when the father is away for at least ten months. However, the largest marginal effects for laundry and food purchase are observed for shorter migration episodes, around six months; changes in other work activities do not appear to coincide with or fully offset changes in household chores. Of course, with such coarse measures of time allocation, it is difficult to rule out offsetting changes in time allocation on intensive margins; I return to this issue in Section 4.

Table 5 presents estimates of the effect of migration on mothers' time allocation (see also Chen, 2006). The probability that mothers do each chore initially increases when the father is away but is decreasing in the number of months away. The effect of months away dominates the "level" effect of migration once the father is away for at least three months. Point estimates are statistically significant for laundry and food preparation, although the marginal effects are relatively small, given that 90% of mothers report doing these tasks. Estimates for mothers' total hours in income-generating activities (wage labor plus "other" non-wage activities such as gardening, household farming, livestock care, fishing, or handicrafts) are similar in sign and significance. Migration of the father initially increases mothers' work hours, but months away has an offsetting effect that again dominates once the father has been away for at least three months. Although the marginal effects are imprecise, they point to as much as a 10% reduction in mothers' work hours.

Taken together, the estimates in Table 5 clearly indicate that, for sufficiently long migration episodes, mothers reduce their time in both household chores and income-generating activities. An increase in mother's leisure, by itself, is not inconsistent with migration in a cooperative household, as leisure is a normal good. Migration may also reduce total demand for household production, reducing demand for mothers' time. However, the reduction in mother's labor hours *combined* with an increase in child labor hours is not consistent with migration in a cooperative model of the household. Moreover, because mothers reduce time in both chores and income-generating activities, the net reduction in their labor hours is almost certainly greater than that for children, even if the increase in children's chores is offset by a reduction in income-generating activities.

First, if migration reduces demand for household production, then both mothers and children should experience a reduction in household labor. Second, if household income is lower during the migration episode (*e.g.*, due to an adverse shock), mothers should increase time in income-generating activities as they shift responsibility for household chores to their children. Alternatively, if migration increases income, it becomes possible to increase mother's household labor while reducing child labor and increasing or maintaining household production as well as mother's utility (via a reduction in market labor hours and/or increase in private consumption). As long as fathers receive greater disutility from child labor than from mothers' labor, a cooperative allocation would not include an increase in child labor without a simultaneous increase in mother's household labor, even when mothers enjoy an increase in leisure.

An increase in mother's bargaining power is also inconsistent with the estimated changes in time allocation, as greater bargaining power would cause the mother to *shift* time away from household production and into income-generating activities, not to reduce time in both. Additionally, we can look at other goods for which mothers may have stronger preferences: child schooling and health. The "level" effect of migration on school enrollment is positive and statistically significant, but the effect of months away is negative and significant (Table 6, column I). Relative effects for girls are opposite in sign and not statistically significant. Overall, marginal effects are very small in magnitude, given that well over 80% of children in this age group are enrolled in school, and generally negative. This may be indicative of learning or network effects; as the father spends more time as a migrant worker, his children receive new information about earnings and work opportunities and/or gain access to denser social networks that aid in the job search process (see de Brauw and Giles, 2006).

Migration is also found to have no statistically significant effects on children's body mass (Table 6, column II), and the marginal effects are again very small: for a 4-foot tall child with BMI in the normal range (approximately 60 lbs), a half point change in BMI is equivalent to change in weight of approximately 1.5 lbs. Recall that controls for wages are included, so the coefficients should be interpreted as effects of migration *net* of income effects. Given findings in other studies, the observed stability in child health and perhaps modest decline in school

Table 6
Human capital for children aged 6–16, child-fixed effects estimates.
(Source: China Health and Nutrition Survey, 1989–2000, UNC Carolina Population Center.)

	I	II
	School enrollment	Body mass index
Father away	0.158 *	0.195
	(0.095)	(0.395)
Months father away	−0.069 *	0.112
	(0.038)	(0.173)
Months away squared	0.006 **	−0.018
	(0.003)	(0.015)
Relative effect for girls		
Father away	−0.120	−0.572
	(0.136)	(0.749)
Months father away	0.034	−0.007
	(0.053)	(0.313)
Months away squared	−0.003	0.008
	(0.004)	(0.027)
Marginal effects for boys		
3 months away	0.007	0.367
6 months away	−0.038	0.214
10 months away	0.070	−0.497 *
Marginal effects for girls		
3 months away	−0.037	−0.157
6 months away	−0.057	−0.127
10 months away	0.001	−0.382
Number of observations	9056	6121

Notes: robust standard errors reported in parentheses.
(*) indicates significance at the 10%, 5% (**) or 1% (***) level.
Includes controls for age of parents, assets owned, household size, parents' wages, month and year of survey, and community-year fixed effects.

enrollment are not consistent with a model in which mothers' bargaining power increases when fathers migrate. Of course, it is difficult to rule out the possibility that this is a full-information environment and, as part of the migration bargain, mothers simply negotiate to shift household chores from themselves to their children. However, given that migration has essentially no effect on child health and schooling, this could only be the case if, for mothers, the marginal utility of child health and schooling and the marginal disutility of child labor are very low relative to the marginal utility of own leisure.

4. Robustness and extensions

The results presented above cannot be explained by standard co-operative models of the household. Non-migrant spouses reduce own labor hours and increase child labor, and this cannot be attributed to an increase in mother's bargaining power because child schooling and health, goods found to be preferred by mothers, do not increase with migration, conditional on income. Nor can the results be explained by a negative income shock precipitating migration, as this would prompt an increase in mothers' income-generating activities, not a reduction. The observed pattern is, however, consistent with the non-cooperative model described in Section 2. In an environment of asymmetric information, migration causes allocations to shift in favor of the non-migrant spouse, irrespective of whether the equilibrium is cooperative or non-cooperative, and a reduction (increase) in own (child) labor is consistent with the non-migrant's preferences. In this section, I provide checks on the robustness of the results and their interpretation and investigate alternate explanations for the observed changes in time allocation.

4.1. Extensive versus intensive margin

Because migration affects time allocation differentially across tasks, it is difficult to conclude, based solely on evidence from extensive margins, that children's (mothers') labor hours have increased (decreased) on the whole. In the absence of reliable data on time allocation, we can, instead, examine data on nutritional intake, as a proxy for energy expenditure. That is, an increase in the time devoted to household activities (provided they require some physical exertion) should be accompanied by either an increase in nutritional intake or a reduction in body mass (Foster and Rosenzweig, 1994). Recall, from Table 6, that migration has no significant effect on children's BMI, with the exception of a modest decline for boys facing long (10 months) migration episodes. Changes in activities should, therefore, be evident in nutritional intake. Table 7 presents estimates of the effect of migration on children's calorie and protein intake. For these specifications, age effects are also allowed to vary with father's migrant status to allow for changes in the health production function throughout adolescence.

Migration of the father significantly increases calorie and protein consumption for girls, with the opposite effect for boys. While this need not indicate a reduction in total work time for boys (some household activities may be calorie-saving), an increase in work effort for girls is the only way to reconcile these results with the findings for BMI. Of course, effort and time may not be equivalent but, in a model with several forms of household labor, it seems plausible that parents would receive disutility from both child work time and work effort. Estimates for mothers' health and nutrition are imprecise but point towards, at most, modest declines in BMI and nutritional intake (Table 8). Moreover, the effect is considerably larger for calories than for BMI, suggesting that mothers are reducing their energy expenditure overall.[11] While this, again, is not conclusive evidence of a reduction in mothers' work time, it clearly is not consistent with an increase in mothers' work effort. Thus, changes on the intensive margin, at least with respect to work effort, are consistent with changes on the extensive margins and again point to an increase in children's labor and a reduction in mothers' labor, as predicted by the non-cooperative model.

Table 7
Nutritional intake for children aged 6–16, child-fixed effects estimates.
(Source: China Health and Nutrition Survey, 1989–2000, UNC Carolina Population Center.)

	I	II
	Daily calorie intake	Daily protein intake
Father away	495.7 **	17.66 *
	(218.0)	(9.707)
Months father away	26.45	1.756
	(74.93)	(3.167)
Months away squared	−6.091	−0.276
	(6.517)	(0.263)
(Age-6)*away	−213.4 ***	−10.77 ***
	(77.44)	(3.324)
(Age-6) squared*away	21.34 ***	1.175 ***
	(8.050)	(0.364)
Relative effect for girls		
Father away	−504.8	−10.20
	(360.2)	(14.77)
Months father away	22.48	−2.128
	(118.2)	(4.602)
Months away squared	0.960	0.263
	(8.973)	(0.349)
(Age-6)*away	290.2 ***	12.77 ***
	(111.3)	(4.736)
(Age-6) squared*away	−32.40 ***	−1.538 ***
	(11.78)	(0.486)
Marginal effects for boys[a]		
3 months away	−13.41	−4.057
6 months away	−98.52	−6.233
10 months away	−382.5 ***	−16.85 ***
Marginal effects for girls[a]		
3 months away	198.9	7.113
6 months away	207.1	5.647
10 months away	74.44	3.327
Number of observations	6547	6527

Notes: robust standard errors reported in parentheses.
(*) indicates significance at the 10%, 5% (**) or 1% (***) level.
Includes controls for age of parents, assets owned, household size, parents' wages, month and year of survey, and community-year fixed effects.
[a] Calculated at age 11.

Note also that the effects of migration on child nutrition operate predominantly through age rather than the length of the migration episode, suggesting that, although children of the same gender make similar adjustments on the extensive margin, changes on the intensive margin are more sensitive to productivity, with older girls taking on more work. This pattern also suggests that (endogenous) variation in the duration of migration episodes cannot fully explain the observed changes in time allocation. Moreover, it is clear from Table 7 that mothers do have the scope to adjust children's nutritional intake. That they do so *without* improving children's health (BMI) again suggests that there has not been a change in spousal bargaining power in response to migration.

4.2. Time-varying shocks to the household

The fixed effects estimation strategy sweeps out sources of unobserved heterogeneity that are fixed over time. However, if migration occurs in response to household-specific, time-varying shocks,

[11] For an average-height adult female with BMI in the normal range, a reduction of 100 calories per day, holding activity level constant, would result in an average weight loss of 10 pounds over a year, equivalent to a 1–2 point change in BMI.

Table 8
Mothers' health, mother-fixed effects estimates.
(Source: CHNS, 1989–2000, UNC Carolina Population Center.)

	I	II	III
	Body mass index	Daily calorie intake	Daily protein intake
Father away	0.317	−156.9	−6.087
	0.387	124.9	4.862
Months father away	−0.0709	48.59	2.285
	0.153	57.31	2.051
Months away squared	0.0015	−4.232	−0.202
	0.012	4.576	0.16
Marginal effects			
3 months away	0.118	−49.253	−1.054
6 months away	−0.054	−17.760	0.335
10 months away	−0.242	−94.274	−3.481
Number of observations	5777	6065	6051

Notes: robust standard errors reported in parentheses. (*) indicates significance at the 10%, 5% (**) or 1% (***) level. Includes controls for own and husband's age and wages, assets owned, household size, month and year of survey, and community-year fixed effects.

Table 9
Probability of doing any chores, fixed effects estimates.
(Source: China Health and Nutrition Survey, 1989–2000, UNC Carolina Population Center.)

	I	II	III	IV
	Base sample	Migrant home at survey	Father debilitated	Migrant away multiple times
Mothers				
Father away/sick	0.077 **	−0.008	0.0165	0.113 **
	(0.036)	(0.042)	(0.015)	(0.054)
Months away/days sick	−0.031 *	0.008	0.001	−0.060 **
	(0.016)	(0.021)	(0.002)	(0.027)
Months/days squared	0.002 *	−0.001	0.000	0.004 **
	(0.001)	(0.002)	(0.000)	(0.002)
Number of observations	6450	6405	5396	5604
Children, aged 6–16				
Father away/sick	0.111	−0.004	0.024	−0.056
	(0.121)	(0.115)	(0.040)	(0.224)
Months away/days sick	−0.021	0.008	0.000	−0.002
	(0.047)	(0.052)	(0.005)	(0.085)
Months/days squared	0.001	−0.002	0.000	0.001
	(0.004)	(0.004)	(0.000)	(0.006)
Relative effect for girls				
Father away/sick	−0.284 *	0.155	0.028	−0.204
	(0.154)	(0.151)	(0.066)	(0.265)
Months away/days sick	0.084	−0.094	−0.003	0.091
	(0.070)	(0.070)	(0.008)	(0.113)
Months/days squared	−0.006	0.010 *	0.000	−0.006
	(0.005)	(0.006)	(0.000)	(0.009)
Number of observations	8739	8670	7393	7482

Notes: robust standard errors reported in parentheses. (*) indicates significance at the 10%, 5% (**) or 1% (***) level. Includes controls for age of parents, assets owned, household size, parents' wages, month and year of survey, and community-year fixed effects. Estimates for mothers include mother fixed effects; those for children include child fixed effects.

about any such shock that would precipitate migration, reduce mothers' labor hours and increase child labor. Illness or injury among mothers could do so and, among migrant households, 11% of mothers report an illness or injury sometime within the last four weeks, compared to 7.8% of mothers in non-migrant households. However, this difference is not statistically significant, and fixed effects regressions reveal no significant effect of mothers' illness/injury on child labor, even though there is a negative and statistically significantly effect on mothers' time in both household and income-generating activities (not shown). A negative income shock could also precipitate migration, while causing a reduction in mothers' labor and increase in child labor, but only for household chores, as labor supply in income-generating activities is a common ex post income smoothing mechanism (Kochar, 1999). That is, with a negative income shock, we should observe a shift from household production to income generating activities, rather than the net reduction in mothers' total labor hours shown in Table 5.

Additionally, there may be shocks that affect both the duration of migration episodes and the intra- household allocation of time. For example, households experiencing negative income shocks may engage in shorter migration episodes as a coping mechanism, while households experiencing positive shocks may migrate for longer periods as part of a long-term strategy. However, neither the "level" effects of migration nor the marginal effects of time away are consistent with simple income shocks under full information, as any income shock induces opposite effects on mothers' labor in the household and in income-generating activities. Even with shocks affecting the productivity of labor, we would still expect to see opposite responses in household work and income-generating work, although the effects may be more muted.

As an indirect test for time-varying shocks associated with migration, we can examine the same labor supply decisions among households who have also self-selected into migration but are not being "treated" at the time of the survey (*i.e.*, the father reports being away for at least one month in the previous year but also reports residing in the household for the entire week preceding the survey). Results presented in column II of Table 9 indicate no significant effect of migration on either mothers' or children's household labor when migrant fathers are present. The point estimates are much smaller in magnitude and, in fact, tend be opposite in sign (estimates for specific household chores, not shown, are very similar in sign and significance), compared to the base sample. Moreover, the duration of the migration episode has no significant effect on time allocation, once the episode is complete. Of course, this does not rule out the possibility that the migration episode was sufficient to smooth consumption, in which case any unobserved household-specific time-varying shocks would not have lasting effects on mothers' and children's labor supply once the father has returned home. However, these results do suggest that the estimated changes in labor supply are related specifically to *absence* of the father, rather than just the choice to engage in migration. As there is little to no scope for non-cooperative behavior when the migrant is residing at home, the difference between these estimates and the main results described above provides suggestive evidence of non-cooperative behavior, in addition to validating the fixed effects estimation strategy.

4.3. Non-enumerated household tasks

The time allocation module of the CHNS includes only three specific household chores: laundry, food preparation and food purchase. It may be the case that fathers engage in other household activities that are not enumerated, and migration forces mothers to substitute into these tasks while children substitute for mothers in the enumerated household tasks. To investigate this, I utilize an alternate sample of households in which fathers experience an illness or injury sometime in the four weeks preceding the survey date. If wives of migrants reduce time in laundry, food preparation and food purchase in order to substitute for husbands' time in other, non-enumerated activities, the same reduction should be evident when husbands' household labor is reduced by illness or injury. Moreover, because illness and injury are largely unanticipated, it will be even more difficult for the household to seek alternate smoothing mechanisms, and changes in time allocation should be even more pronounced for this sample than for migrant households. Estimates in Table 9 (column III) indicate that mothers' participation in the three enumerated chores is essentially unchanged when the father is debilitated, and point estimates are very small in magnitude and not statistically significant (estimates for specific chores are very similar and not shown here). For both boys and girls, the probability of doing any household chores is increased by illness/injury of the father, although estimates are quite small in magnitude and not statistically significant. There is, however, a positive and statistically significant effect on food purchase for both boys and girls (not shown), which is precisely the chore that fathers report most frequently.

Of course, illness and injury affect other aspects of the intra-household allocation process as well. However, the large majority of illnesses and injuries appear to be temporary; less than 30% are reported as "quite severe" (versus "not severe or "somewhat severe"), and only one-third report being debilitated for more than two weeks. Temporary conditions are less likely to affect consumption and allocation patterns via income or household bargaining, given sufficient access to smoothing mechanisms. Still, fathers who are temporarily debilitated can, in many cases, continue to engage in childcare, whereas migrant fathers cannot. If housework and childcare are complements, the changes observed for the migrant sample may simply reflect the fact that mothers must include children in household chores in order to provide the necessary amount of childcare when the father is absent. Under this hypothesis, children of both genders should be equally affected, assuming boys and girls of the same age require the same level of supervision. However, I find that migration affects time allocation for boys and girls differentially, both within and across chores. Thus, while the absence of the father clearly necessitates some reallocation of time, neither the presence of unenumerated chores nor the complementarity between household chores and childcare can fully explain the observed effect of migration on mothers' and children's time allocation.

4.4. Selection on propensity to cooperate

To determine the generality of the main results, I further restrict the sample of migrant households to those in which the father migrates in multiple survey periods. If migration is less likely to occur in households with strong tendencies towards non-cooperation, households in the restricted sample should exhibit a lesser degree of non-cooperative behavior and therefore smaller changes in time allocation. In fact, we see the opposite (column IV, Table 9); the negative effect of months away on mothers' household labor is statistically significant and nearly twice as large. Estimates for children are lacking in precision, as they are for the main sample, but display the same sign pattern and are similar in magnitude (estimates for specific household chores are similar and not presented here). Taken together, these findings suggest that repeat migration may, in fact, increase the scope for non-cooperative behavior.

4.5. Relaxing the assumptions of the model

The utility received from certain goods may depend upon the time spent physically in the home, leading the same individual to have different preferences when he/she is home and away. Allowing for this possibility does not alter the theoretical implication that mother's household labor should increase in the event of migration (see Technical appendix). Intuitively, this is because migration increases income and consumption of private goods, and the household re-optimizes by shifting labor hours away from market activities and towards household production. However, with the migrant away and unable to engage in household production, mothers' time allocation is the only margin available for adjustment. Even allowing children to engage in market labor, migration still leads to an increase in mothers' household labor, as long as child labor yields greater disutility to each parent than does his/her spouse's labor. For the same reasons, allowing market goods to either substitute for or be used in the production of household public goods also does not change the main theoretical implication. Market substitutes may allow for a decrease in mother's household labor, but an increase in mother's household labor should, nevertheless, always precede an increase in child household labor. Allowing borrowing/saving in the model would relax resource constraints, assuming market substitutes for household production are available, permitting a reduction in labor hours for *both* mothers and children as they utilize the migrant's future earnings to offset the current reduction in his household labor hours.

Allowing for complementarities in the household production function also does not affect the main implications of the cooperative model, as long as the complementarities are relatively weak (see Technical appendix). Specifically, if mothers and fathers are strong complements in the household production process, it is possible that migration of the father can lead to a reduction in mother's household work. Unfortunately, the CHNS data are not sufficiently detailed to permit direct estimation of the production function, although descriptive statistics can provide some suggestive evidence. In non-migrant households, roughly 50% of fathers report doing any of the three enumerated chores compared to 97% of mothers (see Table 3). Even for the task that fathers participate in most frequently, purchasing food for the household, only 41% of fathers engage in this activity compared to 61% of mothers, and in only 21% of households do both parents report doing this task. These numbers do not point to strong complementarities in household production; moreover, when the father migrates, food purchase is the one chore for which mothers' time allocation is unaffected. For food preparation, there may be more evidence of complementarity: 20% of mothers and fathers report doing this activity jointly, while only 4% of fathers report doing the activity alone. However, food preparation is the one chore for which migration has no significant effect on children's time allocation, which suggests that complementarities in household production cannot explain the main results.

5. Conclusion

Non-cooperative behavior among spouses is common in anecdotes but difficult to identify in typical survey data. In this paper, I use the incidence of migration to examine such behavior. Migration by one spouse presents a clear opportunity for non-cooperation by introducing imperfect monitoring and increasing the transaction costs associated with enforcing a cooperative equilibrium. I find evidence of non-cooperative behavior, even after accounting for household and child fixed effects, as well as time-varying local economic shocks. Husbands may be able to account for the information asymmetry and achieve cooperative arrangements that are incentive-compatible, but the observed outcomes still reflect the scope for non-cooperation. In particular, the burden of household production is partially shifted from mothers to children when the father migrates. Calories and protein are also redistributed, in order to maintain observable health outcomes. This may be done either to limit the probability that non-cooperative behavior is detected, or because of parents' joint preferences for child quality/health.

The observed changes in household labor are not consistent with a simple reallocation of time in order to compensate for the father's absence, nor are they consistent with a pure income effect. Migration of one spouse in an environment of perfect information should not induce an increase in child labor without a corresponding increase in mothers' time in either household production or income-generating activities, given some basic assumptions about preferences. The changes in time allocation are also inconsistent with an increase in mother's bargaining power, given the stability in children's health and schooling. The conclusion of non-cooperative behavior – either in equilibrium or simply as a threat – is robust to alternative interpretations: (1) time-varying shocks to the household that precipitate migration and/or affect the duration of migration episodes, (2) an increase in the demand for mothers' time in non-enumerated household tasks, and (3) self-selection of migrants on the propensity for non-cooperative behavior, as well as to relaxing assumptions about the utility and production functions.

Increasing opportunities for international migration will exacerbate informational asymmetries. To the extent that this information problem constrains the allocation of remittance income, non-cooperative behavior may generate inefficiencies in investment and hinder growth. Future research should consider the effect of non-cooperative behavior on a broader range of allocations which have more direct implications for economic growth (*e.g.*, schooling-related expenditures and investments in income-generating activities), as well as the scope for non-cooperative behavior on the part of the migrant.

Appendix A

Table A1
Survey attrition, conditional logit estimates.
(Source: China Health and Nutrition Survey, 1989–2000, UNC Carolina Population Center.)

	Boys		Girls		Household	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Father away	1.102	(0.886)	1.021	(0.901)	0.802	(0.737)
Months away in the year	−0.109	(0.133)	−0.036	(0.129)	−0.022	(0.102)
Age	−0.018	(0.052)	0.022	(0.049)		
Mother's age	−0.004	(0.038)	0.024	(0.042)	0.003	(0.032)
Father's age	0.024	(0.035)	−0.041	(0.039)	−0.004	(0.029)
Mother's schooling	0.029	(0.035)	−0.001	(0.033)	0.002	(0.028)
Father's schooling	−0.010	(0.037)	−0.027	(0.036)	−0.006	(0.030)
Father's wage	0.007	(0.012)	0.003	(0.006)	0.004	(0.006)
Mother's wage	−0.005	(0.013)	0.000	(0.011)	−0.005	(0.008)
Area of owned home	0.001	(0.002)	0.000	(0.002)	0.000	(0.002)
Farm land	−0.080	(0.041) *	−0.033	(0.033)	−0.038	(0.030)
Tractor	0.336	(0.547)	−0.915	(0.724)	0.034	(0.512)
Walking tractor	−0.150	(0.507)	−0.961	(0.530) *	−0.569	(0.445)
Irrigation equipment	−0.478	(0.685)	1.012	(0.609) *	0.562	(0.550)
Threshing equipment	0.158	(0.646)	0.259	(0.494)	0.308	(0.423)
Pump	0.134	(0.443)	−1.213	(0.539) **	−0.091	(0.387)
Value of business equip.	0.172	(0.061) ***	−0.037	(0.044)	0.003	(0.018)
Adj. per capita Hh income	0.037	(0.114)	0.061	(0.101)	0.125	(0.086)
Household size	−0.109	(0.141)	−0.087	(0.132)	−0.039	(0.112)
1991	4.979	(0.662) ***	3.990	(0.579) ***	5.090	(0.567) ***
1993	6.719	(0.694) ***	6.227	(0.612) ***	7.366	(0.596) ***
1997	3.483	(0.709) ***	3.423	(0.632) ***	3.465	(0.608) ***

All specifications include controls for month of survey and community-year fixed effects.

Technical appendix

B.1. Full information

B.1.1. First order conditions

$$\lambda\frac{\partial U_m}{\partial t_m}+(1-\lambda)\frac{\partial U_n}{\partial x_n}w_m=0$$

$$\frac{\partial U_n}{\partial t_n}+\frac{\partial U_n}{\partial x_n}w_n=0$$

$$\lambda\frac{\partial U_m}{\partial x_m}-(1-\lambda)\frac{\partial U_n}{\partial x_n}=0$$

$$\lambda\left(\frac{\partial U_m}{\partial t_m}+\frac{\partial U_m}{\partial z}\frac{\partial z}{\partial t_m^h}\right)+(1-\lambda)\left(\frac{\partial U_n}{\partial z}\frac{\partial z}{\partial t_m^h}\right)=0$$

$$\lambda\left(\frac{\partial U_m}{\partial z}\frac{\partial z}{\partial t_n^h}\right)+(1-\lambda)\left(\frac{\partial U_n}{\partial t_n}+\frac{\partial U_n}{\partial z}\frac{\partial z}{\partial t_n^h}\right)=0$$

$$\lambda\left(\frac{\partial U_m}{\partial t_k}+\frac{\partial U_m}{\partial z}\frac{\partial z}{\partial t_k}\right)+(1-\lambda)\left(\frac{\partial U_n}{\partial t_k}+\frac{\partial U_n}{\partial z}\frac{\partial z}{\partial t_k}\right)=0$$

B.1.2. Assumptions

(1) All goods separable in utility.
(2) No complementarities in household production.

Let D denote the determinant of the Hessian, and define its elements as

$$s_{11}=\lambda\frac{\partial^2 U_m}{\partial {t_m}^2}+(1-\lambda)\frac{\partial^2 U_n}{\partial {x_n}^2}w_m^2<0$$

$$s_{12}=(1-\lambda)\frac{\partial^2 U_n}{\partial {x_n}^2}w_m w_n<0$$

$$s_{13}=-(1-\lambda)\frac{\partial^2 U_n}{\partial {x_n}^2}w_m>0$$

$$s_{14}=\frac{\partial^2 U_m}{\partial {t_m}^2}<0$$

$$s_{22}=\frac{\partial^2 U_n}{\partial {t_n}^2}+\frac{\partial^2 U_n}{\partial {x_n}^2}{w_n}^2<0$$

$$s_{23}=-\frac{\partial^2 U_n}{\partial {x_n}^2}w_n>0$$

$$s_{25}=\frac{\partial^2 U_n}{\partial {t_n}^2}\mu_n<0$$

$$s_{33}=\lambda\frac{\partial^2 U_m}{\partial {x_m}^2}+(1-\lambda)\frac{\partial^2 U_n}{\partial {x_n}^2}<0$$

$$s_{44}=\lambda\left[\frac{\partial^2 U_m}{\partial {t_m}^2}+\frac{\partial^2 U_m}{\partial z^2}\left(\frac{\partial z}{\partial t_m^h}\right)^2+\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial {t_m^h}^2}\right]+(1-\lambda)\left[\frac{\partial^2 U_n}{\partial z^2}\left(\frac{\partial z}{\partial t_m^h}\right)^2+\frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial {t_m^h}^2}\right]<0$$

$$s_{45}=\lambda\left(\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h}\right)+(1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h}\right)<0$$

$$s_{46}=\lambda\left(\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_k}\right)+(1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_k}\right)<0$$

$$s_{55}=\lambda\left[\frac{\partial^2 U_m}{\partial z^2}\left(\frac{\partial z}{\partial t_n^h}\right)^2+\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial t_n^{h2}}\right]+(1-\lambda)\left[\frac{\partial^2 U_n}{\partial {t_n}^2}+\frac{\partial^2 U_n}{\partial z^2}\left(\frac{\partial z}{\partial t_n^h}\right)^2+\frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial t_n^{h2}}\right]<0$$

$$s_{56}=\lambda\left(\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_n^h}\frac{\partial z}{\partial t_k}\right)+(1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_n^h}\frac{\partial z}{\partial t_k}\right)<0$$

$$s_{66}=\lambda\left[\frac{\partial^2 U_m}{\partial {t_k}^2}+\frac{\partial^2 U_m}{\partial z^2}\left(\frac{\partial z}{\partial t_k}\right)^2+\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial {t_k}^2}\right]+(1-\lambda)\left[\frac{\partial^2 U_n}{\partial {t_k}^2}+\frac{\partial^2 U_n}{\partial z^2}\left(\frac{\partial z}{\partial t_k}\right)^2+\frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial {t_k}^2}\right]<0$$

$$s_{15}=s_{16}=s_{24}=s_{26}=s_{34}=s_{35}=s_{36}=0$$

$$\left.\frac{dt_m^h}{dw_m}\right|^{compensated}=\frac{1}{D}\Big[\Big((s25s33s56s46-s25s33s66s45)s12+(-s25s56s23s46+s25s66s23s45)s13+\left(s66s33s25^2+s33s56^2s22-s33s66s55s22-s56^2s23^2+s66s23^2s55\right)s14\Big)e\Big]$$

$$\left.\frac{dt_n^h}{dw_m}\right|^{compensated}=\frac{1}{D}\Big[\Big(\left(-s25s33s46^2+s25s33s66s44\right)s12+\left(s25s23s46^2-s25s23s66s44\right)s13+\left(-s23^2s66s45+s33s66s45s22+s46s23^2s56-s46s33s56s22\right)s14\Big)e\Big]$$

$$\left.\frac{dt_k}{dw_m}\right|^{compensated}=\frac{1}{D}\Big[\Big((s25s33s45s46-s25s33s56s44)s12+(-s25s23s45s46+s25s23s56s44)s13+\left(-s46s23^2s55+s23^2s56s45-s33s25^2s46+s46s33s55s22-s33s56s45s22\right)s14\Big)e\Big]$$

$\frac{dt_n^h}{dt_m^h}<0, \frac{dt_k}{dt_m^h}$ *ambiguous*

where $e = -(1-\lambda)\frac{\partial U_n}{\partial x_n}$

$$\left.\frac{dt_n^w}{dw_m}\right|_{t_m^h}^{income} = \frac{1}{D}\left[\left((s12s33\text{–}s13s23\right)\left(s56^2\text{–}s66s55\right)f + \left(-s11s33 + s13^2\right)\left(s56^2\text{–}s66s55\right)g + (s11s23\text{–}s12s13)\left(s56^2\text{–}s66s55\right)i\right]$$

$$\left.\frac{dt_n^h}{dw_m}\right|_{t_m^h}^{income} = \frac{1}{D}\left[\left((s12s25s33\text{–}s13s25s23\right)s66f + \left(-s11s25s33 + s13^2s25\right)s66g + (s11s25s23\text{–} \quad s12s25s13)s66i\right]$$

$$\left.\frac{dt_k}{dw_m}\right|_{t_m^h}^{income} = \frac{1}{D}\left[\left((-s12s25s33 + s13s25s23\right)s56f + \left(s11s25s33\text{–}s13^2s25\right)s56g + (-s11s25s23 + \quad s12s25s13)s56i\right]$$

$$\left.\frac{dt_n^w}{dw_m}\right|_{t_m^h}^{income}<0, \left.\frac{dt_n^h}{dw_m}\right|_{t_m^h}^{income} > 0, \left.\frac{dt_k}{dw_m}\right|_{t_m^h}^{income}<0$$

where $f = -(1-\lambda)\frac{\partial^2 U_n}{\partial {x_n}^2}t_m^w w_m, g = -\frac{\partial^2 U_n}{\partial {x_n}^2}t_m^w w_n, i = (1-\lambda)\frac{\partial^2 U_n}{\partial {x_n}^2}t_m^w$

$$\left.\frac{dt_n^w}{d\lambda}\right|_{t_m^h} = \frac{1}{D}\left[(s12s33\text{–}s13s23)\left(s56^2\text{–}s66s55\right)j + (-s12s13 + s11s23)\left(s56^2\text{–}s66s55\right)k + \left(s11s33\text{–}s13^2\right)(-s66m + s56n)s25\right.$$

$$\left.\frac{dt_n^h}{d\lambda}\right|_{t_m^h} = \frac{1}{D}\left[(s12s25s33\text{–}s13s25s23)s66j + (-s12s25s13 + s11s25s23)s66k + \left(s11s22s33\text{–}s11s23^2\text{–}s22s13^2\text{–}s12^2s33 + 2s12s23s13\right)s66m\right.$$
$$\left. + \left(-2s12s23s13\text{–}s11s22s33 + s12^2s33 + s11s23^2 + s22s13^2\right)s56n\right]$$

$$\left.\frac{dt_k}{d\lambda}\right|_{t_m^h} = \frac{1}{D}\left[(-s12s33 + s13s23)s25s56j + (s12s25s13\text{–}s11s25s23)s56k + \left(-s11s22s33 + s11s23^2 + s22s13^2 + s12^2s33\text{–}2s12s23s13\right)s56m\right.$$
$$\left. + \left(\left(s11s22s33\text{–}s11s23^2 + 2s12s23s13\text{–}s12^2s33\text{–}s13^2s22\right)s55 + \left(-s11s33 + s13^2\right)s25^2\right)n\right]$$

$$\left.\frac{dx_n}{d\lambda}\right|_{t_m^h} = \frac{1}{D}\left[\left(\left(s12s23s55\text{–}s13s22s55 + s13s25^2\right)s66 + (-s12s23 + s13s22)s56^2\right)j + \left(\left(s11s22s55\text{–}s12^2s55\text{–}s11s25^2\right)s66 + \left(-s11s22 + s12^2\right)s56^2\right)k\right.$$
$$\left. + (s11s25s23\text{–}s12s25s13)s66m + (s12s25s13\text{–}s11s25s23)s56n\right]$$

$$\left.\frac{dt_n^w}{d\lambda}\right|_{t_m^h}<0, \left.\frac{dt_n^h}{d\lambda}\right|_{t_m^h} > 0, \left.\frac{dt_k}{d\lambda}\right|_{t_m^h}<0, \left.\frac{dx_n}{d\lambda}\right|_{t_m^h}<0 \quad \text{if} \quad \left(\frac{\partial U_n}{\partial t_k} + \frac{\partial U_n}{\partial z}\frac{\partial z}{\partial t_k}\right)\geq 0$$

where $j = \frac{1}{\lambda^2}\frac{\partial U_n}{\partial x_n}w_m, k = -\frac{1}{\lambda^2}\frac{\partial U_n}{\partial x_n}, m = -\frac{1}{\lambda^2}\left(\frac{\partial U_n}{\partial t_n}\mu_n + \frac{\partial U_n}{\partial z}\frac{\partial z}{\partial t_n^h}\right)$ and

$n = -\frac{1}{\lambda^2}\left(\frac{\partial U_n}{\partial t_k} + \frac{\partial U_n}{\partial z}\frac{\partial z}{\partial t_k}\right).$

B.2. Imperfect information

Definition. $q = q(x_n, z, t_n^h, t_k; t_n^{hc}, t_k^c, \omega_q)$ is the probability that non-cooperative behavior is detected, where

$$\frac{\partial q}{\partial x_n} > 0, \frac{\partial^2 q}{\partial {x_n}^2} > 0 \; for \; x_n > w_n\left(T - t_n^{h^c} - l\right); \quad \frac{\partial q}{\partial x_n} = 0 \text{ for } x_n \le w_n\left(T - t_n^{h^c} - l\right)$$
$$\frac{\partial q}{\partial z} < 0, \frac{\partial^2 q}{\partial z^2} < 0 \text{ for } z < z\left(t_n^{h^c}, {t_k}^c; \tau_n, \tau_k\right); \quad \frac{\partial q}{\partial z} > 0, \quad \frac{\partial^2 q}{\partial z^2} > 0 \text{ for } z > z\left(t_n^{h^c}, {t_k}^c; \tau_n, \tau_k\right);$$
$$\text{and } \frac{\partial q}{\partial z} = 0 \text{ for } z = z\left(t_n^{h^c}, {t_k}^c; \tau_n, \tau_k\right)$$
$$\frac{\partial q}{\partial t_n^h} < 0, \quad \frac{\partial^2 q}{\partial t_n^{h^2}} < 0 \text{ for } t_n^h < t_n^{h^c}; \quad \frac{\partial q}{\partial t_n^h} = 0 \text{ for } t_m^h \ge t_m^{h^c}$$
$$\frac{\partial q}{\partial t_k} > 0, \quad \frac{\partial^2 q}{\partial {t_k}^2} > 0 \text{ for } t_k > {t_k}^c; \quad \frac{\partial q}{\partial t_k} = 0 \text{ for } t_k \le {t_k}^c.$$
$$\frac{\partial q}{\partial \omega_q} > 0, \quad \frac{\partial^2 q}{\partial {\omega_q}^2} > 0$$

The probability of detection is convex for all goods. An increase in ω_q increases the marginal probability of detection for all goods symmetrically. Because changes in t_n^w are exactly proportional to changes in x_n, I assume that the choice of t_n^w does not have an independent effect on the probability of detection, *i.e.* changes in t_n^w do not affect q, holding x_n constant. An increase in x_n is indicative of a decrease in t_n^h and, consequently, the probability of detection must be increasing in x_n. The probability of detection is also increasing in t_k because, for player n, the individual utility-maximizing value is greater than the cooperative value. Conversely, the optimal values of t_n^h is less than the cooperative values, and thus any increase in t_n^h will decrease the probability of detection. The probability of detection is increasing and convex in the absolute difference between z and z^c because the optimal level of household production associated with *don't cooperate* may be higher or lower than the contracted value. Whenever a contracted allocation is chosen, the marginal probability of detection for that good is zero. For simplicity, I have also assumed that the probability of detection is zero for any value of t_n^h greater than $t_n^{h^c}$ and any value of x_n or t_k less than x_n^c or t_k^c, respectively, because any allocations satisfying these conditions would increase the utility of player m. In practice, this assumption simply assures that the wife would not be punished for any non-cooperative behavior that benefits her spouse.

Condition 1

$$p < \frac{U_m\left(t_m^w, z^{c,B}, {t_k}^{c,B}, x_m - s^{c,B}\right) - U_m\left(t_m^w, z^{c,A}, {t_k}^{c,A}, x_m - s^{c,A}\right)}{\left[U_m\left(t_m^w, z^{c,B}, {t_k}^{c,B}, x_m - s^{c,B}\right) - (1-q^*) U_m\left(t_m^w, z, t_k, x_m - s^{c,B}\right) - q^* U_m\left(t_m^w, z, t_k, x_m - s^{nc,B}\right)\right]}$$

Condition 2

$$p \le \frac{U_m\left(t_m^w, z^{c,B}, {t_k}^{c,B}, x_m - s^{c,B}\right) - U_m\left(t_m^w, z', {t_k}', x_m - s'\right)}{U_m\left(t_m^w, z^{c,B}, {t_k}^{c,B}, x_m - s^{c,B}\right) - \left(1 - q^*\left(\omega_q\right)\right) U_m\left(t_m^w, z, t_k, x_m - s^{c,B}\right) - q^*\left(\omega_q\right) U_m\left(t_m^w, z, t_k, x_m - s^{nc,B}\right)}$$

B.2.1. Derivations for proof of Corollary 1

$$\frac{d{V_n}^c}{ds^c} - \frac{d{V_n}^{nc}}{ds^c} = \left[\frac{\partial U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, {t_k}^c, {x_n}^c + s^c\right)}{\partial s^c} - (1-q^*)\frac{\partial U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^c\right)}{\partial s^c}\right] ds^c$$

$$\frac{d{V_n}^c}{dt_n^{h^c}} - \frac{d{V_n}^{nc}}{dt_n^{h^c}} = \left[\frac{\partial U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, {t_k}^c, {x_n}^c + s^c\right)}{\partial t_n^{h^c}} + \frac{\partial U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, {t_k}^c, {x_n}^c + s^c\right)}{\partial z} \frac{\partial z}{\partial t_n^{h^c}}\right] dt_n^{h^c} - \frac{\partial q^*}{\partial t_n^{h^c}}\left[U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^{nc}\right) - U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^c\right)\right]$$

$$\frac{d{V_n}^c}{d{t_k}^c} - \frac{d{V_n}^{nc}}{d{t_k}^c} = \left[\frac{\partial U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, {t_k}^c, {x_n}^c + s^c\right)}{\partial {t_k}^c} + \frac{\partial U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, {t_k}^c, {x_n}^c + s^c\right)}{\partial z} \frac{\partial z}{\partial {t_k}^c}\right] d{t_k}^c - \frac{\partial q^*}{\partial {t_k}^c}\left[U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^{nc}\right) - U_n\left(t_n^w, z, t_n^h, t_k, x_n + s^c\right)\right]$$

$$\frac{d{V_n}^c}{dt_n^{w^c}} - \frac{d{V_n}^{nc}}{dt_n^{w^c}} = \left[\frac{\partial U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, {t_k}^c, {x_n}^c + s^c\right)}{\partial t_n^{w^c}} + \frac{\partial U_n\left(t_n^{w^c}, z^c, t_n^{h^c}, {t_k}^c, {x_n}^c + s^c\right)}{\partial x_n} w_n\right] dt_n^{w^c}$$

where V_n^{nc} denotes the payoff to *don't cooperate* and V_n^c denotes the payoff to *cooperate* for player n.

B.2.2. First order conditions

$$\left(\frac{\partial U_n}{\partial t_n}+\frac{\partial U_n}{\partial x_n}w_n\right)-q\left(\frac{\partial U_n}{\partial x_n}w_n-\frac{\partial U'_n}{\partial x_n}w_n\right)-\frac{\partial q}{\partial x_n}w_n\left(U_n-U'_n\right)=0,$$

$$\left(\frac{\partial U_n}{\partial t_n}+\frac{\partial U_n}{\partial z}\frac{\partial z}{\partial t_n^h}\right)-\left(\frac{\partial q}{\partial t_n^h}+\frac{\partial q}{\partial z}\frac{\partial z}{\partial t_n^h}\right)\left(U_n-U'_n\right)=0 \text{ and}$$

$$\left(\frac{\partial U_n}{\partial t_k}+\frac{\partial U_n}{\partial z}\frac{\partial z}{\partial t_k}\right)-\left(\frac{\partial q}{\partial t_k}+\frac{\partial q}{\partial z}\frac{\partial z}{\partial t_k}\right)\left(U_n-U'_n\right)=0$$

where $U_n=U_n(t_n^w, z, t_n^h, t_k, x_n+s^c)$ and $U_n'=U_n(t_n^w, z, t_n^h, t_k, x_n+s^{nc})$.

B.2.3. Assumptions

(1) All goods separable in utility.
(2) No complementarities in household production.
(3) No cross-good effects in $q(\cdot)$.
(4) $q\left(\frac{\partial U_n}{\partial x_n}w_n-\frac{\partial U'_n}{\partial x_n}w_n\right)+\frac{\partial q}{\partial x_n}w_n\left(U_n-U'_n\right)>0$
(5) $\left(\frac{\partial q}{\partial t_k}+\frac{\partial q}{\partial z}\frac{\partial z}{\partial t_k}\right)>0$
(6) $\sigma_{23}<0$

Let Δ denote the determinant of the Hessian, and define its elements as

$$\sigma_{11}=\frac{\partial^2 U_n}{\partial t_n{}^2}+\frac{\partial^2 U_n}{\partial x_n{}^2}w_n{}^2-q\left(\frac{\partial^2 U_n}{\partial x_n{}^2}w_n{}^2-\frac{\partial^2 U'_n}{\partial x_n{}^2}w_n{}^2\right)-\frac{\partial^2 q}{\partial x_n{}^2}w_n^2\left(U_n-U'_n\right)-2\frac{\partial q}{\partial x_n}w_n\left(\frac{\partial U_n}{\partial x_n}w_n-\frac{\partial U'_n}{\partial x_n}w_n\right)<0$$

$$\sigma_{12}=\frac{\partial^2 U_n}{\partial t_n{}^2}-\left(\frac{\partial q}{\partial t_n^h}+\frac{\partial q}{\partial z}\frac{\partial z}{\partial t_n^h}\right)\left(\frac{\partial U_n}{\partial x_n}w_n-\frac{\partial U'_n}{\partial x_n}w_n\right)<0$$

$$\sigma_{13}=-\left(\frac{\partial q}{\partial t_k}+\frac{\partial q}{\partial z}\frac{\partial z}{\partial t_k}\right)\left(\frac{\partial U_n}{\partial x_n}w_n-\frac{\partial U'_n}{\partial x_n}w_n\right)>0$$

$$\sigma_{22}=\left(\frac{\partial^2 U_n}{\partial t_n{}^2}+\frac{\partial^2 U_n}{\partial z^2}\left(\frac{\partial z}{\partial t_n^h}\right)^2+\frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial t_n^{h^2}}\right)-\left[\frac{\partial^2 q}{\partial t_n^{h^2}}+\frac{\partial^2 q}{\partial z^2}\left(\frac{\partial z}{\partial t_n^h}\right)^2+\frac{\partial q}{\partial z}\left(\frac{\partial^2 z}{\partial t_n^{h^2}}\right)\right]\left(U_n-U'_n\right)<0$$

$$\sigma_{23}=\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_n^h}\frac{\partial z}{\partial t_k}\right)-\left(\frac{\partial^2 q}{\partial z^2}\frac{\partial z}{\partial t_n^h}\frac{\partial z}{\partial t_k}\right)\left(U_n-U'_n\right)<0$$

$$\sigma_{33}=\left[\frac{\partial^2 U_n}{\partial t_c{}^2}+\frac{\partial^2 U_n}{\partial z^2}\left(\frac{\partial z}{\partial t_k}\right)^2+\frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial t_k{}^2}\right]-\left[\frac{\partial^2 q}{\partial t_k{}^2}+\frac{\partial^2 q}{\partial z^2}\left(\frac{\partial z}{\partial t_k}\right)^2+\frac{\partial q}{\partial z}\frac{\partial^2 z}{\partial t_k{}^2}\right]\left(U_n-U'_n\right)<0$$

B.4. Heterogeneous preferences for child quality and leisure, full information

Apply scalars ϕ and σ to child quality and child leisure, respectively, to allow for the possibility that migration reduces the marginal utility that fathers derive from these goods.

$$\lambda U_m(x_m,\phi z,t_m,\sigma t_k)+(1-\lambda)U_n(x_n,z,t_n,t_k)$$

Elements of the Hessian are as given in Section B.2 of the Technical appendix, with the following exceptions:

$$s_{44} = \lambda\left[\frac{\partial^2 U_m}{\partial {t_m}^2} + \phi^2 \frac{\partial^2 U_m}{\partial z^2}\left(\frac{\partial z}{\partial t_m^h}\right)^2 + \phi\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial t_m^{h^2}}\right] + (1-\lambda)\left[\frac{\partial^2 U_n}{\partial z^2}\left(\frac{\partial z}{\partial t_m^h}\right)^2 + \frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial t_m^{h^2}}\right] < 0$$

$$s_{45} = \lambda\left(\phi^2\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h}\right) + (1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h}\right) < 0$$

$$s_{46} = \lambda\left(\phi^2\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_k}\right) + (1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_k}\right) < 0$$

$$s_{55} = \lambda\left[\phi^2\frac{\partial^2 U_m}{\partial z^2}\left(\frac{\partial z}{\partial t_n^h}\right)^2 + \phi\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial t_n^{h^2}}\right] + (1-\lambda)\left[\frac{\partial^2 U_n}{\partial {t_n}^2} + \frac{\partial^2 U_n}{\partial z^2}\left(\frac{\partial z}{\partial t_n^h}\right)^2 + \frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial t_n^{h^2}}\right] < 0$$

$$s_{56} = \lambda\left(\phi^2\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_n^h}\frac{\partial z}{\partial t_k}\right) + (1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_n^h}\frac{\partial z}{\partial t_k}\right) < 0$$

$$s_{66} = \lambda\left[\sigma^2\frac{\partial^2 U_m}{\partial {t_k}^2} + \phi^2\frac{\partial^2 U_m}{\partial z^2}\left(\frac{\partial z}{\partial t_k}\right)^2 + \phi\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial {t_k}^2}\right] + (1-\lambda)\left[\frac{\partial^2 U_n}{\partial {t_k}^2} + \frac{\partial^2 U_n}{\partial z^2}\left(\frac{\partial z}{\partial t_k}\right)^2 + \frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial {t_k}^2}\right] < 0$$

As long as ϕ and σ are strictly greater than zero, the signs of the comparative statics will be the same as long as the following condition still holds:

$$\begin{aligned} s_{45}s_{66} - s_{46}s_{56} = {} & \lambda^2\left(\phi^2\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h}\right)\left[\sigma^2\frac{\partial^2 U_m}{\partial {t_k}^2} + \phi\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial {t_k}^2}\right] + \lambda(1-\lambda)\left(\phi^2\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h}\right)\left[\frac{\partial^2 U_n}{\partial {t_k}^2} + \frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial {t_k}^2}\right] \\ & + \lambda(1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h}\right)\left[\sigma^2\frac{\partial^2 U_m}{\partial {t_k}^2} + \phi\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial {t_k}^2}\right] + (1-\lambda)^2\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h}\right)\left[\frac{\partial^2 U_n}{\partial {t_k}^2} + \frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial {t_k}^2}\right] > 0 \end{aligned}$$

B.5. Complementarities in household production, full information

Elements of the Hessian are as given in Section B.2 of the Technical appendix, with the following exceptions:

$$s_{45} = \lambda\left(\phi^2\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h} + \phi\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial t_m^h \partial t_n^h}\right) + (1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h} + \frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial t_m^h \partial t_n^h}\right)$$

$$s_{46} = \lambda\left(\phi^2\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_k} + \phi\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial t_m^h \partial t_k}\right) + (1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_k} + \frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial t_m^h \partial t_k}\right)$$

$$s_{56} = \lambda\left(\phi^2\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_n^h}\frac{\partial z}{\partial t_k} + \phi\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial t_n^h \partial t_k}\right) + (1-\lambda)\left(\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_n^h}\frac{\partial z}{\partial t_k} + \frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial t_n^h \partial t_k}\right).$$

Again, the signs of the comparative statics will be the same as long as the following condition holds:

$$s_{45}s_{66} - s_{46}s_{56} > 0.$$

This will be true provided complementarities between adults are not too strong:

$$\phi^2\frac{\partial^2 U_m}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h} + \phi\frac{\partial U_m}{\partial z}\frac{\partial^2 z}{\partial t_m^h \partial t_n^h} < 0$$

$$\frac{\partial^2 U_n}{\partial z^2}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_n^h} + \frac{\partial U_n}{\partial z}\frac{\partial^2 z}{\partial t_m^h \partial t_n^h} < 0$$

$$\frac{\partial^2 z}{\partial t_m^h \partial t_n^h}\left(\frac{\partial z}{\partial t_k}\right)^2 < \frac{\partial^2 z}{\partial t_n^h \partial t_k}\frac{\partial z}{\partial t_m^h}\frac{\partial z}{\partial t_k}.$$

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