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Altruism and efficient allocations in three-generation households

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Abstract
In this paper we test the efficiency of family resource allocation in three-generation households. Understanding how the so-called "squeezed middle" generation allocates resources towards the children and grandparents in the household will be increasingly important as populations age, and more elderly people become dependent upon their relations for financial support. Despite a large literature on household resource allocation in two-generation households (parents and children), to the best of our knowledge ours is the first study that includes the third generation. We present a theoretical model and conduct a discrete choice experiment in the context of reductions in the lifetime risk of developing coronary artery disease to verify the efficient resource allocation hypothesis. The data is obtained from a large sample of the Polish population. The sample consists of the middle generation members of three-generation households and hence WTP represents household value from the perspective of the "squeezed middle" parent. The results imply that household resource allocation is efficient. This has implications for understanding the likely response to government financial support aimed at supporting elderly people and their families.

Keywords Altruism · Efficient allocation · Three-generation households · Health risk · Willingness to pay

JEL Classification Q51 · Q58 · D13 · D64

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1 Introduction

Research into the economic value of children's health, and the reduction of health risks for children, is well established (for a comprehensive review, see Robinson et al., 2019). Beginning with Viscusi et al.'s (1988) investigation of the relationship between health risk reduction valuation and altruism in households, subsequent research has focussed mainly on parental values of their children's health. Parents are typically willing to pay (WTP) more to provide (the same absolute) environmental risk reductions for their child than for themselves, according to a review of the literature conducted by Alberini et al. (2010). This finding was mirrored in the more recent review by Robinson et al. (2019) which reported ratios of WTP values for children to adult ranging from 0.6 to 2.9 with most estimates exceeding 1.5. Using a between sample design, Blomquist et al. (2011) show this finding to be consistent across both mortality and morbidity with parental WTP values for children and for adults in a ratio of about 1.7 in the case of the mortality and 1.5 for morbidity.

In some studies, authors have developed models of family resource allocation to explain health valuations (see e.g. Dickie & Gerking, 2006, 2007, 2009; Gerking et al., 2014; Adamowicz et al., 2014). However, this research has taken place in the context of a two-generation household consisting of parents and children. Meanwhile, demographic trends in some countries have led to an increase in three-generation households (Pilkauskas & Martinson, 2014). The impact this has on allocative decisions over family health risks is an open question.

In this paper, we focus on the three-generation family situation in which the grandparent lives with the family, is assumed to be a household member and is dependent on the "parent" (middle generation). Whilst not all-encompassing, this household type is a major subset of the so-called "sandwich generation". As emphasized in Remle (2011) and Soldo (1996), the "sandwich generation" must adapt to a financial "midlife squeeze" as they must balance obligations to young children and grandparents. Public and environmental health policies may be specifically targeted at household members including children and elderly, in order to promote their health and wellbeing. Understanding inter-generational transfers within the family is key to explaining the effectiveness or otherwise of these policies. As Dickie and Gerking (2007)—hereafter DG—noted, in the context of a two-generation household, the effectiveness of government policies will be influenced by whether efficient allocation is taking place. For example, following a government intervention to provide a public good such as mortality or morbidity risk reduction, if households are efficient then government spending could simply crowd out family expenditure, meaning that there will be no overall improvement in heath and/or safety, neither at the level of the household nor for society as a whole.

This issue is significant because, whilst trends in prevalence and type differ across the world, multi-generational families comprise a small but significant grouping, from a policy perspective. In the USA, for example, the percentage of children living in a three-generation household rose slightly from 8.1% to 9.8% over the period 2009–2016 (Pilkauskas et al., 2020). The prevalence of 40-year-olds living in three-generation families has declined across Europe between 1980 and 2010, for example in Greece falling from 9.5% to 4.5% and Austria from 5.5% to 3.5%, although in Romania it has slightly increased from 9.5% to 10.5% which mirrors the trend in the USA (rising from

3.5% to 4%). In Europe, three-generation families are associated with socio-economic disadvantage, although there is a gradual shift to a situation in which grandparents are able to provide rather than being in need of support (Glaser et al., 2018). This family type is most significant in Asia. There, three-generation households account for 21.2% of total households, on average, ranging from 3.0% in Iran to 44.6% in Tajikistan. They are most common in Central and Southern Asia whereby approximately one in five households fall into this category (27.7% and 27% respectively). Eastern Asia shows the lowest share of three-generation households as about 15.1% (Kim, 2020).

Within this general context, we address the specific question as to whether allocations are efficient in a "squeezed middle" context where a parent is responsible for both their child's and the grandparent's health. We draw on Becker's Rotten Kid (Becker, 1974) framework by simply adding a further "Rotten Dependent" to the DG model of household allocations. The DG model describes household production of latent health risk in a two- generation family in which the parent (middle generation) is assumed to be altruistic towards the younger family member. Our extension to the model is to add an older generation, the grandparent, towards whom it is assumed the parent is also altruistic. Our approach captures the intuition of a "squeezed middle" generation, who contributes both to her own parent and to her offspring but receives contributions from neither of them.

If it can be shown empirically that household allocation is efficient for this type of family, then this relatively simple theoretical framework for family health allocations would seem adequate for modelling purposes without the need to internalise other familial allocative activities. These activities might include, but are not restricted to, intergenerational transfers e.g. from the grandparent to the grandchild, "in-kind" services such as childminding, or potential bequests when the grandparent dies, all of which might be potential sources of apparent inefficiencies.

We test for efficiency in household allocation empirically using the results of a stated preference study carried out in Poland. The current structure of Polish households provides a useful opportunity to explore this issue, as the share of three-generation households in Poland is relatively large (10%)[1] in comparison with some other European countries e.g. Italy (3%), Portugal (5%) or the United Kingdom (2%) (GUS, 2014; ONS, 2018; UN, 2019).

We use a split-sample Choice Experiment (CE) to estimate the middle (parent) generation's WTP for reducing their child's (youngest generation) risk of getting heart disease in one subsample, and the middle (parent) generation's WTP to reduce the risk of the same disease for the grandparent (oldest generation) in the other subsample. The risk reducing initiatives are voluntary vaccination programs, and the CE comprises two attributes; the lifetime risk reduction and a price attribute. Overall, our results show that in both cases, household allocations by the middle generation on behalf of the other two generations are efficient.

The remainder of the paper is as follows. The next section introduces our conceptual framework and Section 3 describes the empirical survey. Section 4 describes the econometric analysis used to estimate parental WTP for self, child and the grandparent. Section 5 discusses the results and Section 6 concludes.

[1] For comparison, around one in three households in Poland includes at least one child, and around one in four households in Poland includes at least one child aged 12 or younger (Eurostat, 2019).

2 Conceptual framework

In this section, we provide a brief outline of our conceptual framework, which extends the model presented in DG of altruism that incorporates household production of latent risk in a two-generation family[2,3] We follow DG in assuming a household operating according to a unitary[4] model where a parent (*P*) allocates household resources, but extend it to include an older generation, the elderly parent. Hence, our "family" is three generations composed of an altruistic parent *(P)*, the grandparent t *(G)* and one child *(K)*—all three generations living within a household but each with differing lifetime trajectories: whilst *K* receives transfers from *P* once *K* reaches adulthood, *P* does not receive such transfers from *G*; and whilst *G* is provided for by *P* during her final period of life, *P* does not receive such provision from *K* (indeed, during her final year, *P* is still earning income and making transfers to *K*). In this way, we model a "squeezed middle" in a "sandwich generation" beset not only by a "Rotten Kid" (Becker, 1974), but also by a further "Rotten Dependent". In this framework, P is the allocator, but it is important to note that the identity of the decision maker does not matter in a fundamental way. As long as there are household preferences and there is an altruist allocating resources and/or making transfers, everyone in the household has the incentive to act efficiently according to the preferences of the altruist.

As in DG, each member of the household faces a lifetime risk R_i of some adverse health outcome, which is influenced by consumption of a safety good, S_{it}, which is the argument of risk production functions that are assumed not to shift over time, and whose marginal products of S are assumed to be strictly negative. Household members also enjoy background consumption, C_{it}. The subscript $i = K, P, G$ identifies the household members, with j referring to dependents $j = K, G$. Like in DG, P lives in periods $t = 0, 1$ and K lives in periods $t = 0, 1, 2$. We model G as being alive only in $t = 0$. That is, P is deceased after $t = 1$ and G is deceased after $t = 0$.

In period $t = 0$, P allocates S_{it} and C_{it} to all household members, including herself. In period $t = 1$, P and K are autonomous and decide their consumption based on their own preferences and income, with the possibility that P transfers income to K in this period. In $t = 2$, K consumes autonomously according to their own income and preferences. $U_P(.)$ is the utility function for P, $U_K(.)$ the utility function for K and $U_G(.)$ the utility function for G. K's lifetime utility enters the parent's utility function weighted by $\eta \geq 0$ and G's utility enters P's utility function weighted by $\theta \geq 0$, which captures altruism.

In our conceptual model, we focus on the decisions of P in period $t = 0$, where she is allocating resources to both her dependent child K and the grandparent G. She maximises utility as specified in eq. (1):

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[2] It has been repeatedly suggested that altruism may be an important benefit component (see eg. Viscusi et al. (1988).

[3] In the Appendix, we present a fuller worked explanation of our conceptual framework.

[4] The principle aim here is to explore efficiency of allocations. This framework does not preclude the use of other more complex household models, such as the collective model. Adamowicz et al. (2014) point out that even if allowance were made for two parents with conflicting as well as common interests, or for shared decision-making between the parent and the grandparent, the same type of MRS equalities as those tested here would emerge, as long as resources were allocated efficiently. Hence, the adoption of the unitary model is largely for convenience.

$$U_P(C_{P0}, C_{P1}, C_{K0}, C_{G0}, R_P, R_K, R_G) + \eta U_K^*(C_{K0}, S_{K0}, T, y_{K1}, y_{K2}, r, p_S) + \theta U_G^*(C_{G0}, S_{G0}) \quad (1)$$

subject to the three risk production functions, the restriction that transfers between P and K in $t = 1$ are non-negative, and the budget constraint in eq. (2).

$$y_{P0} + \frac{1}{1+r} y_{P1} = C_{P0} + C_{K0} + C_{G0} + p_S(S_{P0} + S_{K0} + S_{G0}) + (1+r)^{-1}[C_{P1} + T + p_S S_{P1}] \quad (2)$$

in which y_{it} is income of i in period t, r is the interest rate, p_S is the price of the safety good, and T is the transfer from P to K in $t = 1$.

Straightforwardly from the first order conditions outlined in Appendix 1, we follow DG in showing that *P's* marginal rate of substitution between her own consumption and the consumption of her dependents, $C\_MRS_{j,P}^P$ is equal to unity. Our extension demonstrates trivially that this is true for the grandparent as well as for the child. Similarly, we show that *P's* marginal rate of substitution between her own safety good consumption and the safety good consumption of her dependents, $S\_MRS_{j,P}^P$ is equal to unity both for $j = K$ and $j = G$.

Further, *P's* MRS between risk reductions for P and for her dependents is equal to the ratio of marginal products of the risk reductions, which is in turn equal to the ratio of the marginal costs of the risk reductions for each generation:

$$\frac{\frac{\partial U_P}{\partial R_K} + \eta \frac{\partial U_K^*}{\partial R_K}}{\frac{\partial U_P}{\partial R_P}} = \frac{\frac{\partial R_P}{\partial S_P}}{\frac{\partial R_K}{\partial S_K}} = \frac{MC_{K0}}{MC_{P0}} \quad (3a)$$

$$\frac{\frac{\partial U_P}{\partial R_{G0}} + \theta \frac{\partial U_G^*}{\partial R_G}}{\frac{\partial U_P}{\partial R_P}} = \frac{\frac{\partial R_P}{\partial S_P}}{\frac{\partial R_G}{\partial S_G}} = \frac{MC_{G0}}{MC_{P0}} \quad (3b)$$

To generate a more specific hypothesis for our empirical work, we follow DG by focusing on *relative* risk reductions. This restriction allows us to state that the ratio of the marginal product of the safety good is equal to the ratio of the initial risk for P and K, and for P and G.

$$\frac{\frac{\partial R_P}{\partial S_{P0}}}{\frac{\partial R_K}{\partial S_{K0}}} = \frac{R_P}{R_K}; \frac{\frac{\partial R_P}{\partial S_{P0}}}{\frac{\partial R_G}{\partial S_{G0}}} = \frac{R_P}{R_G} \quad (4)$$

By multiplying both sides of eqs. (3a) – (3b) by the inverse of the ratio of the initial lifetime relative risks, we produce the equalities in (5a) – (5b). Since, from (4), the middle terms are unity, this generates our empirical hypotheses to be tested: P's marginal rate of substitution between equal percentage risk changes for P and K, and for P and G, equate to unity.

$$\frac{\frac{\partial U_P}{\partial R_K}+\eta\frac{\partial U_K^*}{\partial \mathrm{R}_K}}{\frac{\partial U_P}{\partial R_P}}\cdot\frac{R_K}{R_P}=\frac{\left(\frac{\partial R_P}{\partial S_P}\right)/R_P}{\left(\frac{\partial R_K}{\partial S_K}\right)/R_K}=\frac{MC_{K0}}{MC_{P0}} \tag{5a}$$

$$\frac{\frac{\partial U_P}{\partial R_{G0}}+\theta\frac{\partial U_G^*}{\partial R_G}}{\frac{\partial U_P}{\partial R_P}}\cdot\frac{R_G}{R_P}=\frac{\left(\frac{\partial R_P}{\partial S_P}\right)/R_P}{\left(\frac{\partial R_G}{\partial S_G}\right)/R_G}=\frac{MC_{G0}}{MC_{P0}} \tag{5b}$$

where:

$MU_K^P=\frac{\partial U_P}{\partial R_K}+\eta\left(\frac{\partial U_K^*}{\partial R_K}\right)$ is the marginal utility of K's safety, for P;
$MU_G^P=\frac{\partial U_P}{\partial R_G}+\theta\left(\frac{\partial U_G^*}{\partial R_G}\right)$ is the marginal utility of G's safety, for P;
$MU_P^P=\frac{\partial U_P}{\partial R_P}$ is the marginal utility of P's own safety, for P;
R_K, R_P, R_G are initial lifetime risk levels.

As noted for the two-generation case in DG, the result that MRS equals unity is independent of the size of the pure altruistic concern for the dependent. That is, regardless of the size of η and θ for K and G, respectively, we expect MRS = 1 in both cases, as long as P is altruistic (pure or paternalistic) towards K and G, and as long as P cares at least somewhat for herself. However, if the parent displays no altruism towards the dependent, MRS = 0; and if the parent displays altruism but no concern for herself, then MRS is arbitrarily large. Hence, the result MRS = 1 implies altruism and efficiency.[5]

Therefore, we set up our empirical test to establish whether this MRS between equal percentage risk changes between self and dependent(s), equals to unity.

Although our paper does not aim to address whether there exists a child and/or elderly parent health premium, we can nonetheless establish whether our results are compatible with such premia. To establish whether this is the case, we draw upon the argument made by Gerking and Dickie (2013). There, they establish that MRS = 1 is consistent with a child health premium under two conditions. The first condition is

[5] An implication of the model for government policymaking is that, if P is at least a little altruistic towards their dependents, and cares at least a little for her/himself, then any government contribution towards the safety of a dependent will be absorbed into the family's household budget, and the overall allocation of consumption and safety good consumption will remain unchanged. If instead the government is more efficient at providing the safety good than the family, then government provision of the safety good would act simply as an income increase, being reallocated such that the relative consumption of the safety good, and relative levels of safety enjoyed across the generations, would remain the same.

convexity in the marginal cost of the risk reduction. The second condition is that the perceived initial lifetime risk is lower for the dependent than for *P* herself, since this means that a relative risk reduction of X% for *P* herself is larger in *absolute* terms than a relative risk reduction of X% for the dependent. Together, these conditions allow Gerking and Dickie to infer that the ratio of WTP for absolute risk reductions to child compared to self is greater than 1, and hence compatible with a child health premium. Extending this logic in our case, if we find that MRS = 1 between *P's* own risk reduction and that of their elderly parent, and if *P* perceives the grandparent to face a higher lifetime risk than P's own, this will be compatible with a grandparent premium, given the assumption that MC of the risk reduction is convex.

3 Survey

3.1 Survey structure and data collection

Our questionnaire is based on the survey in Adamowicz et al. (2017) concerning risk perception and parents' marginal WTP for heart disease risk reduction. We extend this study to investigate a parent's preferences not only towards their child but also towards the grandparent. We use three CEs to estimate the parent's WTP for reducing risks of coronary artery disease (CAD). In one CE we ask about their child's risk of CAD; in another, their own risk; and in the third CE we ask about the grandparent's risk. Each respondent completed two of the three CEs, as outlined below. The risk reducing initiatives we describe are similar to Adamowicz et al.'s voluntary vaccination programs.

In the first section of the study, we collected information about respondents' family structures. In the next section, we tested respondents' risk comprehension and introduced an interactive grid scale for indicating risk and its changes. The grid depicted 100 numbered squares arranged in 10 rows and 10 columns all of which were initially coloured blue. The respondents saw examples of different risks of general health deterioration with squares recoloured from blue to red (red represents risk). Respondents completed a tutorial about measuring risk using the interactive grid scale.

Next, respondents were provided information about CAD. This information included the risk of getting this disease before age 85 for the average person and individual risk factors such as: gender, smoking, current health status, family history, exercise and diet.[6] We elicited information from respondents about how they perceived their own lifetime risk of getting coronary artery disease, as well as their child's lifetime risk, and the grandparent's lifetime risk. The respondents were shown how their perceived risks transformed into a CAD risk profile over each family member's lifetime, by means of personalised graphs indicating cumulative risk functions.

In the next section, we elicited stated preferences for a set of vaccinations to reduce the risk of CAD using the interactive grid scales and graphs with cumulative risk

[6] The respondents were informed that the risk of getting the coronary artery disease for the average person in some European countries e.g. the UK is equal to 25% and that the probably in Poland the risk of getting this disease is higher. We were unable to find the precise risk estimates for Poland. To estimate the risk for the average person in the UK we used QRISK®-lifetime cardiovascular risk calculator.

functions introduced previously. These vaccines were presented as newly available private goods that could provide incremental reductions in lifetime CAD risk. They varied in terms of their effectiveness (different relative risk reductions) and their cost.

Respondents were randomly assigned into one of two conditions. In each condition they faced two separate CEs as illustrated in Table 1—all respondents completed the CE for their own risk reductions, and then completed a CE either for their child or for the grandparent. Hence the respondents did not make any direct trade-offs between their child and the grandparent. The design allows for a direct comparison of our parent-child results with previous studies without the potential confound that could be introduced by the inclusion of the trade-off with the third generation. Respondents were told that the vaccinations would provide extra protection from CAD over and above the benefits that they and their child (Condition 1) or they and the grandparent (Condition 2) could get from eating well and exercising regularly. They were also told that the vaccinations available would differ in terms of their efficacy and price.

The risk reduction was presented using the interactive grid scale and graphs showing lifetime CAD risk reductions (marked as green squares in presented choice sets). Socio-demographic information was collected in the last section.

The study was developed and tested using in-depth interviews. Based on the feedback obtained during the interviews the CEs were revised and tested in a pilot study. The main survey took place in January 2018. In total, 500 face-to-face interviews were conducted by a professional polling agency using computer-assisted personal interviewing (CAPI). Respondents were all parents with at least one biological child aged 3 to 15 years living in the home. Additionally, they lived with at least one parent (the grandparent) 80 years or younger. As far as possible, we prioritised respondents who lived with a biological parent. For respondents with two or more eligible children, one child was randomly selected and designated to be the sample child. The same procedure was applied to the grandparents. We ensured that none of the individual family members had previously been diagnosed with CAD. The split of respondents between conditions is shown in Table 1.

3.2 Attributes and experimental design

Each CE included two attributes: the perceived lifetime risk of CAD and the annual cost of the vaccination. Each choice was between three alternatives. The first two refer to the proposed vaccination programs, the third is a status quo (SQ) option, which delivered no additional risk reduction, and came at no cost. Table 2 shows the full list of attributes and their levels used in the experimental design.

The choice sets were created using the Ngene software, using a Bayesian efficient design applying the D-error optimization criterion (Scarpa & Rose, 2008). The prior values were obtained from models estimated using data from the pilot study. The final design for each CE included 24 choice sets blocked into four subsets of six sets each. In each choice set, respondents were asked to choose which vaccination program they would prefer. The order of CEs in each condition, and choice sets in each CE was randomized.

For the baseline, we used the respondents' own perceived risks that they, their child and/or the grandparent would be diagnosed with CAD before age 85. Before the choice tasks, respondents were presented with graphical representations of the lifetime risk

Table 1 Choice experiments division between conditions

Condition	Choice Experiments – risk reduction recipient			Number of respondents
	Parent	Child	Grandparent	
Condition 1	yes	yes	no	250
Condition 2	yes	no	yes	250

Note: The order of Choice Experiments in each condition was randomized

changes that would be used in the CEs, both in grid scale format and using diagrams indicating cumulative risk functions. In the choice sets, risk changes were indicated using the grid scales where red squares show the perceived risk of getting CAD and green ones indicate the risk reduction. Figures 1 and 2 show example choice sets used in condition 1.

4 Analytical approach

Discrete choice models are used to analyse data from the CEs. In accordance with random utility theory (McFadden, 1974), we assume that the preferences of individual n consist of a systematic component (V^j_{itn}) and an unobservable, stochastic component (ε^j_{itn}). This specification leads to the usual formulation of the utility that an individual derives from choosing alternative i on choice occasion t:

$$U^j_{itn} = V^j_{itn} + \varepsilon^j_{itn} = \mathbf{X}^j_{itn}\boldsymbol{\beta}^j_n + \varepsilon^j_{itn} \qquad (6)$$

In this setting, $\mathbf{X}^j_{itn}$ is a vector of attributes including an alternative specific constant for the status-quo alternative (*ASC_SQ*), relative risk reduction (*Risk*) and monetary cost (*Cost*), whereas $\boldsymbol{\beta}^j_n$ is a vector of parameters (marginal utilities). We allow for preference heterogeneity by letting $\boldsymbol{\beta}^j_n$ vary between respondents according to a chosen distribution. We assume the error component, ε^j_{itn}, follows an independent and identically distributed Gumbel distribution, leading to the Random Parameter Logit

Table 2 Choice Experiment attributes and levels

Choice Experiment	Attribute	Attribute label	Attribute level
Choice Experiment (Parent)	10% reduction in lifetime coronary artery disease risk for the **respondent**	10% risk red. (Parent)	0% (SQ); 20%; 40%, 60%, 80%
Choice Experiment (Child)	10% reduction in lifetime coronary artery disease risk the **respondent's child**	10% risk red. (Child)	
Choice Experiment (Grandparent)	10% reduction in lifetime coronary artery disease risk for **grandparent**	10% risk red. (Grandparent)	
All	Annual cost of vaccination in 10 zł	Cost/10	0 (SQ); 10; 20; 50; 100; 150, 200

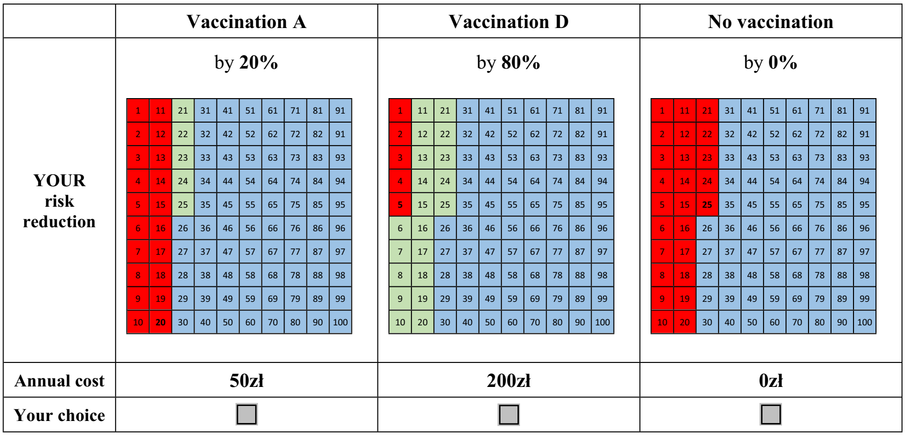

Fig. 1 Example of a choice set for a respondent who declared her/his lifetime coronary disease risk equalled 25%

framework (RPL; Revelt & Train, 1998). In (6) we index all components of the utility function with $j = \{P, K, G\}$, as we estimate separate parameters for respondents' preferences towards herself (P), her child (K), and the grandparent (G). The parameter for *Cost* is an exception, as we assume that a given individual has the same marginal utility of money, whether they make choices for themselves or for their child or the grandparent.

Equation (6) can be considered to be a linear approximation of the indirect utility function stemming from (1), which the respondent employs to choose a safety good (vaccinations) while taking into account the lifetime risk and price of the vaccination. In the CE, the respondent chooses the safety good for each generation (P, K or G) independently, and therefore in (6) we define three utility functions (indexed by j). Nevertheless, the choices are made by the same respondent (middle generation), so, similar to (1), these utility functions jointly describe the preferences of the parent with respect to safety goods and decreased lifetime risks for different generations.

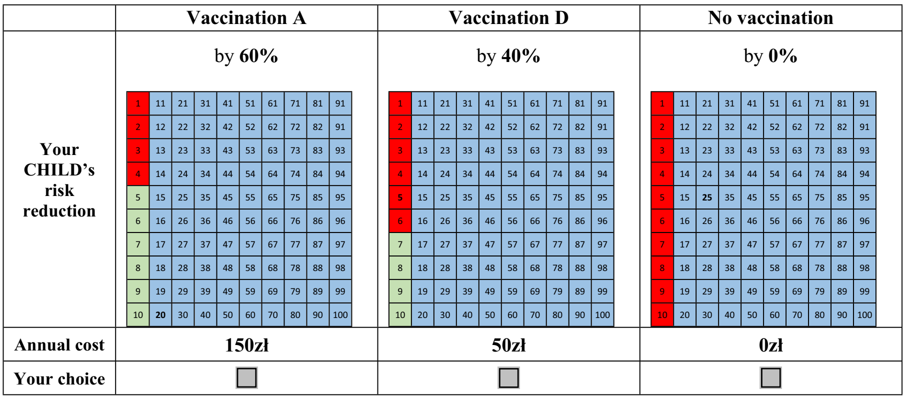

Fig. 2 Example of a choice set for a respondent who declared his/her child's lifetime coronary disease risk equalled 10%

The conditional probability of a respondent choosing alternative i is given by the multinomial logit formula:

$$P\left(i|\mathbf{X}_{tn}^{j},\boldsymbol{\beta}_{n}^{j}\right)=\frac{\exp\left(\mathbf{X}_{itn}^{j}\boldsymbol{\beta}_{n}^{j}\right)}{\sum_{l=1}^{l=3}\exp\left(\mathbf{X}_{ltn}^{j}\boldsymbol{\beta}_{n}^{j}\right)} \tag{7}$$

Nevertheless, as $\boldsymbol{\beta}_{n}^{j}$ is unobserved by the researcher it needs to be integrated out to obtain a likelihood function:

$$L_n=\int\prod_j\prod_t\sum_i y_{itn}^{j}P\left(i|\mathbf{X}_{tn}^{j},\boldsymbol{\beta}_{n}^{j}\right)f(\boldsymbol{\beta}_n|\boldsymbol{\alpha},\Omega)d\boldsymbol{\beta}_n \tag{8}$$

where y_{itn}^{j} is equal to 1 if individuals have chosen a given alternative, and equal to 0 otherwise. Furthermore, $f(\boldsymbol{\beta}_n|\ \boldsymbol{\alpha},\ \Omega)$ is a density function of random parameters, which depends upon a vector of means of random parameters, $\boldsymbol{\alpha}$, and covariance matrix, Ω, which need to be estimated. As there are two conditions in the survey, with respondents answering questions either about themselves and their child or about themselves and the grandparent, we have either $\boldsymbol{\beta}_n=\left(\boldsymbol{\beta}_n^P,\boldsymbol{\beta}_n^K\right)$, or $\boldsymbol{\beta}_n=\left(\boldsymbol{\beta}_n^P,\boldsymbol{\beta}_n^G\right)$. RPL models are estimated separately for the two conditions. We follow a data-driven approach to decide whether to assume that the random parameters are distributed normally or log-normally.

Models were estimated using Maximum Simulated Likelihood method with 2000 scrambled Sobol draws (Czajkowski & Budziński, 2019). Median willingness to pay was estimated using a two-step procedure, following the Krinsky and Robb method (Krinsky & Robb, 1986). First, the underlying coefficients, Ω, were drawn N_1 times from the normal distribution, using their estimates as a mean and an inverse hessian as a covariance matrix. Then, for each vector that was drawn, random parameters were drawn N_2 times from the assumed distributions (either normal or log-normal). Respondents' WTP were calculated as a ratio of coefficients for *Risk* and *Cost.* Finally, we calculated a median over N_2 draws from the second step, and then we calculated a mean over the obtained N_1 medians. We also calculated the standard deviation over the obtained N_1 medians to estimate standard errors. We employed median WTP rather than mean WTP, as very often mean WTP becomes unrealistically large when cost coefficients are log-normally distributed. Furthermore, median WTP is generally found to be more stable than mean WTP (Bateman & Brouwer, 2006).

The same two step procedure was applied when estimating the MRS of the CAD risk reduction between family members. The MRS in condition 1 was calculated as a ratio of coefficients for a relative risk reduction for the child and relative risk reduction for the respondent, and in condition 2, the relative risk reduction for the child was replaced by that for the grandparent. In condition 2 we identified that a normal distribution for risk reduction coefficients provides a better fit to the data than log-normal distribution. As a result, mean MRS cannot be calculated for this condition (Daly et al., 2012) and we therefore calculate median MRS instead.

5 Empirical results

5.1 Descriptive statistics

The basic socio-demographic characteristics of the sample are reported in Table 3. No significant differences were found with respect to age, gender, education and income between respondents in the two conditions. The proportion of women in the sample is the same as in Poland as a whole. People who attained higher and secondary education are overrepresented in the survey while people with only primary education are underrepresented.

55% of respondents reported that they lived with two or more children at home. For this study, the sampling strategy was to prioritise biological links between parents and the grandparents and 82% of respondents declared that they live with at least one biological parent and 18% stated they live with their partner's or spouse's mother or father. Of the sampled grandparents, the average age of a sample grandfather was 66 years (maximum was 80 years) and for sample grandmothers it was 67 years (maximum 79). 56% of the sample children were male, and the average age of the children in the sample was 9 years.

5.2 Risk perception

Table 4 presents the statistics of the perceived lifetime risk of coronary artery disease across the sample. We found statistically significant differences between the respondents' own perceived lifetime risk and that for a child and a grandparent. On average, respondents stated that they perceive the risk of CAD as higher for themselves than for a child or for the grandparent with whom they lived.

5.3 Models results

The theoretical model presented in Section 2 provides a testable hypothesis for an altruistic respondent who maximises their utility defined according to our conceptual framework. The hypothesis is that the MRS of corresponding relative lifetime risk reductions between the respondent and their dependent (either child or grandparent) is equal to 1. We use the results obtained from the RPL regression to test this hypothesis.

Table 3 Descriptive statistics of the sample characteristics

	Share	Mean	Median	Min	Max
Female	51%				
Age (years)		40	40	21	64
Highest educational attainment					
- Primary	4%				
- Secondary	61%				
- Higher	36%				
Net monthly household income (€)		1517	1285	117	8177

Note: Number of respondents, $N = 500$

Table 4 Perception of coronary artery disease lifetime risk

Condition	Child's risk mean (st.dev.)	Parent's risk mean (st.dev.)	Grandparent's risk mean (st.dev.)	t-test (mean-comparison)
Condition 1	20.40 (10.03)	30.03 (16.48)	–	10.7108
Condition 2	–	31.92 (15.71)	26.09 (14.51)	6.0553

The RPL models are used to estimate parameters of the respondents' utility functions. The estimated coefficients reflect marginal utilities associated with changes in the levels of the attributes, and as a result, changes in the probability of selecting an alternative. Several specifications of RPL models were estimated and the models that best fit the data are presented in Table 5. For each attribute in the RPL models, we report the estimated mean and standard deviation of the parameter distribution in the population. The RPL models allow for a correlation of random parameters. As a robustness test, we also ran models without allowing for this correlation, but a likelihood ratio test favoured the models with correlations. In both models we assumed a constant marginal utility of income.[7]

Table 6 shows the results of the marginal rate of substitutions of the CAD lifetime relative risk reductions for different family members and the median WTP results based on the estimations presented in Table 5. These results provide evidence to support the efficiency condition for household resource allocations. Each calculated median WTP for a 10% decrease in lifetime risk of CAD is significantly different from zero at the 1% significance level. We found that in condition 1, parents would pay approximately 8 Euros annually to reduce the lifetime risk of CAD for their child by 10% and 7 Euros to reduce risk for themselves by the same amount. The hypothesis of equality in condition 1 was rejected at the 10% level but not at the 5% level. In condition 2, the results concerning the equality of median WTPs are stronger: no significant difference is found between the median WTP for the respondent and the grandparent.

(Euro per year).

In Table 6 we also present results of the tests verifying the hypothesis that the median MRS between equal proportionate reductions in respondents' own, their child's and the grandparent's lifetime risk equals to 1. First, we calculate median MRS in a similar way to how we estimated median WTP. The MRS is equal to 1.26 and 1.00 for parent and child and for parent and the grandparent, respectively. Although the MRS is higher for the child, in both cases we could not reject the hypothesis that the median MRS is equal to 1 (although in the case of condition 1 these results are weaker). Results of these tests indicate that the median respondent efficiently allocates her resources between family members.[8] The results of tests concerning the equality of distribution of marginal utilities for relative lifetime risk reductions are presented in Appendix 2.

[7] We also tested models accounting for scale effects, but the obtained results suggest that the scale effect is insignificant in both conditions.

[8] We also conducted a study based on the same design as condition 1 where we investigated the allocation in two-generation households consisting of parents and children without the grandparent resident. The results are consistent with those presented in this paper in condition 1—in both cases we find MRS between the lifetime risk reduction for the parent and the child equal to 1.

Table 5 Random parameter logit model results

Condition 1			Condition 2		
Variable	Coefficient	Distrib.	Variable	Coefficient	Distrib.
Mean			*Mean*		
ASC_SQ (child)	−1.691	n	ASC_SQ (grandparent)	−5.395***	n
10% risk red. (child)	1.301***	ln	10% risk red. (grandparent)	1.332***	n
ASC_SQ (parent)	−1.816	n	ASC_SQ (parent)	−3.749***	n
10% risk red. (parent)	1.031***	ln	10% risk red. (parent)	1.220***	n
Cost/10	0.396***	ln	Cost/10	0.304***	ln
St. dev.			***St. dev.***		
ASC_SQ (child)	20.895***		ASC_SQ (grandparent)	10.164***	
10% risk red. (child)	1.731***		10% risk red. (grandparent)	1.049***	
ASC_SQ (parent)	16.965***		ASC_SQ (parent)	9.084***	
10% risk red. (parent)	1.785***		10% risk red. (parent)	1.136***	
Cost/10	2.641***		Cost/10	2.099***	
Model diagnostics					
LL at convergence	−1209.44			−1201.62	
Ben-Akiva-Lerman's pseudo-R^2	0.7004			0.7029	
AIC/n	0.8196			0.8144	
BIC/n	0.8597			0.8545	
n (observations)	3000			3000	
r (respondents)	250			250	
k(parameters)	20			20	

Note: ASC stands for an alternative specific constant. For log-normal distributions of parameters we report exp(μ), which corresponds to the median of the distribution

6 Discussion and conclusions

The purpose of the study was to establish whether household allocation in the context of health risk reductions is efficient in three-generation households. Our results both support and extend the growing empirical consensus that has established efficiency in resource allocations between parent and children in two-generation households, for example DG, Adamowicz et al. (2012), and Gerking et al. (2014). We establish that this efficiency is maintained in the presence of the older generation. Specifically, we found that the marginal rate of substitution between parental expenditures on reducing lifetime risks for themselves and either dependent does not differ significantly from 1. This indicates that even for the "squeezed middle", household resource allocation is carried out efficiently. We found that a typical parent would pay approximately 7 Euros annually to reduce the lifetime risk of CAD by 10% for themselves whereas their WTP to reduce the risk of CAD for both their child and for the grandparent, was approximately 8 Euros per year. However, the difference between WTPs for the parent and their dependents is not statistically significant. Using a very similar approach, Adamowicz et al. (2012) investigated parents' preferences for lifetime risk

Table 6 Willingness to pay and MRS of relative (10%) coronary artery disease lifetime risk reduction.

	Condition 1			Condition 2		
	Child	Parent	Dif. sig.	Grandparent	Parent	Dif. sig.
Median WTP	8.3***	6.6***	*	8.0***	6.9***	–
Median MRS = 1	1.27		*	1.00		–

Note: *, **, *** indicate p values lower than 0.1, 0.05 and 0.01, respectively

reduction for coronary artery disease. They found that parents are willing to pay $1 annually to reduce CAD by 1%. These results are broadly in similar range to our estimates which indicate that the parental WTP to reduce CAD by 10% equals to 7–8 Euros per year.[9]

In line with the underlying conceptual model and other empirical studies to date (see, for example, Adamowicz et al., 2012 and Gerking et al., 2014), we focused on relative risk reductions, rather than absolute, to test the efficiency conditions for household resource allocation. Additionally, in our analyses, we use the risk levels perceived by the respondents, instead of objective risks based on epidemiological evidence. This is for two reasons. Although we informed the respondents about the main factors that can influence the lifetime risk of CAD, to personalise the objective risk to the individual in the survey would have required much more detailed personal profiling of the respondents' health related behaviour including their diet and exercise, as well as their genetic risk of CAD. Secondly, if respondents made decisions based on their own risk perceptions estimates, but the data were analysed based on the assumption that they used objective risks, the results might be misleading.

Like Adamowicz et al. (2012) we found that the parent assessed their own lifetime risk of CAD to be higher than their child's lifetime risk. Gerking and Dickie (2013) suggested that a higher perceived lifetime health risk for parent than child might be related to discounting of risks in the future. This contrasts with our findings with respect to the older generation: the parent estimates a higher perceived lifetime health risk for themselves than for the grandparent. Given our findings on perceived lifetime risks, and under the assumption that the marginal cost of risk reduction is convex (see Gerking & Dickie, 2013), our results are compatible with the existence of WTP premia for a parent towards their child and towards the grandparent.

To the best of our knowledge, our study is the first to investigate how including a third generation alters household decision making over resources using non-market valuation methods. Clearly, further research is needed to investigate the generalisability of these results. Nonetheless, these findings could have profound implications with respect to the degree to which the so-called "sandwich generation" can substitute for the government in the area of health and social care for the elderly, particularly if life expectancy continues to increase.

For example, consider a government intervention to provide reductions in risks of death or illness, intended to mainly support the elderly. Our results suggest that parents

[9] These amounts seem broadly reasonable: the average yearly expenditure on voluntary private health care per capita is estimated in Poland at about 240 Euro (Eurostat, 2020).

in the “squeezed middle” may simply reallocate family expenditure away from providing for the safety of the grandparent, and towards other activities that they perceive to be of benefit to the family. There may be a crowding out of family expenditure on the health and safety of the grandparent. If so, whilst the family’s welfare as judged by the middle generation may be maximised, policies targeted specifically towards helping the elderly may have unanticipated consequences for welfare across generations, at the level of the household and for society as a whole.

Appendix 1: Theoretical background

In this appendix we present the theoretical background for our empirical investigation. We draw on the model presented in Dickie and Gerking (2007, hereafter DG), which incorporates household production of latent risk in a two-generation family. In our extension to that model, we include a third generation, so that a family includes three generations composed of one altruistic parent (*P*), one child (*K*) and the grandparent (*G*) within a household. Our approach captures the intuition of a “squeezed middle” generation, who contributes both to her own parent and to her offspring, but receives contributions from neither of them. In this way, the lifetime trajectories of each generation differ: whilst *K* receives transfers from *P* once *K* reaches adulthood, *P* does not receive such transfers from *G*; and whilst *G* is provided for by *P* during her final period of life, *P* does not receive such provision from *K* (indeed, during her final year, *P* is still earning income and making transfers to *K*). In this way, we model a “squeezed middle” generation beset not only by a “Rotten Kid” (Becker, 1974), but also by a further “Rotten Dependent”.

The three generations each face an independent lifetime risk of an adverse health outcome, with the risks labelled R_P, R_K and R_G, respectively. Following DG, we assume a unitary model in which we disregard the possibility of differences between multiple parents’ interests within the household (although see Blundell et al., 2005 for a discussion of alternative approaches to analysing intra-household decision making and note Adamowicz et al. (2014) who point out that the predictions of MRS equality would also arise within a collective model). We investigate how a parent (*P*) allocates resources between herself, *G* and *K*, assuming that the parent has two periods of life remaining and the child has three. Our extension to the DG model is to add the grandparent with one period of life remaining.

In the first period (t = 0), the parent, *P* receives all family income and she is responsible for providing goods to all members of the three-generation household. We assume that the income contribution of *G* to the household budget is not significant in relation to their needs, and as such we do not model income for *G*, nor any contribution from *G* to the family budget. *P* allocates goods to family members without reference to the opinions of other household members, although she does account for their preferences via an altruistic concern for their overall welfare or utility.

In period 0, the consumption of the safety good *S* and background consumption *C* for *K* and *G* depend solely on *P*’s decisions, which are governed by her paternalistic altruism for her family members. In the next period (t = 1), *K* becomes an adult and makes her own consumption decisions based on her own preferences and her budget, which includes her own income plus possible financial transfers from *P*. In this period,

P's altruistic concern for her child is pure instead of paternalistic, reflecting the autonomy of the adult K. G is no longer alive. In the final period (t = 2), P is also deceased while K continues to consume in accordance with her preferences and income.

Perceived lifetime risk R is influenced by the consumption of the safety good S (a purely instrumental good conferring no direct utility) according to:

$$R_G = R_G(S_{G0}) \tag{9}$$

$$R_P = R_P(S_{P0}, S_{P1}) \tag{10}$$

$$R_K = R_K(S_{K0}, S_{K1}, S_{K2}) \tag{11}$$

The alphabetical subscripts identify the generation and the numerical subscripts refer to the time period. Following DG, we make the simplifying assumptions that the risk production functions do not shift over time, and that the marginal products of S are strictly negative in all production functions.

In $t = 0$ P maximises her utility which depends not only on her own consumption but also on the background consumption of K and of G, and the lifetime perceived risk for all three members of the family. K's lifetime utility also enters the parent's utility function weighted by $\eta \geq 0$. K's lifetime utility depends on her general consumption C_K; her consumption of the safety good S_K; the price of the safety good, p_S; her resources, consisting of income (y_K) in t = 1 and t = 2, and of any transfer, T, made by the parent to the child in $t = 1$; and the interest rate r. Any concern that P has for K in future periods is reflected by $\eta > 0$, which reflects pure altruism, meaning that P need not be concerned about how her current choices influence K's future consumption of S, since P is concerned about K's overall utility, and not directly about her future risk level R_K.

The grandparent G is alive during t = 0, and deceased thereafter. Her remaining lifetime utility depends on the consumption of safety good (S_G) and her background consumption (C_G), which she is allocated by P in t = 0. G's utility enters P's utility function weighted by $\theta \geq 0$.

In period t = 0, P maximizes her utility[10]:

$$U_P(C_{P0}, C_{P1}, C_{K0}, C_{G0}, R_P, R_K, R_G) + \eta U_K^*(C_{K0}, S_{K0}, T, y_{K1}, y_{K2}, r, p_S) \\ + \theta U_G^*(C_{G0}, S_{G0}) \tag{12}$$

subject to three perceived risk production functions in Eq. (9), the restriction $T \geq 0$, and her budget constraint:

[10] Note that consumption C and S enter the utility function of G and K in period 0 directly since these are chosen by P and so cannot be influenced by K or by G. Later C and S consumption (for K) are not directly present, since these will be chosen by K according to their own budget and preferences.

$$y_{P0} + (1+r)^{-1} y_{P1} = C_{P0} + C_{K0} + C_{G0} + p_S(S_{P0} + S_{K0} + S_{G0}) + (1+r)^{-1}[C_{P1} + T + p_S S_{P1}] \quad (13)$$

Lagrangean conditions:

$$\frac{\partial L}{\partial C_{P0}} = \frac{\partial U}{\partial C_{P0}} + \lambda = 0$$
$$\frac{\partial L}{\partial C_{K0}} = \frac{\partial U}{\partial C_{K0}} + \frac{\eta \partial U_K}{\partial C_{K0}} + \lambda = 0$$
$$\frac{\partial L}{\partial C_{G0}} = \frac{\partial U}{\partial C_{G0}} + \frac{\theta \partial G}{\partial C_{G0}} + \lambda = 0$$
$$\frac{\partial L}{\partial S_{P0}} = \frac{\partial U}{\partial R_P} \cdot \frac{\partial R_P}{\partial S_{P0}} + \lambda p_S = 0$$
$$\frac{\partial L}{\partial S_{G0}} = \frac{\partial U}{\partial R_G} \cdot \frac{\partial R_G}{\partial S_{G0}} + \frac{\theta \partial U_G}{\partial R_G} \cdot \frac{\partial R_G}{\partial S_{G0}} + \lambda p_S = 0$$
$$\frac{\partial L}{\partial S_{K0}} = \frac{\partial U}{\partial R_K} \cdot \frac{\partial R_K}{\partial S_{K0}} + \frac{\eta \partial U_K}{\partial R_K} \cdot \frac{\partial R_K}{\partial S_{K0}} + \lambda p_S = 0$$

First order conditions outlined above give the following relationships between the marginal utilities of consumption for each generation:

$$\frac{\partial U_P}{\partial C_{P0}} = \frac{\partial U_P}{\partial C_{K0}} + \eta \frac{\partial U_K^*}{\partial C_{K0}} \rightarrow MU_{C_P} = MU_{C_K} \rightarrow C\_MRS_{K,P}^P = 1 \quad (14)$$

$$\frac{\partial U_P}{\partial C_{P0}} = \frac{\partial U_P}{\partial C_{G0}} + \eta \frac{\partial U_G^*}{\partial C_{G0}} \rightarrow MU_{C_P} = MU_{C_G} \rightarrow C\_MRS_{K,G}^G = 1 \quad (15)$$

Similarly, from the Lagrangean, and as long as the price per unit of the safety good is the same across the three generations, MRS = 1 for consumption of the safety good.

$$\frac{\partial U_P}{\partial R_P} \cdot \frac{\partial R_P}{\partial S_{P0}} = \frac{\partial U_p}{\partial R_K} \cdot \frac{\partial R_K}{\partial S_{K0}} + \eta \frac{\partial U_K^*}{\partial R_{K0}} \cdot \frac{\partial R_K}{\partial S_{K0}} \rightarrow MU_{S_P} = MU_{S_K} \rightarrow S\_MRS_{K,P}^P = 1 \quad (16)$$

$$\frac{\partial U_P}{\partial R_P} \cdot \frac{\partial R_P}{\partial S_{P0}} = \frac{\partial U_p}{\partial R_G} \cdot \frac{\partial R_G}{\partial S_{G0}} + \theta \frac{\partial U_G^*}{\partial C_{G0}} \cdot \frac{\partial R_G}{\partial S_{G0}} \rightarrow MU_{S_P} = MU_{S_G} \rightarrow S\_MRS_{K,G}^G = 1 \quad (17)$$

These give:

$$\frac{\frac{\partial U_P}{\partial R_{P0}}}{MP_{SK}} = \frac{\frac{\partial U_P}{\partial R_K} + \eta \frac{\partial U_K^*}{\partial R_K}}{MP_{SP}} \rightarrow \frac{\frac{\partial U_P}{\partial R_{K0}} + \eta \frac{\partial U_K^*}{\partial R_K}}{\frac{\partial U_P}{\partial R_P}} = \frac{MP_{SP}}{MP_{SK}} \rightarrow MRS_{K,P}^P = \frac{MP_{SP}}{MP_{SK}} \quad (18)$$

$$\frac{\frac{\partial U_P}{\partial R_P}}{MP_{SG}} = \frac{\frac{\partial U_P}{\partial R_G} + \theta \frac{\partial U_G^*}{\partial R_G}}{MP_{SP}} \rightarrow \frac{\frac{\partial U_P}{\partial R_G} + \theta \frac{\partial U_G^*}{\partial R_G}}{\frac{\partial U_P}{\partial R_P}} = \frac{MP_{SP}}{MP_{SG}} \rightarrow MRS_{G,P}^P = \frac{MP_{SP}}{MP_{SG}} \quad (19)$$

where $MRS_{j,P}^P$ ($j = K, G$) is the MRS of P between own and each dependent's lifetime risk.

The ratio of marginal products also equals the ratio of marginal costs, since the safety good S has the same per-unit cost regardless of the recipient (by assumption and following DG). To generate the same size of risk reduction uses the same amount of the good S (since production functions are the same) and so it follows that the ratio of MC equals the ratio of MP.

Together, these give:

$$MRS_{K,P}^P = \frac{MP_{SP}}{MP_{SK}} = \frac{MC_{K0}}{MC_{P0}} \quad (20)$$

$$MRS_{G,P}^P = \frac{MP_{SP}}{MP_{SG}} = \frac{MC_{G0}}{MC_{P0}} \quad (21)$$

So far, we established that MRS between risk reductions for P and her dependents is equal to the ratio of marginal products of the risk reductions, which is in turn equal to the ratio of the marginal costs of the risk reductions for each generation. But so far, we have not said anything about what the ratio is expected to be.

To address this, we focus on *relative* risk reductions. That is, a risk reduction that decreases risk by a given proportion (e.g. 50% reduction in risk). This restriction allows us to state that the ratio of the marginal product of the safety good is equal to the ratio of the initial risk for P and K, and for P and G.

$$\frac{MP_{P,0}}{MP_{K,0}} = \frac{\frac{\partial R_P}{\partial S_{P0}}}{\frac{\partial R_K}{\partial S_{K0}}} = \frac{R_P}{R_K} \quad (22)$$

$$\frac{MP_{\mathrm{P},0}}{MP_{G,0}} = \frac{\frac{\partial R_P}{\partial S_{P0}}}{\frac{\partial R_G}{\partial S_{G0}}} = \frac{R_P}{R_G} \tag{23}$$

Next, we combine Eqs. (18–21) and multiply both sides of the equations by the inverse of the ratio of the lifetime relative risks from Eqs. (22) and (23):

$$\frac{\frac{\partial U_P}{\partial R_K} + \eta \frac{\partial U_K^*}{\partial R_K}}{\frac{\partial U_P}{\partial R_P}} \cdot \frac{R_K}{R_P} = \frac{\left(\frac{\partial R_P}{\partial S_P}\right)/\mathrm{R}_P}{\left(\frac{\partial R_K}{\partial S_K}\right)/R_K} = \frac{MC_{K0}}{MC_{P0}} \tag{24}$$

$$\frac{\frac{\partial U_P}{\partial R_{G0}} + \theta \frac{\partial U_G^*}{\partial R_G}}{\frac{\partial U_P}{\partial R_P}} \cdot \frac{R_G}{R_P} = \frac{\left(\frac{\partial R_P}{\partial S_P}\right)/R_P}{\left(\frac{\partial R_G}{\partial S_G}\right)/R_G} = \frac{MC_{G0}}{MC_{P0}} \tag{25}$$

where:

$MU_K^P = \left[\frac{\partial U_P}{\partial R_K} + \eta\left(\frac{\partial U_K^*}{\partial R_K}\right)\right]$ is the marginal utility of K's safety, for P;

$MU_G^P = \frac{\partial U_P}{\partial R_G} + \theta\left(\frac{\partial U_G^*}{\partial R_G}\right)$ is the marginal utility of G's safety, for P;

$MU_P^P = \frac{\partial U_P}{\partial R_P}$ is the marginal utility of P's own safety, for P;

R_K, R_P, R_G are initial lifetime risk levels.

From the relationship in Eqs. (22) and (23), we can see that the middle terms of Eqs. (24) and (25) are equal to 1. Therefore, we established that the parent's marginal rate of substitution between equal percentage risk changes for P and K, and for P and G, equate to unity.

Therefore, we set up our empirical test to establish whether, in reality, this MRS between equal percentage risk changes between self and dependent(s), equals to unity.

Appendix 2: Further tests of the efficiency condition

Table 7 presents two tests that investigate whether the distributions of marginal utilities for relative lifetime risk reductions are equal, which, if true, would imply that across the distribution, respondents meet the efficiency condition for household resource allocations to (and not only the median respondent). Test 1 is the most rigorous as it tests whether the means and standard deviations of these distributions are equal, as well as whether their correlation is equal to 1. At the 1% and 5% confidence level, we can reject this hypothesis for the child and parent, respectively.

Test 2 analyses whether means and standard deviations of the distributions of marginal utilities are equal, but allows correlation to differ from 1. We cannot reject this hypothesis in either condition. In summary, in general the efficient condition holds

Table 7 Tests for MRS of relative risk reductions being equal to 1

Wald tests	Condition 1		Condition 2	
	Wald stat.	Sig.	Wald stat.	Sig.
Test 1: H0: *Equal distributions*	25.29	***	11.04	**
Test 2: H0: *Equal distributions, but with imperfect correlations*	3.16	–	3.84	–

Note: *, **, *** indicate p value lower than 0.1, 0.05 and 0.01, respectively

in the sample, but the correlation between risk reductions significantly lower than 1 implies that some respondents deviate from the efficient condition. We calculated the correlation between the distributions of marginal utilities for relative risk reductions in both conditions and we found that although the correlation is imperfect, it is very high, equalling 0.9.

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Code availability Code will be available from the authors upon request

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Data availability Data will be available from the authors upon request.

Declarations

Conflicts of interest/competing interests There are no potential conflicts of interest.

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