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ABSTRACT

Several important empirical studies (e.g., Altonji, Hayashi, and Kotlikoff, 1992, 1996, 1997) find that households are not altruistically-linked in a way consistent with the standard Ricardian model, as put forward by Barro (1974). We build a two-sided altruistic-linkage model in which private transfers are made in the presence of two types of shocks: an "observable" shock that is public information (e.g., public redistribution) and an "unobservable" shock that is private information (e.g., idiosyncratic wages). Parents and children observe each other's total income but not each other's effort level. In the second-best optimum, unobservable shocks are only partially shared whereas, for any utility function satisfying a condition derived herein, observable shocks are fully shared. The model, therefore, can generate the low degree of risk sharing found in the recent studies, but Ricardian equivalence still holds.

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1 Introduction

A household is Ricardian if inter-generational altruistic linkages are operative within the household and if it fully understands the government's budget constraint. Ricardian households offset any changes in the timing of taxes with inter-generational transfers (Ricardo, 1820, reprinted in 1951; Barro, 1974). So, for example, an increase in budget deficits or pay-as-you-go social security spending would be offset with larger transfers from parents to their children; a move toward a funded social security system would be offset with smaller transfers, possibly negative (i.e., gifts from children to their parents). As a result, these otherwise important fiscal policies are effectively irrelevant if the Ricardian assumption is an accurate description for many households. It is not surprising, therefore, that Ricardian equivalence has generated a lively debate during the past several decades. See, for example, the literature reviews in Bernheim (1987), Weil (1989), Seater (1993), Barro (1996), Elmendorf and Mankiw (1999), and Smetters (1999).

While many economists do not believe that Ricardian equivalence is a close description of reality,[1] the actual empirical evidence itself is mixed. Extensive empirical work by Evans (1985, 1987*a*, 1987*b*), papers written before modern extensive panel data sets became widely available, shows that different aggregate variables seem fairly invariant over time to changes in the levels of government debt, consistent with Ricardian equivalence. However, Feldstein (1982, 1996) and Evans (1998) show that aggregate U.S. consumption might be substantially impacted by the levels of unfunded U.S. Social Security net wealth, inconsistent with Ricardian equivalence. Leimer and Lesnoy (1982), Lesnoy and Leimer (1985), and CBO (1998), though, argue that social security time series estimates are quite sensitive to how the social

[1]For example, in Slemrod's (1995) survey of the National Tax Association (including 521 academics, 406 government employees, and 381 private sector employees), 89 percent of those responding (45 percent of the academics, 32 percent of the goverment employees, and 28 percent in the private sector) responded in the affirmative to the question, "Does a large federal budget deficit have an adverse effect on the economy?" Of the academics that responded, 84 percent responded in the affirmative. While this question does not probe the perceived *severity* of the negative effect, it still indicates that many economists regard budget deficits as quite material.

security wealth variable is constructed. Seater (1993) reviews many other empirical tests, both supportive and not supportive of Ricardian equivalence. He notes that while some of these indirect tests using aggregated data might lack power (as verified by Cardia, 1997), the sheer number of tests failing to reject Ricardian equivalence provides some support of the Ricardian proposition as an approximation, assuming that the power of the different tests are fairly orthogonal.

Household-level data sets have become more widely available in the past decade or so, thereby allowing for a more direct test of the altruism tenet underlying Ricardian equivalence. Tomes (1981) and Bernheim (1991) find some evidence in favor of the altruism model. The papers by Altonji, Hayashi, and Kotlikoff (1992, 1996, 1997) use the Panel Study of Income Dynamics. They find some evidence of inter-generational transfers consistent with the altruism model, but only a little. For example, AHK (1997) shows that redistributing \$1 from a recipient child to donor parents leads to less than a \$0.13 increase in the inter-generational transfer from parent to child, much less than the \$1 transfer implied by the altruism model.[2] Wilhelm (1996), using federal estate tax return data, also finds little evidence that bequests compensate for earnings differences between parents and children. Most recently, Cox, Hansen, and Jimenez (1999) and Cox (2001) find evidence for risk sharing in developing economies, although short of the strong predictions of the altruism model. Page (forthcoming) finds evidence that inter-generational transfers made by many households are sensitive to differences in tax rates across U.S. states, consistent with the Ricardian model. In sum, the household-level evidence seems to suggest some risk-sharing, but not as strongly as that predicted by the standard altruistic model.

In this paper, we demonstrate that the low level of risk sharing observed between parent households and children households is not necessarily inconsistent with Ricardian equivalence. We build a two-sided altruistic-linkage model in which private transfers are made in the presence of two types of shocks: an "observable" shock that is public information among households (e.g., public redistribution) and an "unobservable" shock that is private information (e.g., idiosyncratic wages). Parents and children observe each other's total income but

[2] Other authors have regressed consumption growth on income growth in order to test for the presence of risk sharing outside of the family. See Cochrane (1991), Mace (1991), and Townsend (1994). Altuğ and Labadie (1994) discuss the empirical methodology in detail.

not each other's endogenous level of labor market effort. Hence, a risk sharing arrangement contingent on effort level (the first-best solution) is not possible. In the second-best optimum, unobservable shocks are only partially shared due to moral hazard. But, at the same time, observable shocks (e.g., tax timing changes) will be fully shared, due to inter-dependent utility, provided that the utility function satisfies a condition derived herein. As a result, our model can reproduce the low degree of risk sharing found in recent studies, but Ricardian equivalence still holds.

The paper is organized as follows. Section 2 of this paper sets up the basic principal-agent model between parents and their children. Section 3 demonstrates how familial risk sharing arrangements distort work incentives (i.e., create moral hazard) when first-best arrangements are not possible. Section 4 formally derives the first-best and second-best optimal risk sharing arrangements. Section 5 presents some examples of utility functions in which Ricardian equivalence holds in the presence of a potentially low level of observed risk sharing. Section 6 discusses the inter-dependence of the risk sharing arrangements for observable and unobservable shocks in the second-best equilibrium. Section 7 concludes.

2 The Model

2.1 Income Shocks and Risk-Sharing Arrangements

Consider two altruistic households, $i \in \{1, 2\}$, e.g., parents and children. Each household places the same weight on each other's utility equal to ϕ, $0 \leq \phi \leq 1$, and receives two types of income shocks, s_i and t_i. The shock s_i is an idiosyncratic income shock to household i that is unobservable to the other household, $-i$. The shock t_i is a government tax transfer to household i that is observable to both households. The "pre-tax" labor income y_i of household i (i.e., before observable shocks) is defined as the sum of its unobservable effort level ("hours worked"), h_i, and unobservable shock s_i, i.e.,

$$y_i = h_i + s_i.$$

The sum y_i is observable, but its components are not independently observable, prohibiting first-best risk sharing.[3] For simplicity, households 1 and 2 receive symmetric shocks —

[3]Hence, our model has some similarities with the optimal income tax literature started by Mirrlees, which also assumes that the government cannot observe hours worked. While parents with children living under the

i.e., household i receives s_i and t_i, and household $-i$ receives $s_{-i} = -s_i$ and $t_{-i} = -t_i$. Hence, these shocks are always insurable within two households. The cumulative probability distributions for s_i and t_i, $F(s_i)$ and $G(t_i)$, are independent and symmetric around zero.[4] So, $E(s_i) = E(t_i) = 0$.

Both types of shocks can be shared among households. Let $\sigma \in [0, 0.5]$ be the risk-sharing plan for unobservable shocks s_i. In particular, σ is equal to the proportion of the unobservable shock, s_i $[s_{-i}]$, that is shared by the other household $-i$ $[i]$. The income of household i after risk sharing, therefore, is defined as

$$(1-\sigma)\,y_i + \sigma\,y_{-i} = (1-\sigma)\,h_i + \sigma\,h_{-i} + (1-2\sigma)s_i, \tag{1}$$

where we used the fact that $s_{-i} = -s_i$. The risk-sharing plan $\sigma = 0$ indicates no risk sharing while $\sigma = 0.5$ indicates perfect risk sharing (equal division of income).

Similarly, let $\tau \in [0, 0.5]$ denote the risk-sharing plan for the observable shock t_i. In particular, τ is equal to the proportion of the observable shock, t_i $[t_{-i}]$, that is shared by the other household $-i$ $[i]$. The amount of the observable shock borne by household i after risk sharing, therefore, is

$$(1-\tau)\,t_i + \tau\,t_{-i} = (1-2\tau)\,t_i, \tag{2}$$

where we used the fact that $t_{-i} = -t_i$. Similarly, the risk-sharing plan $\tau = 0$ indicates no risk sharing, and $\tau = 0.5$ indicates full risk sharing. The notation for the model is summarized in Table 1.

2.2 The Timing of the Model

The timing of the households' actions are as follows:

1. Two households determine the risk-sharing plan (σ, τ) based on the distributions of the shocks, $F(s_i)$ and $G(t_i)$, and the degree of altruism ϕ that is part of their utility function shown below;

same roof might be in a slightly better position than the government to monitor hours worked by their children, most parents are still not able to monitor many key variables captured by our h term including job performance, hours spent looking for work, etc. For households not living under the same roof (comprising most of the sample in the empirical studies referenced in Section 1), observing hours worked is also difficult.

[4] The assumptions of independence and symmetry are just normalizations since two correlated shocks can be decomposed into two uncorrelated shocks (by definining the idiosyncratic shock as the difference), each with mean zero, along with some other deterministic terms.

Table 1: Model Notation

i	$\in \{1, 2\}$	Household
y_i	$\in \mathbf{R}$	Labor income (earnings)
h_i	$\in [0, 1)$	Effort (working hours)
c_i	$\in \mathbf{R}_+$	Consumption of goods
l_i	$\in (0, 1]$	Leisure
ϕ	$\in [0, 1]$	Degree of altruism
s_i	$\in \mathbf{R}$	Unobservable shock to household i's resources $(s_i = -s_{-i})$
t_i	$\in \mathbf{R}$	Observable shock to household i's resources $(t_i = -t_{-i})$
σ	$\in [0, 0.5]$	Proportion of unobservable shock, s_i $[s_{-i}]$, shared by household $-i$ $[i]$
τ	$\in [0, 0.5]$	Proportion of observable shock, t_i $[t_{-i}]$, shared by household $-i$ $[i]$
$F(s_i)$	$\in [0, 1]$	Cumulative probability distribution for the unobserved shock s_i
$G(t_i)$	$\in [0, 1]$	Cumulative probability distribution for the observed shock t_i

2. Each household decides its working hours (effort level), h_i and h_{-i};

3. Two types of shocks, (s_i, s_{-i}) and (t_i, t_{-i}), are realized, where $s_i = -s_{-i}$ and $t_i = -t_{-i}$;

4. Income is redistributed between households based on the risk-sharing arrangement, (σ, τ).

2.3 The Household Problem and Optimal Effort, h

Altruism between parents and children is two-sided. The two households place an equal weight, ϕ, on each other's utility, where $\phi = 1$ indicates full altruism and $\phi = 0$ indicates no altruism. The household i's problem is

$$\max_{c_i, l_i} E\left[u\left(c_i, l_i\right) + \phi\, u\left(c_{-i}, l_{-i}\right)\right] \tag{3}$$

subject to

$$\begin{aligned}
c_i &= (1-\sigma)\, y_i + \sigma\, y_{-i} + (1-\tau)\, t_i + \tau\, t_{-i} \\
&= (1-\sigma)\, h_i + \sigma\, h_{-i} + (1-2\sigma)\, s_i + (1-2\tau)\, t_i, \\
c_{-i} &= (1-\sigma)\, y_{-i} + \sigma\, y_i + (1-\tau)\, t_{-i} + \tau\, t_i \\
&= (1-\sigma)\, h_{-i} + \sigma\, h_i - (1-2\sigma)\, s_i - (1-2\tau)\, t_i, \\
l_i &= 1 - h_i,
\end{aligned}$$

$$l_{-i} = 1 - h_{-i}.$$

Substituting c_i, c_{-i}, l_i, and l_{-i} into the utility function, the problem becomes

$$\max_{h_i} E[u\left((1-\sigma)\,h_i + \sigma\,h_{-i} + (1-2\sigma)\,s_i + (1-2\tau)\,t_i, 1-h_i\right) + \phi\,u\left((1-\sigma)\,h_{-i} + \sigma\,h_i - (1-2\sigma)\,s_i - (1-2\tau)\,t_i, 1-h_{-i}\right)]. \tag{4}$$

The first-order condition with respect to h_i is,

$$(1-\sigma)\,E\,u_c\,(c_i, l_i) - E\,u_l\,(c_i, l_i) + \phi\,\sigma\,E\,u_c\,(c_{-i}, l_{-i}) = 0.$$

By the symmetric assumption, the expected utilities of two households are the same, i.e.,

$$E\,u_c\,(c_i, l_i) = E\,u_c\,(c_{-i}, l_{-i})\,.$$

So, we have

$$(1-\sigma+\phi\,\sigma)\,E\,u_c\,(c_i, l_i) - E\,u_l\,(c_i, l_i) = 0. \tag{5}$$

Moreover, the optimal working hours of two households are the same, i.e.,

$$h_i = h_{-i} = h,$$

and the optimal working hours, $h\,(\sigma, \tau; \phi, F(s_i), G(t_i))$, solve

$$(1-\sigma+\phi\,\sigma)\,E\,u_c\,(h + (1-2\sigma)\,s_i + (1-2\tau)\,t_i, 1-h) - E\,u_l\,(h + (1-2\sigma)\,s_i + (1-2\tau)\,t_i, 1-h) = 0. \tag{6}$$

3 The Impact of Risk Sharing on Effort

Although it is difficult to solve for h analytically since we have not yet specified a utility function, this section characterizes how the optimal working hours vary with the risk-sharing plan, (σ, τ). Toward this end, we make some standard assumptions about the utility function. Utility is assumed to be increasing in the level of the consumption of goods and leisure but at a decreasing rate ($u_c > 0$, $u_l > 0$, $u_{cc} < 0$, $u_{ll} < 0$); the marginal utility of consumption and leisure might be separable or non-separable provided that it is non-decreasing in the level of the other ($u_{cl} = u_{lc} \geq 0$) but at a non-increasing rate ($u_{ccl} = u_{clc} = u_{lcc} \leq 0$; $u_{llc} = u_{lcl} = u_{cll} \leq 0$); and agents do not exhibit imprudence ($u_{ccc} \geq 0$).[5]

Lemma 1 *(Impact of σ on effort, h)*
(1) When two households are not fully altruistic to each other ($0 \leq \phi < 1$), the optimal level of effort, h, is strictly decreasing in the amount of the unobservable shock that is shared by the other household, σ, for all $\sigma \in [0, 0.5]$.
(I.e., $\phi < 1 \Longrightarrow \frac{\mathrm{d}}{\mathrm{d}\sigma} h(\sigma, \tau) < 0$ for $\sigma \in [0, 0.5]$.)
(2) When two households are fully altruistic to each other ($\phi = 1$), the optimal level of effort, h, is unaffected by a small change in σ if σ equals 0.5 or if $u_{ccc} = u_{lcc} = 0$; otherwise, h is strictly decreasing in σ.
(I.e., $\phi = 1 \Longrightarrow \frac{\mathrm{d}}{\mathrm{d}\sigma} h(\sigma, \tau) = 0$ for $\sigma = 0.5$ or $u_{ccc} = u_{lcc} = 0$; and $\frac{\mathrm{d}}{\mathrm{d}\sigma} h(\sigma, \tau) < 0$ for $\sigma \in [0, 0.5)$ and ($u_{ccc} > 0$ or $u_{lcc} < 0$).)

Proof. Totally differentiating the first-order condition (6) with respect to h and σ, we have

$$
\begin{aligned}
&- \{(1-\phi) E\, u_c + 2(1-\sigma+\phi\,\sigma) E[u_{cc} s_i] - 2E[u_{lc} s_i]\} \,\mathrm{d}\sigma \\
&\quad + \{(1-\sigma+\phi\,\sigma)(E\, u_{cc} - E\, u_{cl}) + (E\, u_{ll} - E\, u_{lc})\} \,\mathrm{d}h = 0.
\end{aligned}
$$

This equation implies

$$
\frac{\mathrm{d}}{\mathrm{d}\sigma} h(\sigma, \tau) = \frac{(1-\phi) E\, u_c + 2\{(1-\sigma+\phi\,\sigma) E[u_{cc} s_i] - E[u_{lc} s_i]\}}{(1-\sigma+\phi\sigma)(E\, u_{cc} - E\, u_{cl}) + (E\, u_{ll} - E\, u_{lc})}. \tag{7}
$$

Since $u_{cc} < 0$, $u_{ll} < 0$, and $u_{cl} = u_{lc} \geq 0$, the denominator on the right hand side becomes strictly negative. We now want to prove that the numerator is positive. Since the two types of shocks are normalized to be independent, then

$$
\begin{aligned}
E[u_{cc} s_i] &= \int \left\{ \int u_{cc} \mathrm{d}G(t_i) \right\} s_i \,\mathrm{d}F(s_i), \\
E[u_{lc} s_i] &= \int \left\{ \int u_{lc} \mathrm{d}G(t_i) \right\} s_i \,\mathrm{d}F(s_i).
\end{aligned}
$$

Since $c_i = h + (1-2\sigma) s_i + (1-2\tau) t_i$ (see equation (6)) and $u_{ccc} \geq 0$,

$$
\frac{\mathrm{d}}{\mathrm{d}s_i} \left\{ \int u_{cc} \mathrm{d}G(t_i) \right\} = (1-2\sigma) \int u_{ccc} \mathrm{d}G(t_i) \geq 0,
$$

[5] By definition, a "prudent" agent precautiously supplies extra effort, h, in order to buffer future uncertainty, which, in turn, only happens if $u_{ccc} > 0$. If agents are risk averse ($u_{cc} < 0$) but not prudent ($u_{ccc} = 0$) then consumption and leisure choices will equal their "certainty equivalent" values, as demonstrated by the Quadratic Utility example presented in Section 5.

holding with equality if and only if $\sigma = 0.5$ or $u_{ccc} = 0$. So, $\int u_{cc} \mathrm{d}G(t_i)$ is strictly negative and non-decreasing in s_i. Since $u_{lcc} \leq 0$, we have

$$\frac{\mathrm{d}}{\mathrm{d}s_i}\left\{\int u_{lc} \mathrm{d}G(t_i)\right\} = (1-2\sigma)\int u_{lcc} \mathrm{d}G(t_i) \leq 0,$$

holding with equality if and only if $\sigma = 0.5$ or $u_{lcc} = 0$. So, $\int u_{lc} \mathrm{d}G(t_i)$ is non-negative and non-increasing in s_i. When $F(s_i)$ is symmetric with mean 0, we, therefore, have $E[u_{cc}s_i] \geq 0$ and $E[u_{lc}s_i] \leq 0$. Accordingly, $(1-\sigma+\phi\,\sigma)E[u_{cc}s_i]-E[u_{lc}s_i] \geq 0$, holding with equality if and only if $\sigma = 0.5$ or $u_{ccc} = u_{lcc} = 0$. When $\phi < 1$, since $(1-\phi)E\,u_c > 0$, we have $\mathrm{d}h/\mathrm{d}\sigma < 0$ for all $\sigma \in [0, 0.5]$. When $\phi = 1$, we have $\mathrm{d}h/\mathrm{d}\sigma \leq 0$, holding with equality if and only if $\sigma = 0.5$ or $u_{ccc} = u_{lcc} = 0$. ■

Discussion. Let's first discuss the case in which altruism is not full, followed by the case in which altruism is full.

(1) In words, $\frac{\mathrm{d}}{\mathrm{d}\sigma}h\left(\sigma,\tau\right) < 0$, implies that households exhibit less effort as the level of risk sharing between households increases. When altruism is not full ($\phi < 1$), households attempt to take advantage of a greater amount of risk sharing by working less. Each household values an increase in its own leisure but bears only a fraction of the concomitant decrease in its own wage income under positive levels of risk sharing. As a result, moral hazard is a problem whether households exhibit prudence ($u_{ccc} > 0$) or not ($u_{ccc} = 0$). But when agents are also prudent, the increase in risk sharing, σ, also reduces their prudence-driven supply of effort, h. The reason is that effort level decisions are made before the shocks are realized. Hence, a prudent household will supply less effort in lower risk situations associated with more risk sharing. So the effects of moral hazard and prudence work in the same direction in order to generate less effort as risk sharing increases, thereby allowing us to sign the derivative $\frac{dh}{d\sigma}$ under fairly general conditions.

(2) In words, $\frac{\mathrm{d}}{\mathrm{d}\sigma}h\left(\sigma,\tau\right) = 0$ means that effort is unaffected by the level of risk sharing. Only when altruism is full ($\phi = 1$) will household i $[-i]$ place the same value on its own leisure and consumption as that of household $-i$ $[i]$. As a result, only with full altruism will both households *not* have the incentive to freeride off the risk-sharing provided by the other household since there is no moral hazard. So if, in addition, households are not prudent ($u_{ccc} = 0$), then their level of effort is unaffected by the level of risk sharing. If, however,

household exhibit prudence ($u_{ccc} > 0$), then their effort level, h, decreases as risk sharing improves even without moral hazard, provided that $\sigma < 0.5$.

When altruism is full and $\sigma = 0.5$, effort is unaffected by a small change in σ. The reason is that the functional $h(\sigma, \cdot)$ is parabolic in σ over the domain $[0, 1]$ with a minimum at $\sigma = 0.5$. To understand this fact intuitively, suppose that we hypothetically raised σ *above* 0.5, that is, outside of its proper domain $[0, 0.5]$.[6] Whereas full risk sharing occurs at $\sigma = 0.5$, equation (1) shows that risk-sharing would actually be reduced at values of σ above 0.5. (In the extreme case where $\sigma = 1.0$, for example, both households would simply swap the full amount of their risks with each other without actually sharing any of it.) In other words, any deviation from 0.5 reduces risk sharing. Since households are prudent, their chosen level of effort, h, therefore, must increase if σ is set *above* 0.5, in the same way that effort must increase if σ is set *below* 0.5. Hence, $\sigma = 0.5$ is the minimum of the parabola $h(\sigma, \cdot)$ and so $\frac{\mathrm{d}}{\mathrm{d}\sigma} h(\sigma, \tau) = 0$ at $\sigma = 0.5$.

Lemma 2 *(Impact of τ on effort, h) Regardless of the level of altruism (i.e., $0 \le \phi \le 1$), the optimal level of effort, h, is unaffected by a small change in τ if τ equals 0.5 or if $u_{ccc} = u_{lcc} = 0$; otherwise effort, h, is strictly decreasing in τ.*
(I.e., $\frac{\mathrm{d}}{\mathrm{d}\tau} h(\sigma, \tau) = 0$ for $\tau = 0.5$ or $u_{ccc} = u_{lcc} = 0$; $\frac{\mathrm{d}}{\mathrm{d}\tau} h(\sigma, \tau) < 0$ for $\tau \in [0, 0.5)$ and $(u_{ccc} > 0$ or $u_{lcc} < 0)$.)

Proof. Totally differentiating (6) with respect to τ and h, we have

$$-2\left\{(1 - \sigma + \phi\,\sigma)\, E\left[u_{cc} t_i\right] - E\left[u_{lc} t_i\right]\right\} \mathrm{d}\tau$$
$$+ \left\{(1 - \sigma + \phi\,\sigma)\left(E\, u_{cc} - E\, u_{cl}\right) + \left(E\, u_{ll} - E\, u_{lc}\right)\right\} \mathrm{d}h = 0.$$

This implies

$$\frac{\mathrm{d}h}{\mathrm{d}\tau} = \frac{2\left\{(1 - \sigma + \phi\,\sigma)\, E\left[u_{cc} t_i\right] - E\left[u_{lc} t_i\right]\right\}}{(1 - \sigma + \phi\,\sigma)\left(E\, u_{cc} - E\, u_{cl}\right) + \left(E\, u_{ll} - E\, u_{lc}\right)}. \tag{8}$$

Since $u_{cc} < 0$, $u_{ll} < 0$, and $u_{cl} = u_{lc} \ge 0$, the denominator of the right hand side is strictly negative. Similarly to the previous proof, we can show that $E\left[u_{cc} t_i\right] \ge 0$ and $E\left[u_{lc} t_i\right] \le 0$. Hence, $(1 - \sigma + \phi\,\sigma) E[u_{cc} t_i] - E[u_{lc} t_i] \ge 0$, holding with equality if and only if $\tau = 0.5$

[6] In fact, we could allow σ and τ to be defined over [0.0,1.0]. But it is easy to show that points above 0.5 would never be chosen in equilibrium. In particular, if $\phi < 1$ then moral hazard becomes larger for points above 0.5; the same amount of risk sharing can be obtained with less moral hazard by chosing points below 0.5. If $\phi = 1.0$, then, as shown below, full risk sharing (0.5) is optimal; a point above 0.5 would lower risk sharing.

or $u_{ccc} = u_{lcc} = 0$. So, $\mathrm{d}h/\mathrm{d}\tau \leq 0$, holding with equality if and only if $\tau = 0.5$ or $u_{ccc} = u_{lcc} = 0$. ■

Discussion. Comparing the last two lemmas, notice that the relationship between the level of effort, h, and the amount of the observable risk that is shared, τ, is similar to the response of effort to the amount of the non-observable shock that is shared, σ, under full altruism ($\phi = 1$). Intuitively, there is no private information contained in observable shocks; and when shocks are unobservable, there is no desire to take advantage of the private information when altruism is full. Hence, in both cases, the direct role of moral hazard is not present. However, notice, from equation (8), that $\mathrm{d}h/\mathrm{d}\tau$ is not independent of σ unless $u_{ccc} = u_{lcc} = 0$ (i.e., unless agents are not prudent). In other words, the change in the effort level in response to a change in τ cannot be determined independently from σ since σ also affects the optimal choice for h. The inter-dependence of σ and τ is discussed in Section 6.

4 The Optimal Risk-Sharing Arrangement (σ, τ)

This section derives the first-best and second-best optimal risk-sharing arrangements (σ, τ). As proven below, if first-best risk-sharing arrangements were available (i.e., all shocks were observable) then shocks would be fully insurable. Similarly, full insurance is optimal in the second-best equilibrium provided that agents are fully altruistic ($\phi = 1$). In both of these cases, moral hazard does not exist since either: (i) agents have no private information (as in the first-best equilibrium) or (ii) agents have no incentive to take advantage of their private information (as with full altruism).

In the more general case, when private information exists and altruism is not full ($\phi < 1$), moral hazard becomes relevant. The optimal risk sharing arrangement, therefore, must balance the benefits of risk sharing against the costs of moral hazard. Moral hazard prevents full risk sharing. Still, we demonstrate that *observable* shocks will be fully shared provided that preferences satisfy a condition that we derive. In other words, Ricardian equivalence can hold in the presence of incomplete risk sharing.

Lemma 3 *The optimal risk-sharing arrangement (σ, τ) solves the following set of equa-*

tions:

$$(1-\phi)\,\sigma\, h_\sigma E\, u_c - 2E\left[u_c s_i\right] = 0 \tag{9}$$

and

$$(1-\phi)\,\sigma\, h_\tau E\, u_c - 2E\left[u_c t_i\right] = 0. \tag{10}$$

Proof. By the symmetric shock assumption,

$$E\left[u\left(c_i, l_i\right) + \phi\, u\left(c_{-i}, l_{-i}\right)\right] = (1+\phi)\, E\, u\left(c_i, l_i\right).$$

The optimal insurance combination (σ, τ) is obtained by solving

$$\max_{\sigma,\tau} E\, u\left(c_i, l_i\right) = E\, u\left(h\left(\sigma,\tau\right) + (1-2\sigma)\, s_i + (1-2\tau)\, t_i, 1 - h\left(\sigma,\tau\right)\right).$$

The first order conditions are

$$h_\sigma E\, u_c - 2E\left[u_c s_i\right] - h_\sigma E\, u_l = 0$$

and

$$h_\tau E\, u_c - 2E\left[u_c t_i\right] - h_\tau E\, u_l = 0.$$

Using the first order condition for h, equation (5), to eliminate $E\, u_l$, gives equations (9) and (10). ■

4.1 First-Best Risk-Sharing

The previous lemma nests the solutions to the first-best and second-best equilibrium. To get the first-best equilibrium, we can simply normalize $s_i = 0$ in order to remove the unobservable shock, leaving only the observable shock.[7]

Proposition 4 *With only observable shocks* $(s_i = 0)$*, risk is fully shared (i.e.,* $\tau = 0.5$*).*

[7] Alternatively, we could have two observable shocks by specifying $F(s_i) = 0$ for all $s_i < \hat{s}$ and $F(s_i) = 1$ for all $s_i > \hat{s}$ for some $\hat{s}$ (the atom of the distribution). In this case, it is easy to show that both observable shocks will be fully shared, i.e., $(\sigma, \tau) = (0.5, 0.5)$. The single shock in the text can be interpreted as the simple sum of two shocks.

Proof. If there are no unobservable shocks ($s_i = 0$), no risk sharing based on the labor income, y_i and y_{-i}, is needed, i.e., $\sigma = 0$. Hence, equation (10) implies that $2E\left[u_c t_i\right] = 0$ where

$$E\left[u_c t_i\right] = \int \left\{ \int u_c \mathrm{d}F(s_i) \right\} t_i \, \mathrm{d}G(t_i).$$

Since $u_{cc} < 0$, we have

$$\frac{\mathrm{d}}{\mathrm{d}t_i} \left\{ \int u_c \mathrm{d}F(s_i) \right\} = (1 - 2\tau) \int u_{cc} \mathrm{d}F(s_i) \leq 0,$$

holding with equality if and only if $\tau = 0.5$. When $G(t_i)$ is symmetric with mean 0, we have $E\left[u_c t_i\right] = 0$ if and only if $\tau = 0.5$. ■

Discussion. In the first-best economy, there is no moral hazard. Full risk sharing, therefore, is always desirable in the presence of concave preferences. Risk sharing reduces (in fact, with symmetric shocks, eliminates) the variability in income of each agent without reducing the expected income. This result is analogous to the standard result in insurance economics that full insurance is optimal if there are no premium loads.

4.2 Second-Best Risk-Sharing

We now derive the second-best risk-sharing arrangements in the presence of unobservable shocks, i.e., when $F(s_i)$ is not degenerate. We first consider the case of full altruism ($\phi = 1$) followed by the more general case of non-full altruism ($\phi < 1$).

4.2.1 Full Altruism ($\phi = 1$)

Proposition 5 *When two households are fully altruistic to each other, perfect insurance is optimal for both unobservable and observable shocks, i.e.,* $\phi = 1 \Longrightarrow (\sigma^*, \tau^*) = (0.5, 0.5)$.

Proof. When $\phi = 1$, the first order conditions, (9) and (10), imply

$$E\left[u_c s_i\right] = \int \left\{ \int u_c \mathrm{d}G(t_i) \right\} s_i \, \mathrm{d}F(s_i) = 0$$

and

$$E\left[u_c t_i\right] = \int \left\{ \int u_c \mathrm{d}F(s_i) \right\} t_i \, \mathrm{d}G(t_i) = 0.$$

Since $u_{cc} < 0$, we have

$$\frac{\mathrm{d}}{\mathrm{d}s_i}\left\{\int u_c \mathrm{d}G(t_i)\right\} = (1-2\sigma)\int u_{cc}\mathrm{d}G(t_i) \leq 0$$

which holds with equality if and only if $\sigma = 0.5$. When $F(s_i)$ is symmetric with mean 0, we have $E[u_c s_i] \leq 0$ with equality if and only if $\sigma = 0.5$. Hence, $\sigma^* = 0.5$ is required for $E[u_c s_i] = 0$ to hold. Similarly, $E[u_c t_i] \leq 0$, which holds with equality if and only if $\tau^* = 0.5$. ■

4.2.2 Altruism Less than Full ($\phi < 1$)

Proposition 6 *When two households are not fully altruistic to each other, the second-best level of risk sharing for the unobservable shock is less than full, i.e.,* $\phi < 1 \implies \sigma^* \in (0, 0.5)$.

Proof. By Lemma 1, $h_\sigma = \mathrm{d}h/\mathrm{d}\sigma < 0$ for all $\sigma \in [0, 0.5]$. By assumption, $\phi < 1$. By the previous proof, $E[u_c s_i] \leq 0$ with equality if and only if $\sigma = 0.5$. So, when $\sigma = 0$, the left-hand side of equation (9) becomes

$$(1-\phi)\,\sigma\, h_\sigma E\, u_c - 2E[u_c s_i] = -2E[u_c s_i] > 0,$$

which contradicts equality with zero. When $\sigma = 0.5$,

$$(1-\phi)\,\sigma\, h_\sigma E\, u_c - 2E[u_c s_i] = (1-\phi)\,\sigma\, h_\sigma E\, u_c < 0,$$

again contradicting equality with zero. Since the left-hand side of equation (9) is continuous for all $\sigma \in [0, 0.5]$, the optimal σ that satisfies equation (9) exists and $\sigma^* \in (0, 0.5)$. Moreover, since the left-hand side of equation (9) is positive at $\sigma = 0$ and it is negative at $\sigma = 0.5$, then the second-order requirement for a maximum is also satisfied. ■

Proposition 7 *A sufficient condition*[8] *for observable shocks to be fully shared* $(\tau^* = 0.5)$ *— i.e., for Ricardian equivalence to hold — is*

$$E[u_c t_i]\{\Phi E[u_{cc} s_i] - E[u_{lc} s_i]\} \leq E[u_c s_i]\{\Phi E[u_{cc} t_i] - E[u_{lc} t_i]\}, \tag{11}$$

where $\Phi = 1 - \sigma + \phi\,\sigma$.

[8] Of course, the necessary and sufficient conditions for Ricardian equivalence are that equations (9) and (10) hold with $\tau^* = 0.5$ and $\sigma^* \leq 0.5$.

Proof. Similar to the proof for Lemma 1, it can be shown that $\tau = 0.5$ implies $E[u_{cc}t_i] = E[u_{lc}t_i] = E[u_c t_i] = 0$. From equation (8), $h_\tau = 0$. Thus the first order condition (10) holds for all $\sigma \in [0, 0.5]$. The first-order conditions, (9) and (10), along with equations (7) and (8), imply

$$\frac{E[u_c t_i]}{E[u_c s_i]} = \frac{h_\tau}{h_\sigma} = \frac{\Phi E[u_{cc}t_i] - E[u_{lc}t_i]}{\frac{1}{2}(1-\phi)E\,u_c + \Phi E[u_{cc}s_i] - E[u_{lc}s_i]},$$

where $\Phi = 1 - \sigma + \phi\,\sigma$. Since $E\,u_c > 0$, a necessary condition for τ^* to be less than 0.5 is

$$\frac{E[u_c t_i]}{E[u_c s_i]} < \frac{\Phi E[u_{cc}t_i] - E[u_{lc}t_i]}{\Phi E[u_{cc}s_i] - E[u_{lc}s_i]}$$

at τ^*. In other words, a sufficient condition for $\tau^* = 0.5$ is $\frac{E[u_c t_i]}{E[u_c s_i]} \geq \frac{\Phi E[u_{cc}t_i] - E[u_{lc}t_i]}{\Phi E[u_{cc}s_i] - E[u_{lc}s_i]}$. Since $E[u_c t_i] < 0$ and $E[u_c s_i] < 0$, the inequality (11), therefore, is a sufficient condition for $\tau^* = 0.5$. ■

Proposition 8 *In the special case in which utility is separable ($u_{cl} = u_{lc} = 0$), a sufficient condition for observable shocks to be fully shared ($\tau^* = 0.5$) — i.e., for Ricardian equivalence to hold — is*

$$E[u_c t_i]\,E[u_{cc}s_i] \leq E[u_c s_i]\,E[u_{cc}t_i]\,. \tag{12}$$

Proof. By assumption, $E[u_{lc}s_i] = E[u_{lc}t_i] = 0$. From Proposition 7, the inequality (12) is a sufficient condition for $\tau^* = 0.5$. ■

Corollary 9 *(Existence of (σ^*, τ^*)) If condition (11) or (12) holds, then a second-best risk sharing arrangement, (σ^*, τ^*), exists in which Ricardian equivalence holds despite the presence of imperfect risk sharing* $(0 < \sigma^* < 0.5;\ \tau^* = 0.5)$.

Discussion. Two observations are in order. First, notice that *degree* of altruism does not play an important role in the first-best equilibrium but it does play an important role in the second-best equilibrium. As emphasized by Barro (1974, 1996), the degree of altruism itself is not critical for Ricardian equivalence to hold in the standard deterministic altruistic-linkage model or, similarly, in the first-best equilibrium in the case of uncertainty. As long as altruism is strong enough for inter-generational transfers (in either direction) to be *operative*, all shocks will be fully shared between parents and their children in the first-best equilibrium. In the second-best equilibrium, however, the degree of altruism plays a critical role in limiting the degree to which unobservable shocks are shared. Only if altruism is full ($\phi = 1$) will all shocks be fully shared in the second-best equilibrium since only then do parents and children not have the incentive to take advantage of their private information. When altruism is less than full ($\phi < 1$), only observable shocks will be fully shared in equilibrium.

Second, the inequality (11) or (12) is not strong enough to rule out the possibility of multiple second-best equilibria. Stronger conditions on the utility function are required in order to ensure uniqueness. We do not derive the conditions required for uniqueness in this paper since that issue is both quite complicated and unnecessary for our purposes. (The next section, however, does provide several examples of preferences for which the equilibrium is unique.) Even if multiple equilibria exist for a particular utility function, the above analysis proves that risk sharing will be incomplete at each equilibrium; however, Ricardian equivalence still holds for any utility function satisfying (11) or (12).

5 Examples: Quadratic, CARA, and CRRA

The previous section demonstrated that the second-best level of risk sharing for the unobservable shock is generally less than full (except when $\phi = 1$) but that the observable shock might be fully shared, i.e., Ricardian equivalence holds in the presence of incomplete household risk sharing. This section explores some examples of preferences in which Ricardian equivalence holds, including quadratic, Constant Absolute Risk Aversion, and Constant Relative Risk Aversion. Analytical results can be provided for the cases of quadratic and CARA utility but, not surprisingly, we must rely on numerical calculations for the CRRA case where closed-form solutions are impossible.

Example 10 *(Proposition) When the utility function, $u(c, l)$, is separable in consumption and leisure, and its consumption part takes the quadratic form, full insurance for an observable shock is optimal, i.e., $\tau^* = 0.5$.*

Proof. When the utility function is quadratic, $u_{ccc} = 0$. Then,

$$\frac{\mathrm{d}}{\mathrm{d}s_i}\left\{\int u_{cc}\mathrm{d}G(t_i)\right\} = (1-2\sigma)\int u_{ccc}\mathrm{d}G(t_i) = 0,$$

$$\frac{\mathrm{d}}{\mathrm{d}t_i}\left\{\int u_{cc}\mathrm{d}F(s_i)\right\} \quad = \quad (1-2\tau)\int u_{ccc}\mathrm{d}F(s_i) = 0.$$

When $F(s_i)$ and $G(t_i)$ are symmetric with mean 0, $E[u_{cc}s_i] = E[u_{cc}t_i] = 0$. Thus, the sufficient condition (12) holds with equality. ■

Example 11 *(Proposition) When the utility function, $u(c,l)$, is separable in consumption and leisure, and its consumption part is one of constant absolute risk aversion (CARA), full insurance for an observable shock is optimal, i.e., $\tau^* = 0.5$.*

Proof. When the utility function is CARA with the coefficient of absolute risk aversion η, we have $u_{cc} = -\eta\, u_c$ for all s_i and t_i. Then,

$$E\left[u_c t_i\right] E\left[u_{cc} s_i\right] = E\left[u_c t_i\right] E\left[-\eta\, u_c s_i\right] = E\left[-\eta\, u_c t_i\right] E\left[u_c s_i\right] = E\left[u_{cc} t_i\right] E\left[u_c s_i\right].$$

The sufficient condition (12) holds with equality. ■

Example 12 *(Conjecture) When the utility function is separable and its consumption part is one of constant relative risk aversion (CRRA) with the coefficient of relative risk aversion $\gamma \geq 0$, full insurance for an observable shock is optimal, i.e., $\tau^* = 0.5$.*

Discussion. The CRRA example above is labeled a "conjecture" because closed-form solutions are not possible with CRRA utility. Instead, we constructed a computer program (written in Maple and run with 30 digits precision) that used a grid search algorithm to solve for the *global* optimum, $(\tau^*, \sigma^*) \in [0, 0.5] \times [0, 0.5]$, for a given set of utility parameters. This grid search algorithm was then run over a large range of utility parameters. In each case, $\tau^* = 0.50$.

Table 2 presents some illustrative numerical results for the CRRA specification: $\frac{c^{1-\gamma}}{1-\gamma} + \beta \cdot \frac{l^{1-\gamma}}{1-\gamma}$, where β is set to unity. Obviously, this example is not intended to be a carefully calibrated numerical experiment. Rather, our intention to demonstrate the role of the risk aversion parameter, γ, in helping determine the optimal risk sharing arrangement, (τ^*, σ^*). Notice that $\tau^* = 0.50$ in each case, i.e., the observable shock is always fully shared. Notice also that the σ^* is increasing in γ. One reason that σ^* increases is that moral hazard becomes less important at higher levels of γ; in particular, agents that are very prudent have less incentive to try to freeride off the risk sharing provided by the other agent. To see why,

Table 2: Optimal Level of Sharing of Observable and Non-Observable Shocks

γ	τ^*	σ^*
0.5	0.50	0.04
1.0	0.50	0.11
1.5	0.50	0.18
2.0	0.50	0.23
5.0	0.50	0.40

recall that agent's i's pre-tax income equals, $y_i = h_i + s_i$. Less freeriding (i.e., higher h_i) reduces agent i's probability of suffering from low value of y_i after the unobservable shock s_i is realized. As a result, more risk can be optimally shared among higher prudent agents, since they are less likely to try to take advantage of it. Another reason that σ^* increases in γ is that the utility value of risk sharing increases in γ. As a result, the balance between controlling moral hazard and providing risk sharing shifts toward more risk sharing as the value of γ increases.

6 The Joint Determination of τ^* and σ^* in the Second-Best Economy

Thus far, we have proven that (i) all shocks will be fully shared in the first-best economy while (ii) the non-observable shock will only be partially shared in the second-best economy. Both of these results were proven to hold provided that the derivatives, cross-derivatives and higher-order derivatives of the utility function satisfies some fairly general conditions that were stated in the beginning of Section 2. We then showed that (iii) the observable shock may be fully shared in the second-best equilibrium. However, in proving result (iii), we specified an additional sufficient condition, (11). The presence of this additional condition leads to an interesting question: why wasn't an extra sufficient condition used to demonstrate full risk sharing in the first-best economy, result (i)? In other words, if a shock is fully observable, does it really matter if non-observable shocks are also present, as in the second-best economy? In still other words, why doesn't result (iii) immediately follow from results (i) and (ii), thereby allowing us to avoid the additional sufficient condition (11) that we used to prove result (iii)? This section answers these questions by demonstrating the inter-

Table 3: Utility Levels at the Equilibrium and Various Non-Equilibrium Risk Sharing Arrangments

τ	σ	h	u
0.50*	0.04*	0.486*	2.822*
0.50	0.50	0.200	2.683
0.00	0.50	0.227	2.687

dependence of τ^* and σ^* in the second-best economy whenever agents are prudent.

As noted in Section 2, equation (8) shows that $\mathrm{d}h/\mathrm{d}\tau$ is not independent of σ unless $u_{ccc} = u_{lcc} = 0$ (i.e., unless agents are not prudent). As a result, we generally cannot set τ^* and σ^* independently of each other in the second-best economy (unless agents are not prudent). In contrast, all shocks can, of course, be independently shared in the first-best economy where complete contracting is available.

We now illustrate the joint determination of τ^* and σ^* in the second-best economy using the CRRA example considered in the previous section with $\gamma = 0.5$. Table 3 reports the agent's level of effort, h, and utility, u, at the second-best equilibrium tuple $(\tau^*, \sigma^*) = (0.50, 0.04)$ as well as at two *non-equilibrium* values of (τ, σ). Of course, the highest level of utility is at the second-best equilibrium point that is marked in Table 3 with asterisks (*). But now consider the other two non-equilibrium tuples where the level of risk sharing for the unobservable shock is set above its optimal level (i.e., $\sigma > \sigma^*$). Notice that the tuple $(\tau, \sigma) = (0.50, 0.50)$, where both shocks are fully shared, generates less effort and lower utility than the tuple $(\tau, \sigma) = (0.0, 0.50)$ where the *observable* shock is *not* shared at all. In other words, the "third-best" (i.e., constrained) outcome does not necessarily fully share the *observable* shock when the *unobservable* shock is being shared too much relative to its second-best level. The reason is due to prudence. When $\sigma > \sigma^*$, too much of the unobservable risk is being shared and so the level of effort exerted by each household is below its optimal level. Setting $\tau < 0.50$, therefore, forces households to accept more risk associated with the observable shock and, hence, exert more effort, thereby reducing the moral hazard problem associated with sharing the unobservable shock.

In sum, the values of τ^* and σ^* cannot be determined independently in the second-best economy in the presence of prudent agents. The sufficient condition (11) guarantees, though, that observable shocks will be fully shared in equilibrium. This sufficient condition is not needed in the first-best equilibrium where it is always efficient to share a given risk, independent of how other risks are shared.

7 Conclusion

This paper demonstrates that Ricardian equivalence can hold even in the presence of incomplete risk sharing between parents and their children. Moral hazard prevents unobservable idiosyncratic shocks from being fully shared. Still, observable shocks, including changes in the timing of taxes, might be fully shared in equilibrium, i.e., Ricardian equivalence holds. Ricardian equivalence is proven to hold under a sufficient condition derived herein. We considered several specifications for preferences in which Ricardian equivalence holds, including separable quadratic, separable CARA, and separable CRRA. (In the CRRA case, closed-form solutions are not available and so we can only conjecture that Ricardian equivalence holds based on numerical simulations). Future work could possibly extend our results to an even larger class of utility functions, although we found it difficult to obtain closed-form solutions for cases beyond separable quadratic and separable CARA. Future empirical work using linked household-level data could also attempt to distinguish between non-observable and observable shocks, such as social security reforms. Performing such estimation, however, would be quite challenging at present; modern data sets do not yet span a long enough period containing many policy shocks such as changes in social security benefit levels. In other work in its preliminary stage, we are exploring how a principal-agent model with moral hazard might also be useful in explaining the "equal bequest puzzle" that has been receiving more attention recently (e.g., McGarry, 1999; Bernheim and Severinov, Forthcoming).

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