

HOUSEHOLD RESPONSES TO SEVERE HEALTH SHOCKS AND THE DESIGN OF SOCIAL INSURANCE^{*}

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Abstract

This paper studies how households respond to severe health shocks and the insurance role of spousal labor supply. In the empirical part of the paper, we provide new evidence on individuals' labor supply responses to spousal health and mortality shocks. Analyzing administrative data on over 500,000 Danish households in which a spouse dies, we find that survivors immediately increase their labor supply and that this effect is entirely driven by those who experience significant income losses due to the shock. Notably, widows – who experience large income losses when their husbands die – increase their labor force participation by more than 11%, while widowers – who are significantly more financially stable – decrease their labor supply. In contrast, studying over 70,000 households in which a spouse experiences a severe health shock but survives – for whom income losses are well-insured in our setting – we find no economically significant spousal labor supply responses, suggesting adequate insurance coverage for morbidity (vs. mortality) shocks. In the theoretical part of the paper, we develop a method for welfare analysis of social insurance using only spousal labor supply responses. In particular, we show that the labor supply responses of spouses fully identify the welfare gains from insuring households against health and mortality shocks. Our findings imply large welfare gains from transfers to survivors and identify efficient ways for targeting government transfers.

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1 Introduction

Does the labor supply of household members insure against adverse shocks? The answer to this question is important for our understanding of household behavior and is central to the design of social insurance policies.

This paper studies how households respond to severe health shocks and insure against these shocks through spousal labor supply. In the empirical part of the paper, we provide new evidence on how individuals' labor supply responds to spousal health and mortality shocks. In the theoretical part of the paper, we develop a method for welfare analysis of social insurance that uses only spousal labor supply responses and can be applied to shocks in which the directly affected individual may be at a corner solution. We show that under plausible conditions the labor supply responses of spouses fully identify the welfare gains of insuring households against health and mortality shocks, and map our empirical findings on spousal labor supply responses to the welfare implications of providing more generous social insurance.

For spousal labor supply to provide self-insurance, households must experience sizable income shocks that are otherwise only partially insured. Therefore, our empirical analysis focuses on an extreme shock that leads to significant and permanent income losses – the death of a spouse. To recover the causal effect of this shock we offer a quasi-experimental design that constructs non-parametric counterfactuals to affected households by using households that experience the same shock a few years in the future, and combines event studies for these two experimental groups. The identification strategy we develop relies on the assumption that the *exact* timing of the shock is as good as random, and is therefore applicable to the analysis of a wide range of other common economic shocks.

Analyzing administrative data on health and labor market outcomes from the years 1980-2011, we study over 500,000 Danish households of married and cohabiting couples in which a spouse has died. We find a large increase in the surviving spouses' labor supply immediately after their spouses die, which amounts to an average increase of 7.6% in labor force participation and 6.8% in annual labor income by the fourth year after the shock. These effects are driven by households that experience significant income shocks due to the loss of a spouse, and therefore have greater need for self-insurance through labor supply. In particular, we show that the average increase in labor supply is entirely attributable to survivors whose deceased spouses had earned a large share of the household's income, who have less disposable income at the time of the shock, and who are less formally insured by government transfers. We also find that high-earning survivors, who experience smaller relative income losses and face better financial conditions, decrease their labor supply as their high income is no longer necessary to support two people. Notably, widowers – who tend to be financially stable when losing their wives – decrease their labor supply, while widows – who tend to experience considerably

larger income losses when losing their husbands – significantly increase their labor supply. By the fourth year after their husbands die, widows increase their participation by 11.3%, which translates into a 10.1% increase in their annual earnings.

In contrast, we show that for shocks that are well-insured in our setting (through social and private insurance) and require no additional informal insurance, there are no economically significant labor supply responses of the unaffected spouse. Studying over 70,000 households in which a spouse experiences a heart attack or a stroke, we find that the earnings of the affected individuals drop by 19% by the third year after the shock, while the household’s post-transfer income declines by only 3.3%. Consistent with this lack of an income drop, there are no significant changes in the unaffected spouses’ participation with an economically small decline in labor earnings (of about 1%). The combination of our quasi-experimental design and rich administrative data allows us to precisely estimate this small response, which has proven difficult in previous studies (e.g., Coile 2004 and Meyer and Mok 2013).

In the theoretical part of the paper, we map these estimates of spousal labor supply responses to predictions about the welfare gains from providing more generous social insurance. Using a collective model of household behavior that assumes decisions are Pareto efficient (Chiappori 1988, 1992), we show that spousal labor supply responses fully identify the benefits of social insurance and develop a new method for welfare analysis that depends only on the spouse’s labor supply behavior. This result relies on the observation that within each state of nature the spouse’s labor force participation decision reveals the household’s valuation of additional consumption (in the form of labor earnings). Hence, the sensitivity of spousal labor supply to shocks and economic incentives reveals the household’s preference for consumption across different states of nature, which captures the benefits from insurance. We also consider both theoretically and empirically the welfare implications of potential health-state dependence of the unaffected spouse’s willingness to work.¹

Applying our welfare method to mortality shocks, we find substantial gains from benefit increases for elderly widows. Under our benchmark calibration, an additional dollar to widows over 67 is equivalent to an additional \$1.55 to other elderly households, creating a net benefit of \$0.55 per \$1. However, for younger widows who are more attached to the labor force, we find very small gains from additional benefits through the social insurance system, with a net benefit of only \$0.04 per \$1.² A key implication of our findings, driven by the differential attachment to the labor force over the life-cycle, is that social insurance policies should be age-dependent.

¹As we mentioned above, we find that the increases in surviving spouses’ labor supply are consistently driven by those who experience large income losses. In addition, we find that among survivors who did not work before their spouses died, those who increased their labor force participation were those whose spouses worked before the shock (and not those who consumed more joint leisure with non-working spouses). As we discuss later in the paper, these results strongly suggest that the average increase in labor supply can be attributed to self-insurance and not to a state-contingent preference for social integration.

²Nonetheless, we find that younger widows highly value the system in place. The average dollar given to younger widows is equivalent to a \$1.54 transfer to other households. See Section 6.

This paper relates to several strands of the literature. First, numerous empirical studies have analyzed spousal labor supply and its responses to shocks in order to uncover the extent to which it is used as insurance. However, while spousal labor supply is commonly modeled as an important self-insurance mechanism against adverse shocks to the household (e.g., Ashenfelter 1980, Heckman and Macurdy 1980, and Lundberg 1985), this prior empirical work has been unable to find evidence of significant increases in spousal labor supply in response to shocks (e.g., Heckman and Macurdy 1980, 1982, Lundberg 1985, Maloney 1987, 1991, Gruber and Cullen 1996, Spletzer 1997, Coile 2004, and Meyer and Mok 2013). The leading explanation for this lack of evidence has been that within the context of temporary unemployment, on which the empirical literature has focused, income losses are small relative to the household’s lifetime income and are already sufficiently insured through formal social insurance (Heckman and Macurdy 1980; Cullen and Gruber 2000). In order to uncover the self-insurance role of spousal labor supply within unemployment shocks, Cullen and Gruber (2000) study whether it is crowded-out by unemployment insurance benefits and find a large crowd-out effect. We take an alternative empirical approach and directly study the effects of severe health shocks with different degrees of income loss – mortality shocks, which impose large and permanent income losses, and morbidity shocks, which are well-insured.

Second, prior work on estimating welfare gains from insurance has focused on studying the “consumption-smoothing” effects of insurance to identify its welfare benefits.³ This consumption-based method has two limitations. First, it is sensitive to the value of risk aversion, for which the literature has a wide range of estimates, as well as to the degree of consumption utility state dependence, which has proven hard to estimate (see Finkelstein, Luttmer, and Notowidigdo 2009 and Chetty and Finkelstein 2013). Second, the choice of the studied consumption measure – most commonly food consumption – is usually driven by data availability rather than theoretical underpinnings. As emphasized by Aguiar and Hurst (2005), focusing on one aspect of expenditure can lead to very misleading conclusions about actual consumption in the presence of home production.⁴

The labor market approach to welfare analysis that we develop addresses these problems by relying solely on directly-observed participation rates and elasticities. Our approach does not involve fragile estimates of preference parameters. In addition, the wide availability of large-scale accurate data from the labor market and the long tradition of studying labor supply decisions render our approach

³See, e.g., reduced-form studies in the context of health shocks in Stephens (2001), Meyer and Mok (2013), and Ball and Low (2014), and in the context of the death of a spouse in Auerbach and Kotlikoff (1991) and Bernheim, Carman, Gokhale, and Kotlikoff (2003). Examples of empirical studies that rely on structural economic modeling can be found in Benitez-Silva, Buchinsky, and Rust (2006), Chandra and Samwick (2009), Bound, Stinebrickner, and Waidmann (2010), and Low and Pistaferri (2012) in the context of disability insurance, and İmrohoroglu et al. (1995, 2003), Huang, İmrohoroglu, and Sargent (1997), Kotlikoff, Smetters, and Walliser (1999), and Nishiyama and Smetters (2007) in the context of Social Security.

⁴Even comprehensive and accurate data on overall expenditure across health states, which is rarely available, would have to be accompanied by time-use data (on home production) and would require strong assumptions on its translation into individual consumption. Among other things, this procedure should take into account consumption flows of durable goods as well as economies of scale in the household’s consumption technology. See, e.g., Browning, Chiappori, and Lewbel (2013).

desirable for empirical applications.

Our method relates to and builds on recent work on labor market methods for welfare analysis in the context of unemployment.⁵ Chetty (2008) recovers gains from social insurance using liquidity and substitution effects in the search effort of the unemployed, and Shimer and Werning (2007) use comparative statics of reservation wages with respect to government benefits.⁶ In the shocks we consider, these methods cannot be applied because the directly affected individual may be unresponsive to economic incentives and hence cannot fully reveal the household’s preferences through labor market behavior. Exploiting the household’s collective labor supply decisions, our method uses only the responses of the indirectly affected spouse, and offers a labor market method that is also applicable to any economic shock in which the directly affected individual may be at a corner solution.

The remainder of this paper is organized as follows. Section 2 uses a household model of labor force participation to describe the self-insurance role of spousal labor supply and to develop our method for welfare analysis. Section 3 describes the institutional environment and the data sources we use to estimate individuals’ labor supply responses to severe spousal health shocks, and section 4 specifies our empirical research design. Section 5 presents our main estimates for the unaffected spouses’ labor supply responses to shocks and their self-insurance role. In section 6 we study the welfare implications of these responses. Section 7 concludes.

2 A Collective Model of Household Labor Force Participation

2.1 Baseline Model

We begin with a baseline static model of extensive labor supply decisions. In Sections 2.2 and 2.3 we discuss important extensions to the simple framework.⁷

Setup. Households consist of two individuals, w and h . We consider a world with two states of nature: a “good” state (state g) in which h is in good health and works, and a “bad” state (state b) in which h experiences a shock and drops out of the labor force. Households spend a share of μ^g of their adult life in state g and a share of μ^b in state b ($\mu^g + \mu^b = 1$). In what follows, the subscript $i \in \{w, h\}$ refers to the spouse and the superscript $s \in \{g, b\}$ refers to the state of nature.

Individual preferences. Let $U_i(c_i^s, l_i^s)$ represent i ’s utility as a function of consumption, c_i^s , and

⁵The advantage of the sufficient statistics approach to welfare analysis, to which these methods as well as our own belong, is that it offers results about optimal policy that do not utilize strong assumptions made in structural studies for tractability and identification. The cost is that it can only be used to analyze marginal changes in policy. See Chetty (2009) for a more detailed discussion on this issue.

⁶Following Chetty (2008), who uses variations in severance payments, other recent papers estimate the magnitude of the liquidity effects of social insurance programs – LaLumia (2013) uses variations in the timing of EITC refunds and Landais (forthcoming) uses kinks in the schedule of unemployment insurance benefits.

⁷Our model is most closely related to the collective setting analyzed in Blundell, Chiappori, Magnac, and Meghir (2007), in which one spouse is on the participation margin while the other is on the intensive margin, as well as to Immervoll, Kleven, Kreiner, and Verdelin (2011) who study optimal tax-and-transfer programs for couples with extensive-margin labor supply responses.

labor force participation, l_i^s , in state s (such that $l_i^s = 1$ if i works and $l_i^s = 0$ otherwise). We assume that $U_i(c_i^s, l_i^s) = u_i(c_i^s) - v_i \times l_i^s$, where the utility from consumption, $u_i(c_i^s)$, satisfies $u_i'(c_i^s) > 0$ and $u_i''(c_i^s) < 0$, and v_i is i 's disutility from labor. The couple's disutilities from labor (v_w, v_h) are distributed according to a continuous density distribution defined over $[0, \infty) \times [0, \infty)$. We denote the marginal probability density function of v_w by $f(v_w)$ and its cumulative distribution function by $F(v_w)$.

Household preferences. We follow the collective approach to household behavior (Chiappori 1988, 1992; Apps and Rees 1988) and assume that household decisions are Pareto efficient.⁸ Therefore, with equal Pareto weights for both spouses, household decisions can be characterized as solutions to the maximization of $U_w(c_w^s, l_w^s) + U_h(c_h^s, l_h^s)$.⁹

Policy tools. The planner observes the state of nature as well as the employment status of each spouse. Since some spouses work and earn more than others do, the optimal policy is dependent on whether the spouse is employed. We denote the tax on spouse i 's labor income in state g by T_i^g and the benefits given to non-working spouses in state g by b^g . In state b , households in which the unaffected spouse, w , works receive transfers of the amount B^b and households in which w does not work receive benefits of the amount b^b . This tax-and-benefit structure allows for the analysis of flexible policy designs and mimics features of existing social insurance programs in most developed countries (e.g., income-testing which is common to programs in the US and in Denmark).¹⁰ We denote taxes by $T \equiv (T_w^g, T_h^g)$ and benefits by $B \equiv (b^g, B^b, b^b)$, and let $B(l_w^s)$ represent the actual transfers received by a household as a function of w 's participation.¹¹

Household's problem. The household's choices reduce to the allocation of consumption to each spouse i in state s , c_i^s , as well as w 's labor force participation in each state, l_w^s . Note that there are no savings decisions involved in the baseline static model. We introduce endogenous savings in the dynamic extension to the model in Section 2.3. Each choice of w 's employment determines the household's overall income in state s , $y^s(l_w^s)$, such that $y^s(l_w^s) = A + \bar{z}_h^s \times l_h^s + \bar{z}_w^s \times l_w^s + B(l_w^s)$, where A is the household's wealth, z_i is i 's labor income, and $\bar{z}_i^s = z_i - T_i^s$ is i 's labor income net of taxes (with $T_i^b = 0$).¹² At each of w 's potential employment statuses, consumption is efficiently allocated

⁸We discuss this assumption in Section 2.1.1

⁹More generally, household decisions can be characterized as solutions to the maximization of $\beta_w U_w(c_w^s, l_w^s) + \beta_h U_h(c_h^s, l_h^s)$, where β_w and β_h are the Pareto weights on w and h , respectively. However, setting $\beta_w = \beta_h = 1$ is without loss of generality as long as the spouses' relative bargaining power is stable across states of nature. Similar to Chiappori (1992), baseline weights do not affect our welfare results.

¹⁰For example, Supplemental Security Income (SSI) within the Old-Age, Survivors and Disability Insurance in the US and the Social Disability Insurance in Denmark.

¹¹It is worth mentioning that the exact way in which we model transfers is not necessary for our results, and any system that conditions transfers on the state of nature and employment can be analyzed in our framework.

¹²More generally, the model allows for any type of state-contingent income and assets. These include life insurance and any other source of private insurance, employer-provided insurance, transfers from relatives, social insurance, medical expenses, etc.

across spouses, such that the consumption bundles $c_w^s(l_w^s)$ and $c_h^s(l_h^s)$ are the solutions to

$$\begin{aligned} V(y^s(l_w^s)) &\equiv \max_{c_w^s, c_h^s} u_w(c_w^s) + u_h(c_h^s) \\ \text{s.t. } c_w^s + c_h^s &= y^s(l_w^s). \end{aligned} \quad (1)$$

For later reference, we define y_{-w}^s as the household's resources excluding those directly attributed to w 's labor supply decision – i.e., $y_{-w}^s \equiv A + \bar{z}_h^s \times l_h^s$.

The unaffected spouse, w , works in state s if and only if $v_w < \bar{v}_w^s \equiv V(y^s(1)) - V(y^s(0))$.¹³ That is, the unaffected spouse works if the household's valuation of the additional consumption of his or her labor income compensates for his or her utility loss from working. Therefore, this simple decision rule reveals the household's preferences for additional consumption and is the key source for identifying the gains from insurance based on the unaffected spouse's labor supply (as we show below). We denote w 's participation rate in state s by $e_w^s \equiv F(\bar{v}_w^s)$.¹⁴

At this point it is easy to see the self-insurance role of spousal labor supply responses to shocks, which is our main outcome of interest. Denote the income loss from the shock by $d \equiv y_{-w}^g - y_{-w}^b$. Then, in each state the participation rate of the unaffected spouses decreases in their unearned income: $\frac{\partial e_w^s}{\partial y_{-w}^s} = -f(\bar{v}_w^s)[u'_w(c_w^s(0)) - u'_w(c_w^s(1))] < 0$. This implies that $e_w^b > e_w^g$ whenever $d > 0$ – that is, income shocks lead to self-insurance through the unaffected spouse's labor force participation. Furthermore, the unaffected spouses' labor supply response to the shock increases in the income loss d – i.e., $\frac{\partial(e_w^b/e_w^g)}{\partial d} = \frac{f(\bar{v}_w^b)}{F(\bar{v}_w^g)}[u'_w(c_w^b(0)) - u'_w(c_w^b(1))] > 0$. These comparative statics are no more than simple income effects at the household level and are a direct implication of the concavity of $u_i(c_i^s)$, which translates into the concavity of $V(y^s(l_w^s))$.

Planner's problem. Let $W^s(v_w)$ denote the household's value function in state s such that

$$W^s(v_w) \equiv \begin{cases} V(y^s(1)) - v_h \times l_h^s - v_w & \text{if } v_w < \bar{v}_w^s \\ V(y^s(0)) - v_h \times l_h^s & \text{if } v_w \geq \bar{v}_w^s. \end{cases}$$

Therefore, the household's expected utility is $J(B, T) \equiv \mu^g \int_0^\infty W^g(v_w) f(v_w) dv_w + \mu^b \int_0^\infty W^b(v_w) f(v_w) dv_w$.

The social planner's objective is to choose the tax-and-benefit system that maximizes the house-

¹³The complete formal description of the household's problem in each state is

$$\begin{aligned} \max_{l_w^s \in \{0,1\}, c_w^s(l_w^s), c_h^s(l_h^s)} & l_w^s (U_w(c_w^s(1), 1) + U_h(c_h^s(1), l_h^s)) + (1 - l_w^s) (U_w(c_w^s(0), 0) + U_h(c_h^s(0), l_h^s)) \\ \text{s.t. } & c_w^s(l_w^s) + c_h^s(l_h^s) = y^s(l_w^s) \\ & y^s(l_w^s) \equiv A + \bar{z}_h^s \times l_h^s + \bar{z}_w^s \times l_w^s + B(l_w^s). \end{aligned}$$

¹⁴There is another natural approach to modeling the household's decision-making process. One can assert that each individual works if his or her *own* utility from working is higher than his or her *own* utility from not working, and then – conditional on the participation decisions – the couple engages in efficient bargaining that allocates resources according to their respective bargaining power (which in our case implies maximizing $u_w(c_w^s) + u_h(c_h^s)$). The qualitative theoretical results of our analysis remain unchanged in this alternative model.

hold's expected utility subject to the requirement that expected benefits paid, $\mu^g(1 - e_w^g)b^g + \mu^b(e_w^b B^b + (1 - e_w^b)b^b)$, equal expected taxes collected, $\mu^g(T_h^g + e_w^g T_w^g)$. Hence, the planner chooses the benefit levels B and taxes T that solve

$$\max_{B,T} J(B,T) \quad \text{s.t.} \quad \mu^g(1 - e_w^g)b^g + \mu^b(e_w^b B^b + (1 - e_w^b)b^b) = \mu^g(T_h^g + e_w^g T_w^g). \quad (2)$$

2.1.1 Optimal Social Insurance

To solve the planner's problem we characterize the first-order conditions of (2) by perturbing the tax-and-benefit system. For a given level of government revenues, we consider the optimal distribution of benefits to households with non-working spouses across states b and g . To do so, we consider a small increase in b^b financed by a corresponding balanced-budget decrease in b^g . In the simple model, this captures the efficient distribution of transfers to low-income households across different health states. Any other perturbation of the system will follow the steps of the analysis conducted below, and the complete optimal system can thus be characterized in the same manner. We focus on this particular aspect of the policy since it captures the essence of insuring households against shocks in a simple and policy-relevant way.

The welfare gain from a \$1 (balanced-budget) increase in b^b is $\frac{dJ(T,B)}{db^b} = \mu^b \frac{\partial}{\partial b^b} (\int_0^\infty W^b(v_w) f(v_w) dv_w) + \mu^g \frac{\partial}{\partial b^g} (\int_0^\infty W^g(v_w) f(v_w) dv_w) \frac{db^g}{db^b}$. Since this is expressed in utility units with no cardinal interpretation, we follow the recent social insurance literature¹⁵ and normalize it by the welfare gain from a \$1 transfer to households with non-working spouses in the good state, scaled by the targeted population.¹⁶ Differentiating the budget constraint to calculate $\frac{db^g}{db^b}$ and using the household's choices, which imply that $\frac{\partial}{\partial b^b} (\int_0^\infty W^b(v_w) f(v_w) dv_w) = u'_w(c_w^b(0))(1 - e_w^b)$ and $\frac{\partial}{\partial b^g} (\int_0^\infty W^g(v_w) f(v_w) dv_w) = u'_w(c_w^g(0))(1 - e_w^g)$, yield the normalized welfare gain

$$M_W(b^b) = MB(b^b) - MC(b^b), \quad (3)$$

where the marginal benefit is $MB(b^b) \equiv \frac{u'_w(c_w^b(0)) - u'_w(c_w^g(0))}{u'_w(c_w^g(0))}$, the marginal cost is $MC(b^b) \equiv \frac{\varepsilon(1 - e_w^b, b^b) - \varepsilon(1 - e_w^g, b^g)}{1 + \varepsilon(1 - e_w^g, b^g)}$ and $\varepsilon(1 - e_w^s, b^s) = \frac{\partial(1 - e_w^s)}{\partial b^s} \frac{b^s}{(1 - e_w^s)}$ is the elasticity of the unaffected spouse's non-participation with respect to government benefits. Note that when the consumption of h is positive (e.g., when he or she survives the shock), $MB(b^b)$ is also the gap in his or her marginal utilities due to consumption allocation efficiency in the household, which is determined by the program in (1).

Equation (3) is a simple variant of Baily's (1978) and Chetty's (2006) formula for the optimal

¹⁵See the recent review by Chetty and Finkelstein (2013).

¹⁶That is, the normalized net gain is $M_W(b^b) \equiv \frac{\frac{dJ(T,B)}{db^b} / \mu^b(1 - e_w^b)}{\frac{\partial J(T,B)}{\partial b^g} / \mu^g(1 - e_w^g)}$.

level of social insurance. The marginal benefit from a balanced-budget increase in b^b is captured by the insurance value of transferring resources from the good to the bad state, which is measured by the gap in marginal utilities of consumption across the two states. The marginal cost of transferring \$1 across states is due to behavioral responses, which capture the fiscal externality that households impose on the government budget when changing their participation decisions. In our case, the government's revenue could decrease since there are more spouses not working in the bad state due to higher benefits but could increase since there are fewer spouses not working in the good state as they receive fewer transfers.

Identifying the benefits of social insurance. While estimating the marginal cost is conceptually straightforward, estimating the marginal benefit is challenging since it requires knowledge of the consumption utility function, particularly of the value of risk aversion, and of each individual's overall consumption. To circumvent the challenges posed by this consumption-based approach, which we discuss below, we use simple but powerful implications of the household's labor supply decisions, which allow us to rewrite the marginal benefit solely in terms of the unaffected spouse's labor supply. The following proposition summarizes this main welfare result and demonstrates the way in which the unaffected spouse's labor supply behavior fully reveals the gap in the marginal utilities of consumption across states of nature. We provide a simple proof and then discuss the intuition behind the formula; namely, that it identifies the gains of insurance by evaluating changes in the consumption of leisure.

Proposition 1. *Under a locally linear approximation of F , the marginal benefit from raising b^b by \$1 is*

$$MB(b^b) \cong L^b + M^b, \quad (4)$$

$$\text{where } L^b \equiv \frac{e_w^b - e_w^g}{e_w^g} \text{ and } M^b \equiv \left(\frac{|\varepsilon(e_w^b, b^b)|/b^b}{|\varepsilon(e_w^g, b^g)|/b^g} - 1 \right) \frac{e_w^b}{e_w^g}.$$

Proof. Recall that the unaffected spouse works when the value of additional consumption from his or her labor income, $\bar{v}_w^s \equiv V(y^s(1)) - V(y^s(0))$, outweighs his or her disutility from labor, v_w . This decision rule reveals the household's consumption value of an additional dollar, $V'(y^s(0))$, through the change in the critical labor-disutility threshold below which the spouse works (\bar{v}_w^s) in response to an increase in benefits, since $\left| \frac{\partial \bar{v}_w^s}{\partial b^s} \right| = V'(y^s(0))$. In addition, since (1) implies that $V'(y^s(0)) = u'_w(c_w^s(0))$, we can rewrite the marginal benefit from social insurance using the change in the marginal entrant's disutility of labor – that is, $MB(b^b) = \frac{\left| \frac{\partial \bar{v}_w^b}{\partial b^b} \right| - \left| \frac{\partial \bar{v}_w^g}{\partial b^g} \right|}{\left| \frac{\partial \bar{v}_w^g}{\partial b^g} \right|}$. The last step to represent $MB(b^b)$ by using labor supply responses of the unaffected spouse is to map this expression onto directly observable participation rates, $e_w^s = F(\bar{v}_w^s)$, and their

elasticities, $\varepsilon(e_w^s, b^s)/b^s = \frac{f(\bar{v}_w^s)}{F(\bar{v}_w^s)} \frac{\partial \bar{v}_w^s}{\partial b^s}$, with simple algebra. Together, the equalities $MB(b^b) = \left(\left| \frac{\partial \bar{v}_w^b}{\partial b^b} \right| - \left| \frac{\partial \bar{v}_w^g}{\partial b^g} \right| \right) / \left| \frac{\partial \bar{v}_w^g}{\partial b^g} \right|$, $e_w^s = F(\bar{v}_w^s)$, $\varepsilon(e_w^s, b^s)/b^s = \frac{f(\bar{v}_w^s)}{F(\bar{v}_w^s)} \frac{\partial \bar{v}_w^s}{\partial b^s}$ and the approximation in the proposition yield the result.¹⁷

This formula shows that the marginal benefit from social insurance can be fully recovered from two moments of the unaffected spouse's labor supply, which we examine successively. The first term, L^b , is composed of the unaffected spouse's labor supply response to the shock – or the labor force participation “shock elasticity” – which captures exactly the self-insurance role of the spouse's labor supply. Recall that the increase in labor force participation across states of nature increases with the income loss due to the shock and therefore reveals the extent to which the household needs to self-insure against this loss.

The second term, M^b , captures the gains from the consumption of leisure by the marginal spouses due to behavioral responses to the policy change. When we increase benefits to non-working spouses in the bad state, b^b , we let more spouses meet their consumption needs if they choose not to work and consume more leisure – which is a welfare gain from the individual's and hence from the planner's perspective. The relative share of spouses who are on the labor force participation margin is captured by the semi-elasticity $|\varepsilon(e_w^b, b^b)|/b^b$, which quantifies the percent change in labor force participation in state b when we increase non-participation transfers b^b by \$1. This is illustrated in Figure 1: Panel A depicts the pre-perturbation labor force participation in state b , and Panel B depicts the response of the spouses that are on the participation margin in state b . Since we finance the increase in b^b by a decrease in b^g , the marginal spouses in state g who now work as a response – and whose relative share is $|\varepsilon(e_w^g, b^g)|/b^g$ – represent a welfare loss due to their reduced consumption of leisure. Therefore, the net gain through the change in the consumption of leisure due to the policy change is captured by $\frac{|\varepsilon(e_w^b, b^b)|/b^b}{|\varepsilon(e_w^g, b^g)|/b^g} - 1$.¹⁸ To scale these within-state elasticities into cross-state terms (which are relevant for our cross-state perturbation), we multiply this gain by the relative labor supply across states, $\frac{e_w^b}{e_w^g}$.¹⁹

¹⁷Specifically, the proposition uses a locally linear approximation of $F(v_w)$ in the threshold region, $(\bar{v}_w^g, \bar{v}_w^b)$. This local first-order expansion of $F(v_w)$ is supported by the empirical analysis of the spouse's participation across states of nature, which implies that \bar{v}_w^g and \bar{v}_w^b are within a small region of the support $[0, \infty)$. If one wishes to avoid this approximation, one can accompany the analysis with assumptions regarding the family of distributions to which F belongs, and then calibrate its parameters with the participation rates observed in the data. Note that this approximation is isomorphic to a second-order approximation of the search effort function in a search model of participation that we analyze in Appendix A.

¹⁸Note that *within* a state, marginal spouses are indifferent between working and not working. In the absence of full insurance, this is not the case *across* states, which is the relevant comparison for our policy change and is represented by the semi-elasticity ratio.

¹⁹Recall that we study the welfare implications of transferring resources from state g to state b . This transfer induces behavioral responses within each state of nature, which are expressed here in terms of semi-elasticities, since it changes the economic incentives within each state. However, to evaluate the implications of these elasticities in “cross-state” rather than “within-state” terms, we need to scale the elasticity ratio by the relative labor supply flow across states, $\frac{e_w^b}{e_w^g}$. Note that the first term of the welfare formula is already in cross-state terms so that no scaling is required.

This results in the second term of the formula: $M^b \equiv \left(\frac{|\varepsilon(e_w^b, b^b)|/b^b}{|\varepsilon(e_w^g, b^g)|/b^g} - 1 \right) \frac{e_w^b}{e_w^g}$. Note that whenever we transfer resources from the good to the bad state, the formula adjusts through the semi-elasticity ratio that enters this term; it is always the ratio of the responses to the specific policy tools that we consider changing.

Discussion. The alternative method for recovering welfare gains from social insurance is consumption-based and aims at directly identifying the gap in marginal utilities of consumption across states of nature. The reduced-form literature uses the approach developed by Baily (1978) and Chetty (2006) and was first implemented by Gruber (1997) in the context of unemployment insurance. This approach is based on analyzing consumption fluctuations across states, which are transformed to utility losses with estimates for the curvature of the utility function. The structural literature follows a similar approach but with the additional complexity of estimating the full set of the economic model’s primitives.²⁰ Our approach maps the identification problem from the consumption domain to the labor supply domain. By doing so, it does not rely on assumptions regarding the appropriate value of risk aversion about which there is tremendous uncertainty in the literature and to which the consumption-based calculations of gains from insurance are highly sensitive (Chetty and Finkelstein 2013). Additionally, it requires only data from the labor market, which is typically more precise and widely available than is consumption data. While consumption measures are usually partial (and cover only a sub-set of goods, such as expenditure on food), and strong assumptions are needed to translate overall expenditure into individuals’ consumption bundles, labor market data exactly matches the theoretical behaviors of interest, namely, participation and earned income.

Two other labor-market methods have been developed in the context of unemployment in the modern literature on social insurance. These are based on the labor supply responses of the directly affected individual. Chetty (2008) recovers gains from social insurance using liquidity and substitution effects in the search effort of the unemployed, while Shimer and Werning (2007) rely on comparative statics of reservation wages with respect to government benefits. However, these methods are not applicable to the case of a severe health shock in which the sick individual’s labor supply can no longer identify preferences. This is because a non-negligible share of those experiencing severe health shocks (and whose ability to work is directly affected) may be forced out of the labor market and become unresponsive to economic incentives. Their implied small behavioral responses to changes in policy tools and other economic incentives may wrongly imply a low value of additional insurance, while they are actually driven by significant shocks to their ability to work. Our approach falls within this group of labor market approaches but extends the scope of identifying welfare gains from social insurance using labor supply responses. In particular, it can be applied to important cases in which the directly affected individual may be at a corner solution, such as a severe health shock or the

²⁰See examples for these papers in Footnote 3.

extreme case of death.²¹

The analysis above has also shown that, in contrast to conventional wisdom, the level of optimal benefits does not necessarily decrease in the crowd-out of self-insurance by social insurance. It is indeed the case that increased benefits to non-working spouses in the bad state impose a fiscal externality on the government's budget through an increase in this group's non-participation rate, which is captured by the non-participation elasticity $\varepsilon(1 - e_w^b, b^b)$ in $MC(b^b)$. However, at the same time, the decreased participation entails a gain from consumption of additional leisure, which is captured by the participation elasticity $\varepsilon(e_w^b, b^b)$ in $MB(b^b)$. Therefore, our analysis formalizes Gruber's (1996) argument that in any assessment of net welfare gains from social insurance both effects have to be taken into account and weighted appropriately.

Identifying assumption: efficiency. Before we proceed with extensions to the basic model, it is worth emphasizing the source of identification of the household's preferences by using the unaffected spouse's labor supply responses. The key assumption underlying our analysis is that household decisions are Pareto efficient. This implies that on the margin, all members of the household exhibit the same returns to additional resources; hence any member not at a corner solution can reveal the preferences of each member of the household.

This approach relies on the premise that when spouses have symmetric information about each other's preferences and consumption (because they interact on a regular basis) we would expect them to find ways to exploit any possibilities of Pareto improvements. Importantly, as emphasized by Browning, Chiappori, and Weiss (2014), this does not preclude the possibility of power issues such that the allocation of resources within the household can depend on its members' respective Pareto weights. The approach simply assumes that no resources are left on the table. An additional advantage of the collective model is that it does not require specifying the mechanism that households use, e.g., the bargaining process, but only assumes such a mechanism exists. Note that the unitary model is a special case of our collective framework, and therefore our results readily apply to the unitary assumption that is widely used in models of the household.²²

2.2 State-Dependent Preferences

There are several important ways in which preferences can be directly affected by the shocks that we analyze. In this section, we consider different potential types of state dependence in the household's preferences and illustrate how they affect the analysis. Since our welfare method identifies gains from the labor supply behavior of the unaffected spouse, the sort of state dependence that affects the

²¹We discuss additional examples of such shocks in the Conclusion.

²²There are some cases in which the efficiency assumption fails (see discussion in Browning, Chiappori, and Weiss 2014). To model these cases, one would need to specify the underlying model of household decision making and make additional assumptions in order to identify one spouse's preferences from the other spouse's behavior.

theoretical analysis is confined to potential changes in the unaffected spouse’s labor disutility as we show below. We assess its empirical implications in Section 5.2.

Let $U_i^s(c_i^s, l_i^s)$ represent i ’s utility in state s as a function of consumption, c_i^s , and labor force participation, l_i^s , in state s and assume that $U_i^s(c_i^s, l_i^s) = u_i^s(c_i^s, l_i^s) - v_i^s \times l_i^s$. This formulation generalizes preferences in the following important ways. First, it allows for a completely flexible dependence of consumption utility on the state of nature. Note in particular that this allows us to study the death of h within our framework since it corresponds to setting $u_h^b(c_h^b, l_h^b) = 0$. Second, it allows for flexible consumption-leisure complementarities by allowing the consumption utility to depend freely on participation. These two extensions to the baseline model have no effect on the welfare formulas since we mapped the welfare evaluation problem from the consumption domain completely onto the labor force participation domain. This simplifies the analysis tremendously since the estimation of consumption utility state dependence has proven very challenging (Finkelstein, Luttmer, and Notowidigdo 2009) and also allows us to avoid the common practice of assuming consumption-leisure independence.²³

Furthermore, we allow labor disutility, v_i^s , to change across states of nature. Since we identify welfare gains from the behavior of the unaffected spouse, allowing the labor disutility of the affected spouse to change completely across states of nature does not affect the analysis. It is indeed the underlying motive for studying the unaffected spouse’s behavior in the first place since the affected spouse’s preferences can change in many unidentifiable ways as a result of the shock.

An extension that affects the welfare analysis and that we consider here is the potential state dependence of the unaffected spouse’s labor disutility. For example, when the bad state is h ’s sickness, v_w^b might be greater than the baseline labor disutility v_w^g if w places greater value on time spent at home – e.g., to take care of his or her sick spouse. When the bad state is h ’s death, working may become less desirable if the surviving spouse experiences depression and has difficulties working, or conversely, working may become more desirable if the surviving spouse wishes to seek social integration. For simplicity, we model this type of state dependence as $v_w^g = v_w$ and $v_w^b = \theta^b \times v_w^g$, such that θ^b captures the mean percent change in the utility cost of labor compared to the baseline state g .²⁴ The adjustment of the welfare formula to this extension is presented in the following proposition.

Proposition 2. *Under a locally linear approximation of F , the marginal benefit from raising b^b by \$1 is*

$$MB(b^b) \cong L^b + M^b + S^b, \quad (5)$$

²³For later reference in Section 5.2, we denote the household’s “consumption value function” for this extension by $V^s(y^s(l_w^s)) \equiv \max u_w^s(c_w^s) + u_h^s(c_h^s)$ s.t. $c_w^s + c_h^s = y^s(l_w^s)$.

²⁴In Appendix A we show that this is a simplification and that it is not necessary to define such a global parameter. We illustrate how it can be locally and non-parametrically defined in the more general dynamic search model. In addition, in Appendix C we offer an example for allowing heterogeneity in θ^b .

where $L^b \equiv \frac{e_w^b - e_w^g}{e_w^g}$, $M^b \equiv \left(\frac{|\varepsilon(e_w^b, b^b)|/b^b}{|\varepsilon(e_w^g, b^g)|/b^g} - 1 \right) \frac{e_w^b}{e_w^g}$, and $S^b \equiv (\theta^b - 1) (1 + L^b + M^b)$.

Proof. With these preferences, it is straightforward to show that $MB(b^b) = \left(\theta^b \left| \frac{\partial \bar{v}_w^b}{\partial b^b} \right| - \left| \frac{\partial \bar{v}_w^g}{\partial b^g} \right| \right) / \left| \frac{\partial \bar{v}_w^g}{\partial b^g} \right|$. Combining this equality with $e_w^s = F(\bar{v}_w^s)$, $\varepsilon(e_w^s, b^s)/b^s = \frac{f(\bar{v}_w^s)}{F(\bar{v}_w^s)} \frac{\partial \bar{v}_w^s}{\partial b^s}$, and the approximation in the proposition yields the result.²⁵

The additional component, $(\theta^b - 1) (1 + L^b + M^b)$, essentially “prices” in utility terms the cost of the first two labor supply “quantity” expressions, L^b and M^b . The unaffected spouse’s labor supply is more costly by $\theta^b - 1$ percent. This additional cost needs to be applied to the overall relative labor supply response across health states, i.e., the sum of the baseline participation rate (normalized to 1) and the two quantity components: $1 + L^b + M^b$. Since our welfare method identifies the gains from insurance by evaluating the change in the consumption of leisure, higher valuation of leisure, that is, a higher θ^b , renders leisure more valuable in state b , which makes the transfer of resources from state g to state b more socially desirable. We offer a way to assess θ^b in our empirical analysis below (see Section 5.2).

2.3 Additional Generalizations and Extensions

Dynamic life-cycle model. In the context of social insurance over the life-cycle, it is important to consider households’ self-insurance through ex-ante mechanisms such as precautionary savings. In Appendix A, we analyze life-cycle participation decisions using a dynamic search model that allows for endogenous savings. The general result of this analysis is that our formulas extend to the dynamic case with the adjustment that post-shock responses in the static case are replaced by mean responses at the *onset* of a shock.²⁶ This is exactly what we recover in our empirical analysis. Hence, our results as well as the welfare analysis we conduct readily apply to the dynamic case. The intuition behind this theoretical result is that responses of forward-looking households to shocks internalize the full expected path of future consumption and leisure. Therefore, responses in periods right after a shock occurs reveal the household’s life-time welfare implications of additional transfers.²⁷

The dynamics of the life-cycle analysis likewise enter the marginal costs of social insurance. A household in state g not only decreases its labor supply due to higher taxes in the present, but also in response to increased benefits in the hitherto unencountered state b . The prospect of higher benefits

²⁵Specifically, the proposition uses a locally linear approximation of $F(v_w)$ in the threshold region, $(\bar{v}_w^g, \bar{v}_w^b)$.

²⁶The robustness of our approach to the inclusion of additional margins of response is a general feature of the sufficient statistic approach to welfare analysis (see Chetty 2006).

²⁷The setting we analyze in the appendix also extends the model by allowing for multiple and sequential shocks. In particular, we analyze a model in which h can experience a health shock and may die as a consequence. This illustrates our analysis in a more complex and realistic setting that can be applied to different types of sequential shocks.

in the case that the household experiences a shock lowers its need to save for that scenario, which translates into a decrease in labor supply in state g .

Intensive-margin model of labor supply. One can construct similar formulas for the case in which the household’s intensive labor supply decisions are considered. Since there are no individuals on the participation margin, the formulas consist only of the labor supply changes across states of nature and the potential change in the utility cost of labor. See Appendix B for an analysis of this model. Note that the choice of the appropriate model for welfare analysis should depend on the data. For example, studying a sub-population with full employment before a shock occurs calls for the intensive-margin model because in such a case work intensity is the operative margin.²⁸

3 Data and Institutional Background

To study labor supply responses to severe spousal health shocks we turn to the Danish institutional setting and its rich administrative data on health and labor market outcomes. In this section, we describe the Danish insurance environment as it relates to sick individuals and surviving spouses as well as our data sources. It is useful to distinguish between two types of insurance: health insurance (coverage of medical care) and income insurance (insurance against income losses in different health states). Health insurance in Denmark is a universal scheme in which all costs are fully covered by the government.²⁹ Therefore, the Danish setting allows us to concentrate on (social and private) income insurance for losses that go beyond immediate medical expenses, as we describe below.³⁰

Institutional background. In Denmark, income insurance against severe health shocks and the death of a spouse consists of four main components that are typical of systems in developed countries: temporary sick-pay benefits, permanent Social Disability Insurance, privately purchased insurance policies, and other indirect social insurance programs.

During the first four weeks after a health shock occurs, workplaces are obliged to provide the sick employee with sick-pay benefits, which fully replace wages as long as the employee is ill within this period. Some common agreements and work contracts insure wage earnings against sicknesses of longer duration. For example, some blue-collar common agreements in the private sector provide wages during periods of sickness for up to one year. If the sick worker’s contract does not provide

²⁸Studying the discrete participation decision rather than the intensive-margin decision has several important advantages. First, it allows for flexible consumption-leisure complementarities. Second, it captures additional moral hazard responses that the social insurance literature discusses. By modeling means-tested transfers that can condition on household-level income we can study the welfare effects of the potential crowd-out of spousal labor force participation. Third, labor market frictions (such as hour requirements set by employers) can limit employees’ ability to optimize; hence participation decisions may reveal preferences more accurately (since the potential costs of non-optimization are higher).

²⁹There are a few exceptions such as dental care, chiropractic treatments and prescription drugs which entail out-of-pocket expenses.

³⁰Note, however, that the theory allows for medical expenses (and any other state-contingent expenses) and that our method is robust to any degree of medical coverage.

such a scheme, then the local government must provide flat-rate sick-pay benefits from the fifth up to the fifty-second week after the worker has stopped working.³¹

If the worker remains sick and is unable to work, he or she can apply at the municipality level for Social Disability Insurance (Social DI) benefits that will provide income permanently. For example, in 2000, subject to income-testing against overall household income, a successful application amounted to DKK 110,400 (\$13,800) per year for married or cohabiting individuals and DKK 144,500 (\$18,000) for single individuals.

The Danish Social DI program has a broad social insurance scope since it can be awarded for “social reasons”. In 1984 the notion of “social reasons” came to replace a complex mix of programs, such as survivors benefits for women and special old-age pensions for single women. The motive behind this rule change was that the pre-1984 rules discriminated between genders, which did not comply with EU legislation. Social DI is therefore the relevant insurance mechanism for surviving spouses who are unable to maintain their standard of living after losing their partners. Indeed, we find sharp increases in the Social DI benefits received by survivors immediately after their spouses die.

While Social DI is a state-wide program, it is locally administered. Regional councils (in a total of 15 regions) decide whether to approve or reject an individual’s application, and municipal caseworkers (in a total of 270 municipalities) administer the application and handle all aspects of each case – including any contact with the applicant, preparation of the application, collection of physician records, communication with previous employers, etc. The local administration of the program has led to differential application behavior across municipalities, which has resulted in substantial variation in rejection rates across municipalities – ranging from 7% to 30% – and thus in the mean receipts of Social DI benefits across the different municipalities (Bengtsson 2002). We exploit this cross-municipality variation in DI awards over time later in the paper.

An additional source of income to a household that experiences health shocks or in which a member dies is payments from an employer-based insurance policy, an element that is standard in labor-market pension plans. Since 1993, most sectors covered by common agreements (75% of the labor force) have mandatory pension savings, part of which consists of life insurance and insurance against specific health shocks. These pay out a lump-sum to the sick worker, as long as he or she is making contributions to the pension plan, or to the surviving spouse in case the plan member dies. The rates of these payouts are set by the individual pension funds. In addition, individuals can purchase private insurance policies of a similar structure.

Lastly, there are social insurance programs that can indirectly protect survivors or households

³¹During this period the sick worker receives a fixed daily rate that in 2000 added up to DKK 11,400 (\$1,425) per month (exactly the same as the unemployment benefit rate).

that experience other shocks. When crossing into their 60s and until they reach their old-age pension retirement age, individuals who have (voluntarily) been members of an unemployment fund for a sufficiently long period (10 years before 1992 and gradually increasing to 20 years thereafter) are eligible for the Voluntary Early Retirement Pension (VERP). Approximately 80% of the population is eligible for VERP, which provides a flat-rate annual income of roughly DKK 130,000 (\$16,250). At age 67 (or 65 for those born after July 1, 1939) all residents become eligible for the Old-Age Pension (OAP), which provides income-tested annuities of up to DKK 99,000 (\$12,375) per year for singles and DKK 75,000 (\$9,375) for coupled individuals (at 2000 rates). The VERP and OAP pension schemes indirectly serve as social insurance against shocks for those eligible, who can decide to take them up at different ages according to their financial needs. Note that the dependence of OAP and Social DI benefits on the structure of the household (with higher benefits for singles as compared to married or cohabiting individuals) further insures the standard of living of surviving spouses.

Data sources. We have merged data from several administrative registers to obtain annual information on Danish households of married and cohabiting couples from 1980 to 2011. We use the following registers: (1) the national patient register, which covers all hospitalization records (from both private and public hospitals), and from which we extract information on all the individuals that experienced a heart attack or a stroke; (2) the cause of death register, from which we identify death dates; (3) income registers, which include all sources of household income – e.g., labor income, capital income, annuity payouts, and government benefits from any program – as well as annual measures of gross wealth and liabilities; and (4) the Integrated Database for Labor Market Research, which includes measures from which we construct full-time and part-time labor supply variables and extract demographic variables.³² All nominal values are deflated based on the consumer price index and are reported in 2000 prices. In that year the exchange rate was approximately DKK 8 per US \$1.³³

4 Research Design

In this section we describe our empirical strategy for identifying the causal effect of spousal health and mortality shocks on individuals' labor supply, e_w^b/e_w^g . Our method relies on the simple intuition that within a short period of time the *exact* timing of a severe health shock or death is as good as random. In particular, we construct non-parametric counterfactuals to affected households using households that experience the same shock a few years in the future, and recover the treatment effect by performing event studies for these two experimental groups. Before formally describing our

³²We postpone describing the summary statistics of the analysis sample to the next section since they directly relate to the discussion on the advantages of our research design.

³³In our sample, the net assets of the median household amount to only DKK 13,236 (\$1,655) while the median annual household-level income is DKK 239,922 (\$29,990). Therefore, our analysis of labor supply responses focuses on income losses, and we use the wealth data for robustness checks.

research design, we illustrate its basic intuition with a concrete example.

Illustration. Let us focus on a treatment group of individuals born between 1930 and 1950 who experienced a severe health shock, in particular, a heart attack or a stroke, in 1995. Consider studying the effect of the shock on some economic outcome of these individuals, e.g., their labor force participation. Panel B of Figure 2 plots the outcome for these households as well as for households that experienced the same shock in 2010 (15 years later), in 2005 (10 years later), in 2000 (5 years later) and in 1996 (1 year later). Studying the behavior of households that experienced the shock in different years reveals increasingly comparable patterns to those of the treatment group’s behavior – in trends before 1995 – the closer the year in which the individual experienced the shock was to 1995. These patterns confirm our intuition and suggest using households that experienced a shock in $1995 + \Delta$ as a control group for households that experienced a shock in 1995. Our method, which we describe formally below, generalizes this example by aggregating different calendar years.

The trade-off in the choice of Δ can be immediately seen in Panel C of Figure 2. On the one hand, we would want to choose a smaller Δ such that the control group is more closely comparable to the treatment group, e.g., year 1996 which corresponds to $\Delta = 1$. On the other hand, we would want to choose a larger Δ in order to be able to identify longer-run effects of the shock, up to period $\Delta - 1$. For example, using those who experienced a shock in 2005 ($\Delta = 10$) will allow us to estimate the effect of the shock for up to 9 years. However, this entails a potentially larger bias since the trend in the behavior of this group is not as tightly parallel to that of the treatment group. Our choice of Δ is five years, such that we can identify effects up to four years after the shock. Perturbations to this choice are inconsequential to our results.

Formal description. Fix a group of cohorts, denoted by Ω , and consider estimating the treatment effect of a shock experienced at some point in the time interval $[\tau_1, \tau_2]$ by individuals who belong to group Ω . We refer to these households as the treatment group and divide them into sub-groups indexed by the year in which they experienced the shock, $\tau \in [\tau_1, \tau_2]$. We normalize the timing of observation such that the time period, t , is measured with respect to the year of the shock – that is, $t = year - \tau$ (where $year$ is the calendar year of the observation). As a control group, we match to each treated group τ the households among cohorts Ω that experienced the same shock at $\tau + \Delta$ for a given choice of Δ . For these households we assign a “placebo” shock at $t = 0$ by normalizing timing in the same way as we do for the treatment group ($t = year - \tau$).³⁴ Denote the mean outcome of the treatment group at time t by y_t^T and the mean outcome of the control group at time t by y_t^C and choose a baseline period (or periods) prior to the shock (e.g., period $t = -2$), which we denote by p (for “prior”). For any $n > 0$, the treatment effect can be simply recovered by the differences-in-differences estimator $\beta_n \equiv (y_n^T - y_n^C) - (y_p^T - y_p^C)$. The treatment effect in period n is measured by

³⁴By construction, their actual shock occurs at $t = \Delta$.

the difference in outcomes between the treatment group and control group at time n , purged of the difference in their outcomes at the baseline period, p . Note that the choice of Δ puts an upper bound on n such that $n < \Delta$.

Simply put, our design conducts event studies for two experimental groups: a treatment group composed of households that experience a shock in year τ , and a matched control group composed of households from the same cohorts that experience the same shock in year $\tau + \Delta$.

Identifying assumption. The identifying assumption is that, absent the shock, the outcomes of the treatment and control groups would run parallel. In particular, in accordance with the differences-in-differences research design, there is no requirement regarding the levels of outcomes. The plausibility of this assumption relies on the intuition that within the short window of time of length Δ the *exact* time at which the shock occurs is as good as random. To test the validity of our assumption, we accompany our empirical analysis with the treatment and control groups' behavior in the five years prior to the shock year 0 in order to assess their co-movement in the pre-shock period.

Other papers that use similar identifying assumptions include earlier studies in the context of the long-run effects of job displacement (Ruhm 1991) and the effect of arrests on employment and earnings (Grogger 1995), as well as more recent studies such as that by Hilger (2014), who exploits variation in the timing of fathers' layoffs in order to study the effect of parental income on college outcomes. More generally, our quasi-experimental design can be applied to any shock of which the exact timing is random, which can be easily validated in any particular setting by studying the pre-trends of the experimental groups.

Comparison to pure event studies. Pure event studies, which analyze the evolution of outcomes of a treated group around the time of a shock, suffer from three main shortcomings in our application. First, they identify short-run responses by relying on immediate and sharp responses at the onset of a shock. However, we are interested in identifying longer-run effects because of potential delays in adjustment due to, e.g., labor market frictions. A pure event study would misleadingly attribute gradual responses and delays in adjustment to the outcome's trend and would overlook the treatment effect. Second, potentially complex life-cycle trends in, e.g., spouses' labor force participation as depicted in Figure 3, may lead to biased extrapolations of the counterfactual behavior of an outcome in the absence of a shock if based on pre-shock behavior. Third, potential time trends in outcomes are a common confounding factor and a concern to any event study design. Our research design addresses these concerns by constructing a control group that recovers non-parametrically the treatment group's counterfactual behavior.

Summary statistics. Table 1 displays key summary statistics for the analysis sample. Our main analysis sample of households in which one spouse died between ages 45 and 80 is comprised of 310,720 households in the treatment group and 409,190 households in the control group. The table

reveals the advantage of our research design – the comparability of the year of observation and the age of unaffected spouses across experimental groups. The average survivor in the treatment group loses his or her spouse in 1993 at age 62.86 and the average unaffected spouse in the control group experiences the placebo shock in year 1993 at age 62.27, with even closer similarities in the sub-sample of survivors under age 60.³⁵ The sample for our secondary analysis of severe health shocks includes households in which one spouse experienced a heart attack or a stroke (for the first time) and survived for at least three years. We focus on households with both spouses under 60 to ensure that the results we document are driven only by the health shock and not by eligibility for retirement benefits.³⁶ The sample consists of 37,432 households in the treatment group and 54,926 households in the control group. The unaffected spouse is on average 45.7 years old in the treatment group at the time of the shock and 45.3 years old in the control group, where the mean calendar year of the shock is around 1992 for both groups.³⁷

5 Spousal Labor Supply Responses

5.1 Labor Supply Responses to the Death of a Spouse

In this section, we present our main empirical analysis and study the survivors' labor supply responses to the death of their spouses. We begin by estimating the average labor supply responses. Then, we analyze the heterogeneity of these responses by the degree of income loss imposed by the loss of a spouse in order to study the self-insurance role of spousal labor supply.

Mean responses. Figure 4 plots the average labor supply response of individuals whose spouse died between ages 45 and 80.³⁸ Panel A reveals an immediate increase in labor force participation following the death of a spouse. By the fourth year after the shock, the surviving spouses' participation increases by 7.6% – an increase of 1.6 percentage points (pp) on a base of 20.6 pp. Panel B of Figure 4 shows that this response translates into a 6.8% increase in annual earnings, which represents an annual increase of DKK 2,572 (\$322) from a low base of DKK 37,952 (\$4,744).³⁹

Since men and women face substantially different financial distress when they lose their spouse we analyze widowers and widows separately. Panel A of Figure 5 reveals the stark differences in

³⁵By construction, the research design nets out calendar year effects non-parametrically. However, due to the randomness of the exact timing of the shock, it also nets out life-cycle effects by comparing groups of very similar ages so that we effectively compare spouses who experience a shock at age a to those who experience a shock at age $a + \Delta$.

³⁶We constrain the sample for this shock (and not for the death events) because the average age of the unaffected spouses at the time of the shock in the unconstrained sample is very close to sixty (60.67), and because there are large life-cycle responses in labor force participation exactly at this age (when the majority of individuals become eligible for early retirement benefits as displayed in Figure 3).

³⁷We also report the means of main labor supply outcomes in Table 1 for completeness. Note that participation and earnings are slightly higher for the control group, which poses no threat to the validity of the design since comparability requires similar trends and not similar levels.

³⁸We define participation as having any positive level of labor income during the calendar year.

³⁹These means include zeros for those who do not work.

responses. While on average widowers do not change their labor force participation when their wives die, widows immediately and significantly increase their labor force participation when they lose their husbands. Four years after the shock, widows' labor force participation increases by 2.2 pp from a baseline participation rate of 19.5 pp, which amounts to a large increase of 11.3% in their labor force participation.

This differential response reveals that female survivors experience greater income losses when they lose their spouses and hence have greater need to self-insure through labor supply as compared to their male counterparts. To see this, we plot the evolution of overall household income (from any source) around the death of a spouse, including earnings, capital income, annuity payouts and benefits from social programs. We begin by plotting the household's income in the absence of behavioral responses from the unaffected spouse in order to capture the income loss directly attributable to the loss of an earning spouse. In Panel A of Figure 6, we plot the household's overall income, holding the unaffected spouse's earnings and social benefits at their pre-shock level.⁴⁰ The graph shows that widowers who lose their wives experience a 32% loss in household income, while widows who lose their husbands experience a significantly larger loss of 40%. Panel B of Figure 6 studies the actual change in household income, taking into account the surviving spouses' labor supply responses and any change in the benefits they may receive from social or private insurance. The figure shows that widowers experience an actual loss of 31% and that widows manage to decrease their potential loss to incur an actual lower loss of 35%.

Note that surviving spouses do not fully compensate for a loss in household income since as singles they do not need the full pre-shock level of income. However, potential economies of scale in the household's consumption technology may make half of the pre-shock level of household income insufficient for maintaining the pre-shock level of utility (see, e.g., Nelson 1988 and Browning, Chiappori and Lewbel 2013). The share of household income that keeps consumption utility at its pre-shock level is usually assumed to lie between 0.5 and 1 and is commonly referred to as the adult "equivalence scale". We return to this issue in Section 5.2 below.

We continue with further investigation of the heterogeneity in the survivors' labor supply responses across different subgroups and show that the responses are proportional to the survivors' degree of financial stability and to the income loss they experience. First, we focus on the subsample of surviving spouses under 60, who have a stronger attachment to the labor force and are therefore more financially resilient after the loss of an earning spouse.⁴¹ The overall mean response for this group is plotted in Panel A of Figure 7. Consistent with the view that their higher participation rates and

⁴⁰Specifically, we fix the surviving spouse's labor income, Social Disability and Social Security benefits as well as sick-pay benefits at their level in $t = -1$.

⁴¹Recall that at 60 there is a sharp drop in participation when most of the labor force becomes eligible for early retirement benefits.

annual earnings effectively insures them against losing an earning spouse, survivors under 60 exhibit a smaller relative increase in labor force participation compared to the universe of survivors – only 2.1% (1.4 pp on a base of 67.2). Similar to the overall treatment effect, this increase is entirely driven by women. As seen in Panel B of Figure 7, widows increase their labor force participation by 3.3%, while widowers – who experience the shock at a significantly higher participation rate (0.78) as compared to widows (0.715) – decrease their participation by 1.1%. Panel A of Figure 8 shows that these responses translate to a 3.2% increase in annual earnings for the lower-earning widows and a decrease of 4.1% in annual earnings for the higher-earning widowers, who as singles do not need their entire higher pre-shock levels of income. As before – and as displayed in Panel B of Figure 8 – these differential responses reveal the differential financial shock that they experience, with men experiencing a decline of 31% in household income and women experiencing a striking loss of 44%.

We report estimates for the regression counterparts of these figures in Table 2, which replicates our results. As we alluded to in Section 4, the treatment effect can be recovered by a simple differences-in-differences regression of the form:

$$l_{w,i,t} = \beta_0 + \beta_1 treat_i + \beta_2 post_{i,t} + \beta_3 treat_i \times post_{i,t} + \beta_4 X_{i,t} + \alpha_i + \varepsilon_{i,t}. \quad (6)$$

In this regression $l_{w,i,t}$ denotes an indicator for the labor force participation or annual earnings of the unaffected spouse w in household i at time t ; $treat_i$ denotes an indicator for whether a household belongs to the treatment group; $post_{i,t}$ denotes an indicator for whether the observation belongs to post-shock periods; $X_{i,t}$ denotes a vector of controls, and α_i is a household fixed effect. The parameter β_3 represents the causal effect of the death of a spouse on the labor supply of the unaffected spouse.

As we show in Appendix Figure 1, in periods 0 and 1 there are temporary transitions to part-time work, consistent with spending time with the dying spouse and mourning his or her loss. These transitions stabilize thereafter such that the active decision margin becomes full-time work vs. non-participation.⁴² Throughout the analysis, $post_{i,t}$ therefore assumes the value 1 for periods 2 to 4.

Within-gender regression analysis. Next, we study the effect of the death of a spouse on labor force participation by the degree of income loss for each gender separately. To this end, for each household we calculate the potential income loss due to the shock in the following way.

First, similarly to Panel A of Figure 6 and Panel B of Figure 8, we calculate for each household the overall income holding the unaffected spouse’s earnings and social benefits at their pre-shock level. Second, we calculate the ratio of this “potential income” measure in $t = 1$ to the household’s income in $t = -1$. Third, we normalize this ratio for the treated households by the mean ratio of the control households in order to purge life-cycle and time effects. This leaves us with an ex-ante measure of the

⁴²Indeed, this is one of our reasons for focusing the theoretical analysis on the participation margin rather than work intensity.

potential income replacement rate for each treated household, which we denote by rr_i , that captures the change in household income directly attributed to (and only to) the loss of a spouse.

To study the heterogeneity in labor supply responses by the income replacement rate we estimate the following augmented differences-in-differences model

$$l_{w,i,t} = \beta_0 + \beta_1 treat_i + \beta_2 post_{i,t} + \beta_{3i} treat_i \times post_{i,t} + \beta_4 X_{i,t} + \alpha_i + \varepsilon_{i,t}, \quad (7)$$

where

$$\beta_{3i} = \beta_{30} + \beta_{31} rr_i + \beta_{32} Z_{i,t}.$$

In this regression $l_{w,i,t}$ denotes an indicator for the labor force participation of the unaffected spouse w in household i at time t . We augment the basic differences-in-differences design by allowing the treatment effect, β_{3i} , to vary across households and model it as a function of the household's potential replacement rate rr_i . Our parameter of interest is β_{31} , which captures the extent to which the surviving spouse's labor supply response correlates with the income loss he or she experiences. Since β_{31} can capture other dimensions of heterogeneity beyond the income replacement rate, we let the treatment effect vary with additional household-level characteristics, $Z_{i,t}$, such that β_{31} further isolates the treatment effect's partial correlation with the loss of household income.⁴³

Table 3 reports the results of estimating (7) separately for each gender, with and without $Z_{i,t}$, for the entire sample of surviving spouses and only the sub-sample of survivors under age 60. The results consistently show throughout the specifications the strong correlation between labor supply responses and income losses; survivors in households with lower potential income replacement rates (lower rr_i) who experience larger income losses are much more likely to increase their labor force participation in response to the shock. Since controlling for the additional interactions with $Z_{i,t}$ does not change the results much, the evidence suggests that the heterogeneous responses are indeed driven by differential income replacement rates. In addition, the estimation results reveal quite similar sensitivity to income losses across genders and verify that gender differences in preferences do not drive the average labor supply responses.

Responses by own earnings. The heterogeneity in responses due to the household's degree of income insurance that we have analyzed so far has focused on income losses relative to pre-shock income flows. An additional strategy for studying this sort of heterogeneity focuses on the levels of the surviving spouses' disposable income available at the time of the shock. To do this, we turn to analyze how labor supply responses of surviving spouses may vary with their own level of earnings

⁴³The variables we include in $Z_{i,t}$ are age dummies for the surviving spouse, dummies for the age of the deceased at the year of death, year dummies, indicators for the number of children in the household as well as the surviving spouse's months of education (and its square). The results are also robust to the inclusion of a quadratic in the household's net wealth. Note that $X_{i,t}$ always includes the variables in $Z_{i,t}$ as well as their interaction with $treat_i$ and $post_{i,t}$.

when their spouses die, since higher-earning survivors have more disposable income and are therefore better insured.

We constrain the sample in the following way. First, we exclude surviving spouses whose average labor income before the shock (in periods -5 to -2) was lower than that of their experimental-group-specific 20th percentile. Then, for each household we calculate the pre-shock labor income share of the deceased spouse out of the household’s overall labor income and include only households in which both spouses were sufficiently attached to the labor force. Specifically, we keep households for whom the average share was between 0.20 and 0.80. These restrictions allow us to focus on households in which there has been some loss of income due to the death of a spouse and in which the surviving spouse has earned non-negligible labor income both in levels and as a share within the household.⁴⁴

We divide the remaining sample into five equal-sized groups according to their pre-shock level of earnings and plot in Panel A of Figure 9 the average labor income response (as well as its 95-percent confidence interval⁴⁵) against the pre-shock mean earnings for each group. The figure reveals a strong gradient of labor supply responses with respect to the survivors’ own level of earnings when the shock occurs. Survivors at the bottom of the income distribution increase their earnings by 7.8% in order to meet their consumption needs, while those at the top decrease their earnings by 2.93% as their high income is no longer necessary to support two people.

Since the household’s pre-shock labor income is composed of two earners, we need to account for the pre-shock earnings of the dying spouse. Hence, we divide the sample into two groups – households in which the dying spouse’s pre-shock labor income fell within the bottom three quintiles of its group-specific distribution, to which we refer as “low-earners”, and households in which the dying spouse’s pre-shock labor income fell within the top two quintiles, to which we refer as “high-earners”. Panels B and C of Figure 9 reveal that the gradient prevails in both sub-samples, such that surviving spouses with lower earnings are much more likely to increase their labor supply when their spouse dies, regardless of whether their spouse was a high- or low-earner. Panel A of Table 4 shows that the relationship is robust to the inclusion of controls (dummy variables for age and year) by separately estimating the corresponding differences-in-differences equation for each surviving spouses’ quintile.⁴⁶ Note that merely analyzing the average earnings response in this sample would have masked the substantial heterogeneity we documented. Panel B of Table 4 shows that the average labor income increase for this sample is DKK 585 (0.39%) and is not statistically different from zero.

In summary, the results reveal a clear pattern: there are significant increases in labor supply in response to losing a spouse, which are entirely driven by households that experience large income losses.

⁴⁴Furthermore, to guarantee that our results are not driven by outliers, we exclude households with dying spouses whose mean pre-shock earnings did not fall within their group-specific 5th and 95th percentiles or households with unaffected spouses whose mean pre-shock earnings were higher than that of their group-specific 95th percentile.

⁴⁵Standard error are calculated using the Delta method.

⁴⁶The gradient is also robust to the inclusion of a quadratic in the household’s net wealth.

The results provide clear evidence of the self-insurance role of spousal labor supply in the extreme case of the death of a spouse, which translates into large and permanent income losses for most households.

5.2 Labor Disutility State Dependence

In Section 2.2 we discussed the theoretical implications of state dependence of the unaffected spouse’s labor supply. If labor supply becomes more costly due to the shock (that is, $\theta^b > 1$), then for any given increase in labor supply it is more socially desirable to transfer resources to spouses in state b to avoid their loss of (more valued) leisure. On the other hand, lower cost of labor supply ($\theta^b < 1$) can lead to an increase in labor force participation even if households are well insured. The welfare implications of labor supply responses in this case are different since they are driven by preferences and not by under-insurance. One empirical motivation to account for this sort of state dependence is the striking change in the surviving spouse’s health-care utilization following the loss of a spouse. Figure 10 shows that the overall expenditure on primary medical care (Panel A) as well as the prescription rate for antidepressants (Panel B) exhibit sharp increases in the year of bereavement. While part of these phenomena may be purely driven by changes in take-up of medical care and supply-side responses rather than in actual changes in health, it calls for an empirical investigation of labor disutility state dependence.

In this section, we provide a formal method to assess the extent to which survivors’ labor disutility changes in response to the death of their spouse and then apply it to our setting. Our key result, which we derive in detail below, is that individuals do not fully adjust their post-shock consumption to their pre-shock level of consumption utility, implying that their labor disutility increases in response to the shock.

Calibrating θ^b : method. Consider the following thought experiment. First, assume that we could mimic a full income insurance environment. Normally, this would imply fully insuring the household’s pre-shock level of income. However, in our case, as the composition of the household changes, we need to ask how much income does a surviving spouse need as a single to achieve the same level of consumption utility that he or she enjoyed before the shock? The classic answer to this question is the adult “equivalence scale”,⁴⁷ which is commonly assumed to lie within the interval (0.5,1). It is less than 1 since the household becomes a one-person household and is more than 0.5 due to economies of scale in consumption within a two-person household. We denote the equivalence scale by r^0 . A direct implication of its definition is that in the absence of labor disutility state dependence, when $\theta^b = 1$, the labor force participation of the surviving spouses would not change across states of nature if they receive r^0 of their pre-shock household income.⁴⁸

⁴⁷See, e.g., Blundell and Lewbel (1991).

⁴⁸We focus on the adult equivalence scale since we study older households. The median age of the youngest child of our treated

Second, assume we observe the replacement rate – denoted by r^{eq} – that surviving spouses are implicitly willing to accept in equilibria when their labor supply remains unchanged after they experience the shock. In that case, the comparison of the two replacement rates, r^0 and r^{eq} , can reveal the degree of state dependence. Intuitively, if $r^{eq} < r^0$, survivors are willing to accept less than “full insurance” to avoid self-insuring through labor supply, which implies an increase in its utility cost, $\theta^b > 1$. That is, incomplete adjustment of post-shock consumption (captured by r^{eq}) to the consumption level which achieves the pre-shock level of utility (captured by r^0) implies that labor disutility increased. If $r^{eq} \cong r^0$, then state dependence on average is likely to be negligible. To formalize this procedure we begin by stating the following lemma:

Lemma. *Let $V^s(y^s(1))$ denote the household’s consumption value function when w works in state s ,⁴⁹ $\theta^u \equiv V^{b'}(y^b(1))/V^{g'}(y^g(1))$ denote the change in the marginal value of household income, and $\gamma \equiv -[V^{g''}(y^g(1))/V^{g'}(y^g(1))] \times y^g(1)$ denote the household-level pre-shock relative risk aversion. Then, in equilibria in which w ’s labor supply is the same in state g and state b the following holds*

$$\theta^u(1 + \gamma(1 - r^{eq})) \cong \theta^b, \quad (8)$$

where $r^{eq} \equiv y^b(1)/y^g(1)$ is the steady state replacement rate that satisfies this relationship.

Proof. The proof relies on the necessary relationship between household income streams across states of nature in equilibria where labor supply remains unchanged such that $\bar{v}_w^g = \bar{v}_w^b$, where $\bar{v}_w^s \equiv \frac{1}{\theta^s}[V^s(y^s(1)) - V^s(y^s(0))]$. See Appendix D for details.

The relationship in (8) has a simple intuition: if labor supply is unchanged when the shock occurs, then the change in the cost of labor must equal the change in the marginal utility from income. The right-hand side of the equation captures the change in the marginal entrant’s labor disutility by the definition of θ^b . The left-hand side evaluates the marginal utility from income in the new state. It is the baseline pre-shock marginal utility from income (normalized to one), augmented by the change in the marginal utility due to income changes, $1 - r^{eq}$, and the curvature of the consumption value function $V^s(y^s(1))$, γ . Then, we multiply the resulting expression by the change in the marginal value of household income across states, θ^u .

When r^{eq} is directly observed (i.e., revealed by individuals’ choices) – as in the case of widowers who do not change their mean participation rate when their wives die – we can recover θ^b with two simple steps, which correspond to the two steps of the intuitive explanation above. First, since (8)

individuals born after 1930 (for whom we have data on children) is 30, with only 10% having a youngest child under 18.

⁴⁹See Footnote 23 for its formal definition.

is satisfied when $\theta^b = 1$ and $r^{eq} = r^0$, we can recover θ^u by $\theta^u = 1/(1 + \gamma(1 - r^0))$, if we borrow estimates for r^0 from the literature as we discuss below. Second, we can use θ^u and the observed r^{eq} to recover θ^b using (8), such that $\theta^b \cong \frac{1+\gamma(1-r^{eq})}{1+\gamma(1-r^0)} = 1 + \frac{\gamma(r^0-r^{eq})}{1+\gamma(1-r^0)}$. This formalizes our intuition: whenever $r^{eq} < r^0$ – that is, whenever survivors are willing to accept less than what they need – it follows that self-insurance became more costly when the shock occurred, $\theta^b > 1$.

When r^{eq} is not directly observed by choices – e.g., when participation increases in response to a shock – we can use the equilibrium responses to construct a bound on θ^b with the additional identifying assumption of monotonicity as defined below.

Assumption (monotonicity). *Define the potential outcome $Y_i(0)$ to be i 's participation decision that would be realized were he or she not to experience a shock and $Y_i(1)$ to be i 's participation decision that would be realized if he or she were to experience a shock. If $Y_i(1) \geq Y_i(0)$ for every i , we say that monotonicity is satisfied.*

Under monotonicity, the mean increase in the participation of spouses is driven by individuals who switch from working to not working (“compliers”), while the remaining spouses either keep working (“always-takers”) or stay out of the labor force (“never-takers”). Given this response, we observe an aggregate income replacement rate in the data, denoted by r' , which is composed of the rate among compliers, denoted by r'_c , and a replacement rate for the rest of the sample. Now, assume that we change the environment only by offering the compliers a higher income if they do not work. Since working is costly, there must exist $r''_c < r'_c$ such that compliers prefer receiving r''_c without working to receiving r'_c and working. Therefore, under monotonicity, in an equilibrium in which the mean participation rate does not change when the shock occurs, r^{eq} (which involves r''_c) must be smaller than the r' that we actually observe (which involves r'_c). This imposes a lower bound on θ^b such that $\theta^b \cong 1 + \frac{\gamma(r^0-r^{eq})}{1+\gamma(1-r^0)} \geq 1 + \frac{\gamma(r^0-r')}{1+\gamma(1-r^0)}$.

Calibrating θ^b : results. We begin by studying the implications of a commonly used equivalence scale – the modified OECD equivalence scale which implies $r^0 = 0.67$. Other widely used adult equivalence scales deliver similar approximations.⁵⁰ Combining widows and widowers in Panel B of Figure 6 yields an average post-shock replacement rate of $r' = 0.665$. Given the increase in mean labor force participation and using the bound we derived above, these estimates imply that $\theta^b \geq 1$ and suggest that state dependence is negligible.

Next, we consider model-based estimates for adult equivalence scales. In particular, we use recent estimates from Browning, Chiappori, and Lewbel (2013), which offer separate estimates for “indifference scales” for men and women.⁵¹ Since widowers do not change their mean participation rate

⁵⁰For example, the square-root scale which implies $r^0 = 0.71$ (see, e.g., Cutler and Katz 1992 and OECD 2011). Note that the implicit equivalence scale in the Danish Social DI is approximately 0.65 and is 0.66 in the Old-Age Pension. See Section 3 for institutional details.

⁵¹Their notion of “indifference scales” is an individual-based version of equivalence scales, which aims at identifying the fraction

when their wives die, we can directly observe their r^{eq} . Recall from Panel B of Figure 6 that widowers experience an actual loss of 31% in household income and hence for them $r^{eq} = 1 - 0.31 = 0.69$. This implies that they are willing to accept 69% of their pre-shock level of household income to avoid increasing their labor supply. Browning, Chiappori, and Lewbel (2013) find that in households with equal sharing of income among the two spouses, the indifference scale for males is about 0.80. This suggests that for widowers $r^0 = 0.80 > r^{eq} = 0.69$ and thus on average their labor disutility increases when they lose their wives – that is, $\theta^b \cong 1 + \frac{0.11\gamma}{1+0.20\gamma} > 1$. For widows, who increase their labor force participation, we can recover a bound for state dependence using Browning, Chiappori, and Lewbel’s (2013) indifference ratio of 0.72. Recall from Panel B of Figure 6 that for widows $r' = 1 - 0.35 = 0.65$. This implies a lower bound of $\theta^b \geq 1 + \frac{0.07\gamma}{1+0.28\gamma} > 1$, which suggests that on average labor disutility likewise increases for widows when they lose their husbands.

While these calibrations are suggestive, they provide further evidence that our results for the surviving spouses’ labor force participation are driven by self-insurance and large income losses.⁵² The data is inconsistent with the conjecture that the increases in labor supply are driven by lower cost of labor (e.g., due to the desirability of social integration) since in that case we would expect to observe noticeably larger actual replacement rates than the “needed” ones suggested by equivalence scales.⁵³

5.3 Labor Supply Responses to Spousal Health Shocks

In this section we briefly study individuals’ labor supply responses to severe health shocks to their spouses. The purpose of studying this additional shock is to provide further evidence for the self-insurance hypothesis of spousal labor supply. Recall that our analysis sample for this shock consists of households in which a spouse experienced a heart attack or a stroke (for the first time) and survived for at least four years (until $t = 3$), and in which both spouses were under age 60.

Panel A.1 of Figure 11 shows that within three years of the shock, the affected spouse’s participa-

of the household’s income a member would need in order to buy a bundle of privately consumed goods at market prices that put him or her on the same indifference curve over goods that he or she attained as a member of the household. Their method relies on recovering the consumption demand functions of individuals within a household based on a collective household model, which they estimate by using the Canadian Survey of Family Expenditures.

⁵²In section 6, we also show that the increase in widows’ participation due to the shock declines in the formal insurance they receive from the government, which further strengthens the self-insurance hypothesis.

⁵³In addition, we test a potential implication of the specific hypothesis that seeking social integration after losing a partner with whom the surviving spouse has spent his or her leisure time may drive his or her labor supply response. Consider surviving spouses who did not work before the shock in a model where time is divided between labor and leisure. A spouse in a household in which the deceased spouse did not work before his or her death consumed more joint leisure and may have a higher chance of experiencing loneliness. On the other hand, a spouse in a household in which the deceased spouse worked before his or her death consumed less joint leisure and experience larger income losses. The social integration hypothesis is consistent with the former household increasing its labor supply more than the latter does, while the self-insurance hypothesis is consistent with the opposite pattern. The data reveals that labor supply increases are driven by the latter group, which provides additional support for the self-insurance hypothesis.

tion sharply falls, which translates into a large loss of annual earnings as shown in Panel A.2. Table 5 quantifies these effects by estimating a differences-in-differences regression, in which we allow for differential treatment effects in the “short run” (periods 1 and 2) and the “medium run” (period 3), to account for the gradual responses documented in Panel A of Figure 11.⁵⁴ Columns 2 and 4 of Table 5 reveal that by the third year after the shock the labor force participation of the sick spouse drops by 12 pp – about 17% – and that annual earnings drop by DKK 36,015 (\$4,500) – a significant drop of 19%.

However, while there is a significant drop in the sick spouse’s earnings, Columns 5 and 6 of Table 5 show that the actual loss of income that the household experiences is much smaller and amounts to only 3.3% of overall household income. That is, taking into account the entire household income, including any transfers from social or private sources, reveals that these shocks are very well-insured in our Danish setting. Therefore, as shown in Panel B of Figure 11 and Columns 7 to 10 of Table 5, there are no economically significant labor supply responses among unaffected spouses as there is no significant need to self-insure.

Note that the rich data-set and our research design allow for a precise estimation of these economically insignificant spousal responses to shocks.⁵⁵ In particular, our results imply a small but positive degree of complementarity in spouses’ labor supply in response to health shocks, with an estimate of 0.065 for the unaffected spouse’s earnings elasticity with respect to the affected spouse’s earnings. Since the household’s income is not perfectly insured, this response implies – in the context of our theoretical framework – health-state dependence of the household’s utility. Intuitively, the fact that given a small loss in income the unaffected spouse’s decrease in labor supply involves an additional (very small) loss is consistent with two main state dependence channels. First, it is consistent with households in the bad state valuing income less than do households in the good state – i.e., a consumption utility state dependence. Second, it is consistent with an increase in the unaffected spouse’s utility loss from time spent away from home either because he or she would like to take care of his or her sick spouse or due to his or her preference for joint leisure – i.e., a labor disutility state dependence. With no additional assumptions, we can only reach conclusions about the ratio of these two types of potential state dependence. See Appendix E for a formal analysis.

⁵⁴We estimate the following specification

$$y_{i,t} = \beta_0 + \beta_1 treat_i + \beta_{2a} post_{i,t}^a + \beta_{3a} treat_i \times post_{i,t}^a + \beta_{2b} post_{i,t}^b + \beta_{3b} treat_i \times post_{i,t}^b + \alpha_i + \varepsilon_{i,t}, \quad (9)$$

where $y_{i,t}$ denotes an outcome of household i at time t , $post_{i,t}^a = 1$ in periods 1 and 2 and zero otherwise, and $post_{i,t}^b = 1$ in period 3 and zero otherwise. Therefore, β_{3a} captures the “short-run” effect, and β_{3b} captures the “medium-run” effect.

⁵⁵This may explain the survey-based noisy estimates of Coile (2004) and Meyer and Mock (2013), who study responses to health shocks in the US. Note that Meyer and Mock (2013) similarly find that the typical disabled individual in the US loses about 21% in earnings but only 6.75% in post-transfer household income by the fourth year after the shock.

6 Welfare Implications

We now turn to illustrate our method for welfare analysis and to study the welfare implications of the surviving spouses' labor supply responses. In accordance with the theoretical analysis in Section 2.1.1, consider the following policy question: how should we divide a given budget between households of widows and non-widows? This is essentially a comparison of the social “returns” of two “investment” vehicles – a \$1 transfer to non-working spouses in state b that yields a return of $u'_w(c_w^b(0))$ vs. a \$1 transfer to non-working spouses in state g that yields a return of $u'_w(c_w^g(0))$. We therefore focus on the marginal benefit from increasing b^b by lowering b^g , and abstract from the associated costs on which the literature has focused. We employ the formula of Proposition 1 (equation (4)) and abstract from labor disutility state dependence by assuming $\theta^b = 1$. Since the data is consistent with $\theta^b \geq 1$, this approach delivers a lower bound on the welfare gains from this policy change (as implied by Proposition 2).

In order to assess the marginal benefit from this policy perturbation, we need to calibrate the ratio $\frac{\varepsilon(c_w^b, b^b)}{\varepsilon(c_w^g, b^g)}$. Here we make the simplifying assumption of equal elasticities and use the approximation that this ratio is locally constant, which allows us to illustrate our method in the simplest possible way.⁵⁶ Assuming that $\frac{\varepsilon(c_w^b, b^b)}{\varepsilon(c_w^g, b^g)} = 1$, the formula for the welfare benefits is reduced to

$$MB(b^b) \cong \frac{b^g}{b^b} \times \frac{e_w^b}{e_w^g} - 1.$$

To study existing social programs in Denmark, we divide the analysis into two sub-populations. First, we consider widows over age 67, who are eligible for the Danish Old-Age Pension (the equivalent of Social Security in the US) and analyze the perturbation within this program. Second, we consider widows younger than 67 who are more attached to the labor force and analyze changes to Social DI benefits for which they can apply.

Old-Age Pension. In Panel A of Figure 12 we plot the responses of widows over 67. Panel A.1 reveals that even the elderly need to self-insure and increase their participation by 1.08 pp on a very low base of 1.19 pp. This implies that the participation rate of widows over 67 almost doubles when their husbands die with $\frac{e_w^b}{e_w^g} = \frac{0.0227}{0.0119} = 1.91$. As the Old-Age Pension includes adjustments to the household's composition (as explained in Section 3 and seen in practice in Panel A.2 of Figure 12), widows during our sample period received on average DKK 87,454 (\$10,932) and their non-widow counterparts received DKK 70,684 (\$8,836) such that for this population $\frac{b^g}{b^b} = \frac{70,684}{87,454} = 0.81$.

⁵⁶In Appendix F we provide suggestive estimates – that require some additional structure – for these elasticities in the case of surviving spouses under 60 that imply a ratio of 1.375.

Together, these imply that

$$MB(b^b) \cong \frac{b^g}{b^b} \times \frac{e_w^b}{e_w^g} - 1 = 0.81 \times 1.91 - 1 = 0.55.$$

That is, an additional \$1 transferred to widows through the Old-Age Pension creates a net benefit equivalent to 55 cents as compared to transferring \$1 to non-widows. This large marginal benefit from an additional dollar to elderly widows is driven by their significant relative increase in participation, which reveals their high valuation of additional insurance. This suggests that increasing the relative compensation to *older* widows within the Old-Age Pension beyond the current household-composition adjustment entails significant welfare improvement.

Social Disability Insurance. To focus on the value of Social DI, we constrain the sample to widows under 67 (the age at which the program transitions into the Old-Age Pension). In addition, we constrain the sample to the period prior to 1994 due to a data break in the reporting method of benefits received through Social DI. Panel B.1 of Figure 12 plots the labor force participation behavior of this sample and shows that $\frac{e_w^b}{e_w^g} = \frac{0.4718}{0.4537} = 1.04$, which is smaller than the effect among the elderly as well as among the overall sample of widows as shown in Section 5.1. Panel B.2 of Figure 12 clearly displays the insurance role of Social DI for widows, whose take-up of the program increases by more than 50% in the year that their husbands die. For this time period, the mean benefits received from Social DI by those on the program are the same for widows as for non-widows and, therefore, $\frac{b^g}{b^b} \cong 1$.⁵⁷ Combining these estimates, it follows that

$$MB(b^b) \cong \frac{b^g}{b^b} \times \frac{e_w^b}{e_w^g} - 1 = 1 \times 1.04 - 1 = 0.04.$$

That is, an additional \$1 transfer to widows through Social DI is worth 4 cents more to each household than is transferring this additional \$1 to non-widows. These small (but positive) welfare gains are a direct result of the relative increase in labor force participation among widows that are eligible for this program (under 67), which is smaller than the effect among the universe of widows.

Therefore, a key implication of our findings, driven by the differential attachment of individuals to the labor force over the life-cycle, is that the social insurance policy should be age-dependent.

An additional valuable welfare exercise allows us to use our method to assess how far the benefits are from their optimal levels by evaluating the local rate at which marginal benefits change, $MB'(b^b)$. To estimate this derivative we take advantage of spatial variation in the administration of Social DI. Recall that while Social DI is a state-wide program, it is locally administered so that regional councils decide whether to approve or reject an application and municipal caseworkers (in a total of 270 municipalities) administer the application and handle all aspects of each case. Since this structure has

⁵⁷The exact figures are $b^b = \$8,115$ for widows and $b^g = \$8,016$ for non-widows (in 2000 dollars).

led to substantial variation in rejection rates across municipalities, it has created significant variation in the mean receipts of Social DI benefits across the different municipalities over time (Bengtsson 2002). We use these year by municipality average receipts as an instrument for actual receipts. In particular, we calculate for each municipality, the average benefits received by non-working surviving spouses through Social DI in each year. Then, we assign to each widow of household i in the treatment group the respective mean in municipality m at time t excluding her own benefits (the “leave-one-out” mean), denoted by $\overline{DI}_{-i,t,m}$. We estimate the following augmented differences-in-differences regression

$$l_{w,i,t} = \beta_0 + \beta_1 treat_i + \beta_2 post_{i,t} + \beta_3 treat_i \times post_{i,t} + \beta_4 X_{i,t} + \varepsilon_{i,t}, \quad (10)$$

where

$$\beta_{3i} = \beta_{30} + \beta_{31} DI_i.$$

In this regression, $l_{w,i,t}$ denotes the participation of individual w of household i at time t , and $X_{i,t}$ includes municipality m ’s unemployment rate and average earnings, as well as age, year and municipality fixed effects. DI_i are actual Social DI receipts for which we instrument using $\overline{DI}_{-i,t,m}$. The identifying assumption is that, given our set of controls, the average of Social DI benefits transferred to widows in a municipality in a given year affects a widow’s participation only through its influence on her own DI receipts. Note that the source of variation we use is within municipalities over time since we include municipality and calendar year fixed effects as controls. The two-stage least squares results are presented in Appendix Table 1.⁵⁸ The estimate for our parameter of interest, $\beta_{31} = \frac{\partial(e_w^b - e_w^g)}{\partial b^b}$, is -.0057.⁵⁹

Using this estimate, Figure 13 plots the behavior of $MB(b^b)$ around the sample mean of DKK 65,000 (\$8,115). The figure shows that additional DKK 1,500 (\$188) in annual benefits decrease the excess benefit to zero. Converting these monetary values into net replacement rates out of the deceased spouse’s pre-shock earnings,⁶⁰ the current system stands at 0.648 and the optimal allocation of benefits across states stands at 0.663, suggesting that for *younger* widows the current levels are near optimal. To evaluate the overall value of the program, we can approximate the integral $\int_0^{65,000} MB(b^b) db^b$ by using our estimates. This integral answers the question: within the Social DI system in Denmark, what is the welfare gain from the benefits given to widows relative to non-widow beneficiaries of the program? The estimate amounts to DKK 99,942 (\$12,500) annually, which means

⁵⁸The F-statistic on the excluded instrument in the first stage is 24.3.

⁵⁹The benefits (b^b) are measured in annual DKK 1,000 (\$125) terms. With an average of DKK 23,262 (\$2,908) in actual DI receipts by widows in the analysis sample (including zeros for those not on the program) and a participation rate of 0.5054, this estimate implies a participation elasticity of $\varepsilon(e_w^b, b^b) = -0.26$ for widows under 67.

⁶⁰We calculate the average earnings in $t = -1$ for affected spouses who had positive earnings the year before they passed away. The average is DKK 170,000 (\$21,250), which implies net wage earnings of DKK 100,300 (\$12,538) using an average labor income tax rate of 41% (OECD estimates).

that transfers to widows relative to non-widows create a benefit of $(\$12,500/\$8,115-1=)$ 54%. That is, on average, each dollar given to younger widows through Social DI generates a net benefit equivalent to 54 cents relative to a dollar given to non-widow recipients, which reveals the large social value of survivors benefits.

7 Conclusion

This paper provides clear evidence of household self-insurance through labor supply in response to large and persistent income losses and develops a new labor market method for welfare analysis of social insurance. Studying the critical event of the death of a spouse, we find large increases in the surviving spouses' labor force participation rate driven by households for whom this event imposes significant income losses. We show that the unaffected spouse's self-insurance response fully reveals the household's marginal utility from consumption. As the gap in marginal utilities across states of nature captures the value of insurance, we offer a way to recover the gains from social insurance based solely on spousal labor supply responses. Applying this method to spousal mortality shocks, we show that allocation of additional resources to elderly widows has significant welfare gains and that survivors benefits should be age-dependent.

We additionally exploit the Danish setting to analyze households in which an individual has experienced a severe health shock but survived, for which income losses are well-insured. Together, the results point to a potential explanation for the elusiveness of the insurance role of spousal labor supply in previous literature. In support of the hypotheses raised by Heckman and MaCurdy (1980) and Cullen and Gruber (2000), we find that spousal labor supply plays a significant self-insurance role when the income loss incurred by the shock is large relative to the household's lifetime income – as in the death of a spouse – and is irrelevant when the loss is sufficiently insured through formal social insurance – as in spousal health shocks.

Our findings have further implications for potentially improving efficiency in the distribution of government benefits. The significant heterogeneity in responses we find across different *pre-shock* dimensions of household characteristics suggests that enriching the policy tools to condition transfers on these observable characteristics may be welfare improving. For example, since increases in the surviving spouse's labor supply are strongly correlated with the income shock that he or she experiences after losing an earning spouse, it may be welfare improving to let survivors benefits increase in the deceased spouse's pre-shock share of annual household earnings.⁶¹

More broadly, our quasi-experimental design for identifying the effect of shocks as well as our method for welfare analysis can be applied to other important economic questions. Our research

⁶¹ A similar feature is implicit in the US system, where survivors are eligible for their deceased spouses' Social Security benefits, which are a function of the deceased's work history.

design, which relies on comparing households that are affected only a few years apart, can be applied to estimating the effect of a shock in any setting in which its exact timing is likely to be random. Our welfare analysis method, which relies on spousal labor supply, can be applied to evaluating the welfare gains from social insurance in any setting in which the directly affected individual may be at a corner solution. For example, relevant to the debate on the privatization of Social Security, the value of protecting against pension-wealth losses in the 401(k) account of a working individual can be recovered by the labor supply response of his or her spouse. Spousal labor supply can also be used to evaluate the welfare losses caused by the discontinuation of an employee's compensation, such as health insurance, as well as the value of unemployment insurance for the long-term unemployed (whose long durations of unemployment significantly harm their employment prospects).⁶²

⁶²See Kroft, Lange, and Notowidigdo (2013) on the adverse effect of longer unemployment spells.

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TABLE 1
Summary Statistics of Analysis Sample

		<i>Death Event Sample</i>				<i>Health Shock Sample</i>	
		All Ages		Under 60		Under 60	
		(1)		(2)		(3)	
		Treatment	Control	Treatment	Control	Treatment	Control
<i>Characteristics</i>							
Unaffected Spouse	Year of Observation	1993.13	1993.09	1992.74	1992.75	1991.83	1991.95
	Age	62.86	62.27	47.60	47.48	45.69	45.30
	Education (months)	118.66	119.94	129.19	129.38	130.94	132.48
	Percent female	0.6937	0.6632	0.7485	0.7485	0.7551	0.7367
Affected Spouse	Age	64.84	64.01	52.51	52.14	47.80	47.27
	Education (months)	123.57	124.05	131.80	132.22	134.90	136.31
<i>Outcomes</i>							
Unaffected Spouse	Participation	0.3474	0.3719	0.7389	0.7445	0.7709	0.7820
	Earnings (DKK)	62,455	67,452	160,799	162,094	163,336	168,311
Affected Spouse	Participation	0.2723	0.3211	0.6033	0.6560	0.7621	0.7790
	Earnings (DKK)	51,579	61,791	143,118	158,447	198,723	204,191
Number of Households		310,720	409,190	55,103	80,578	37,432	54,926

Notes: This table presents means of key variables in our analysis sample. All monetary values are reported in nominal Danish Kroner (DKK) deflated to 2000 prices using the consumer price index. In this year the exchange rate was approximately DKK 8 per US \$. For each event, the treatment group comprises households that experienced a shock in different years, to which we match households that experienced the same shock five years later as a control group ($\Delta=5$). Columns 1 and 2 report statistics for the death event sample of households in which a spouse died of any cause between ages 45 and 80 from 1985 to 2011. Column 1 reports statistics for the entire sample, and Column 2 reports statistics for the sub-sample of surviving spouses under age 60. Column 3 reports statistics for the health event sample. It includes households in which one spouse experienced a heart attack or a stroke between 1985 and 2011 and survived for at least three years, and in which both spouses were under age 60. The values reported in the table are based on data from two periods before the shock occurred (period $t = -2$).

TABLE 2
Survivors' Labor Supply Responses to the Death of Their Spouse

A. Surviving Spouses of All Ages								
Dependent variable:	Widowers				Widows			
	Participation (1)	Participation (2)	Earnings (3)	Earnings (4)	Participation (5)	Participation (6)	Earnings (7)	Earnings (8)
Treat × Post	-.0016 (.0017)	-.0017 (.0016)	-939* (485)	-906** (448)	.0188*** (.0011)	.0164*** (.0010)	2,957*** (201)	2,707*** (188)
Household FE	X	X	X	X	X	X	X	X
Year and Age FE		X		X		X		X
Number of Obs.	1,397,030	1,397,030	1,397,030	1,397,030	2,919,946	2,919,946	2,919,946	2,919,946
Number of Households	232,973	232,973	232,973	232,973	486,890	486,890	486,890	486,890

B. Surviving Spouses under 60								
Dependent variable:	Widowers				Widows			
	Participation (1)	Participation (2)	Earnings (3)	Earnings (4)	Participation (5)	Participation (6)	Earnings (7)	Earnings (8)
Treat × Post	-.0075** (.0036)	-.0071** (.0036)	-7,902*** (1444)	-7,730*** (1439)	.0207*** (.0023)	.0219*** (.0023)	4,093*** (522)	4,423*** (516)
Household FE	X	X	X	X	X	X	X	X
Year and Age FE		X		X		X		X
Number of Obs.	203,569	203,569	204,438	204,438	607,437	607,437	608,742	608,742
Number of Households	34,104	34,104	34,118	34,118	101,529	101,529	101,562	101,562

Notes: This table reports the differences-in-differences estimates of the surviving spouses' labor supply responses (equation (6)). The sample includes individuals whose spouses died between ages 45 and 80 from 1985 to 2011. The treatment group comprises households that experienced the shock in different years, to which we match households that experienced the same shock five years later as a control group ($\Delta=5$). Panel A reports the responses of all survivors by gender, where widowers are those who lost their wives and widows are those who lost their husbands. Panel B reports the responses of survivors under 60 by gender. The pre-shock periods include periods -5 to -3. The post-shock periods include periods 2 to 4. Robust standard errors clustered at the household level are reported in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

TABLE 3
Survivors' Labor Force Participation Responses to the Death of Their Spouse by the Degree of Income Loss

A. Surviving Spouses of All Ages			
<i>Baseline Regression</i>	Both Genders (1)	Widowers (2)	Widows (3)
Treat × Post	0.1265*** (0.0023)	0.1220*** (0.0042)	0.1170*** (0.0027)
Treat × Post × Replacement Rate	-0.1889*** (0.0035)	-0.1894*** (0.0061)	-0.1744*** (0.0044)
Number of Obs.	4,288,621	1,387,615	2,901,006
Number of Households	714,892	231,318	483,574
<i>Regression with Interactions</i>	Both Genders (1)	Widowers (2)	Widows (3)
Treat × Post × Replacement Rate	-0.1989*** (.0045)	-0.2021*** (.0081)	-0.1927*** (.0056)
Number of Obs.	2,741,690	821,742	1,919,948
Number of Households	459,622	137,724	321,898
B. Surviving Spouses under 60			
<i>Baseline Regression</i>	Both Genders (1)	Widowers (2)	Widows (3)
Treat × Post	0.0883*** (0.0054)	0.0652*** (0.0125)	0.0954*** (0.0063)
Treat × Post × Replacement Rate	-0.1270*** (0.0083)	-0.1081*** (0.0168)	-0.1338*** (0.0101)
Number of Obs.	803,158	201,487	601,671
Number of Households	134,199	33,720	100,479
<i>Regression with Interactions</i>	Both Genders (1)	Widowers (2)	Widows (3)
Treat × Post × Replacement Rate	-0.1481*** (0.0091)	-0.1375*** (0.0186)	-0.1499*** (.0110)
Number of Obs.	704,370	173,620	530,750
Number of Households	118,812	29,288	89,524

Notes: This table reports the interaction of the treatment effect of the death of a spouse with the household's post-shock income replacement rate (equation (7)). The sample includes individuals whose spouses died between ages 45 and 80 from 1985 to 2011. The treatment group comprises households that experienced the shock in different years, to which we match households that experienced the same shock five years later as a control group ($\Delta=5$). Panel A reports estimates for the sample of all survivors by gender; Panel B reports estimates for the sample of survivors under age 60 by gender. In each panel, we report estimates of two specifications. The upper half of each panel estimates a baseline differences-in-differences specification which interacts the treatment effect with the replacement rate variable. This replacement rate is calculated as follows. First, we fix the surviving spouse's labor income, Social Disability and Social Security benefits as well as sick-pay benefits at their pre-shock levels (in period -1). Then, we calculate the ratio of this adjusted household income in period 1 (post-shock) to that in period -1 (pre-shock), and normalize it by the average ratio for the control group in order to account for calendar year trends as well as for life-cycle effects. The lower half of each panel extends this specification to include interactions of the treatment effect with additional household characteristics: age dummies for the surviving spouse, dummies for the age of the deceased at the year of death, year dummies, indicators for the number of children in the household as well as the surviving spouse's months of education (and its square). The results are also robust to the inclusion of a quadratic in the household's net wealth. All the variables that are interacted with "Treat × Post" are interacted with "Treat" and "Post" and enter the regressions separately as well. All specifications include year, age and household fixed effects. The pre-shock periods include periods -5 to -3. The post-shock periods include periods 2 to 4. Robust standard errors clustered at the household level are reported in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

TABLE 4
Survivors' Annual Earnings Responses to the Death of Their Spouse

<i>A. Mean Responses by Quintiles of Own Pre-Shock Earnings</i>							
		All Survivors		Low-Earning Deceased		High-Earning Deceased	
		(1)		(2)		(3)	
Quintile 1	Treat × Post	6,062*** (1,211)	8,847*** (978)	7,237*** (2,194)	9,034*** (1,784)	5,105*** (1,481)	8,565*** (1,199)
	Mean Earnings	75,092		58,025		84,202	
	Percent Change	8.07%	11.78%	12.47%	15.57%	6.06%	10.17%
Quintile 2	Treat × Post	5,946*** (1,348)	7,283*** (1,070)	7,012*** (2,530)	7,120*** (2,014)	4,919*** (1,641)	6,860*** (1,313)
	Mean Earnings	115,830		92,992		123,835	
	Percent Change	5.13%	6.26%	7.54%	7.66%	3.97%	5.54%
Quintile 3	Treat × Post	1,154 (1,369)	3,744*** (1,049)	-667 (2,505)	2,341 (1,893)	1,370 (1,674)	3,919*** (1,305)
	Mean Earnings	148,700		128,151		156,070	
	Percent Change	0.78%	2.52%	-0.52%	1.83%	0.88%	2.51%
Quintile 4	Treat × Post	-2,203 (1,495)	-934 (1,157)	-2,224 (2,746)	-986 (2,095)	-2,644 (1,818)	-1,484 (1,416)
	Mean Earnings	185,311		162,883		192,568	
	Percent Change	-1.19%	-0.50%	-1.37%	-0.60%	-1.37%	-0.77%
Quintile 5	Treat × Post	-7,494*** (1,765)	-5,846*** (1,399)	-4,872 (3,211)	-3,703 (2,498)	-8,877*** (2,170)	-7,466*** (1,718)
	Mean Earnings	239,994		217,992		246,641	
	Percent Change	-3.12%	-2.45%	-2.23%	-1.7%	-3.60%	-3.03%
Household FE		X	X	X	X	X	X
Age and Year FE			X		X		X

<i>B. Mean Responses by Gender</i>			
	Both Genders	Widowers	Widows
	(1)	(2)	(3)
Treat × Post	585 (667)	-6,623*** (1,342)	3,405*** (729)
Counterfactual Earnings	150,994	163,010	145,969
Household FE	X	X	X
No. of obs.	686,521	220,125	466,392
No. of Households	114,462	36,705	77,756

Notes: This table reports the differences-in-differences estimates of the surviving spouses' annual earnings by the level of their own earnings when their spouses died. The sample includes individuals whose spouses died between ages 45 and 80 from 1985 to 2011, where we constrain the sample in the following way. First, we exclude surviving spouses whose average labor income before the shock (in periods -5 to -2) was lower than their experimental-group-specific 20th percentile. Then, we calculate for each household the pre-shock labor income share of the deceased spouse out of the household's overall labor income and include only households in which both spouses were sufficiently attached to the labor force; specifically, we keep households for whom the average share was between 0.20 and 0.80. These restrictions allow us to focus on households for which there has been some loss of income due to the death of a spouse and in which the surviving spouse has earned non-negligible labor income both in levels and as a share within the household. In addition, to guarantee that our results are not driven by outliers, we exclude households with dying spouses whose mean pre-shock earnings did not fall within their group-specific 5th and 95th percentiles or households with unaffected spouses whose mean pre-shock earnings were higher than their group-specific 95th percentile. We divide the remaining sample into five equal-sized groups by their pre-shock level of earnings. Panel A separately estimates a differences-in-differences specification for each surviving spouses' quintile. Column 1 includes all surviving spouses; Column 2 includes households in which the dying spouses' pre-shock labor income fell within the bottom three quintiles of its group-specific distribution, to which we refer as "low earners"; Column 3 includes households in which the dying spouses' pre-shock labor income fell within the top two quintiles, to which we refer as "high earners". The gradient is also robust to the inclusion of a quadratic in the household's net wealth. Panel B reports the average treatment effect for this sample. The second row reports the counterfactual outcome based on the differences-in-differences estimation. The pre-shock periods include periods -5 to -3. The post-shock periods include periods 2 to 4. Robust standard errors clustered at the household level are reported in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

TABLE 5
Household Responses to Severe Health Shocks in which the Affected Spouse Survived

Dependent variable:	Affected Spouse				Household Income		Unaffected Spouse			
	Participation		Earnings				Participation		Earnings	
	Short	Medium	Short	Medium	Short	Medium	Short	Medium	Short	Medium
	Run	Run	Run	Run	Run	Run	Run	Run	Run	Run
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treat × Post	-.0861*** (.0023)	-.1212*** (.0027)	-29,012*** (741)	-36,015*** (879)	-12,114*** (2168)	-18,665*** (2380)	-.0018 (.0020)	-.0071*** (.0024)	-1,712*** (538)	-2,041*** (628)
Household FE	X	X	X	X	X	X	X	X	X	X
Counterfactual Post-Shock Mean of Dependent Var.	.7328	.7147	195,433	191,225	503,460	503,318	.7489	.7366	166,216	165,756
Percent Change	-12%	-17%	-15%	-19%	-2.4%	-3.7%	0	-1%	-1.03%	-1.23%
Percent Change Excluding the Unaffected Spouse's Responses					-2.1%	-3.3%				
Number of Observations	644,699		646,272		645,817		644,359		645,817	
Number of Households	92,349		92,358		92,356		92,324		92,356	

Notes: This table reports the differences-in-differences estimates of household labor supply responses to severe health shocks in which the affected spouse survived and the effect of these shocks on overall household income (equation (9) in footnote 54). The sample includes households in which one spouse experienced a heart attack or a stroke and survived for at least three years, and in which both spouses were under age 60. The treatment group comprises households that experienced the shock in different years, to which we match households that experienced the same shock five years later as a control group ($\Delta=5$). We allow for differential treatment effects for the “short run” – periods 1 and 2 – and the “medium run” – period 3, to account for the gradual responses documented in Panel A of Figure 11. The pre-shock periods include periods -5 to -2. Household income (Columns 5 and 6) includes income from any source – including earnings, capital income, annuity payouts, and benefits from any social program. The third row reports the counterfactual outcome based on the differences-in-differences estimation. Robust standard errors clustered at the household level are reported in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

APPENDIX TABLE 1

Widows' Labor Force Participation Responses to the Death of Their Spouse by Social Disability Benefits

Dependent Variable:	Widows' Participation
Treat \times Post \times DI	-.0057*** (.0020)
Average Treatment Effect	1.8 pp
Counterfactual Participation	48.7 pp
No. of obs.	364,100
No. of clusters	268

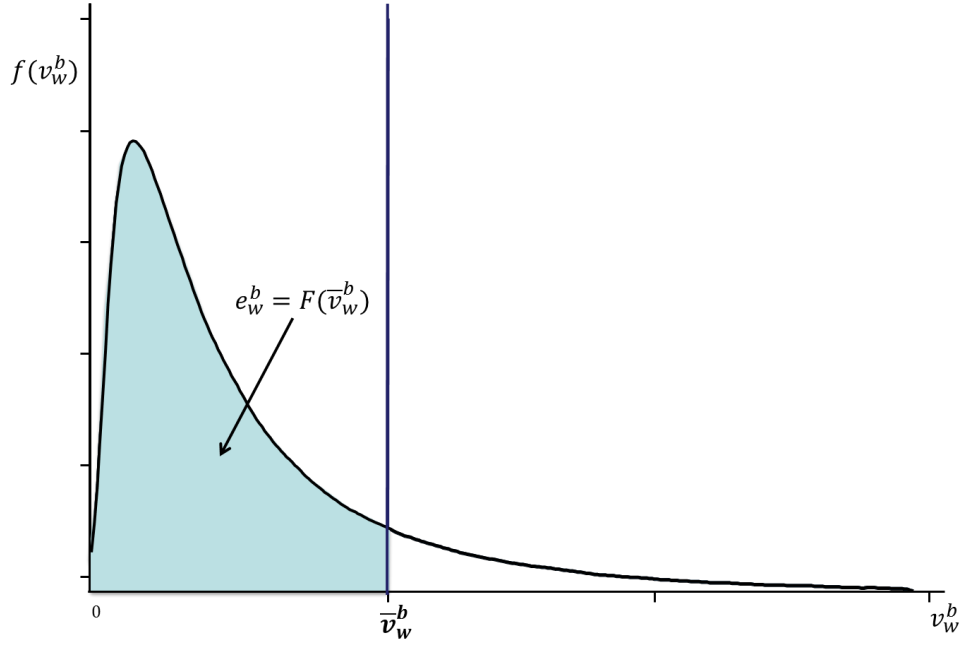
Notes: This table reports the interaction of the treatment effect of the death of a spouse with the actual Social Disability Insurance (Social DI) benefits widows received (equation (10)). The regression is estimated by two-stage least squares, where the instrument for actual benefits is constructed as follows. In each year we calculate for each municipality the average benefits received by non-working surviving spouses through Social DI. Then, we assign to each widow in the treatment group her respective municipality-year leave-one-out mean. The sample includes widows under age 67 (the age at which the program transitions into the Old-Age Pension) in years prior to 1994 (when there is a data break in the reporting method of benefits received through Social DI). The controls included in the estimation are municipality unemployment rate and average earnings as well as age, year and municipality fixed effects. The identifying assumption is that, given our set of controls, the average Social DI benefits transferred to widows in a municipality in a given year affects a widow's participation only through its influence on her own DI receipts. Note that the source of variation we use is within municipalities over time since we include municipality and calendar year fixed effects as controls. The pre-shock periods include periods -5 to -3. The post-shock periods include periods 2 to 4. Robust standard errors clustered at the municipality level are reported in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

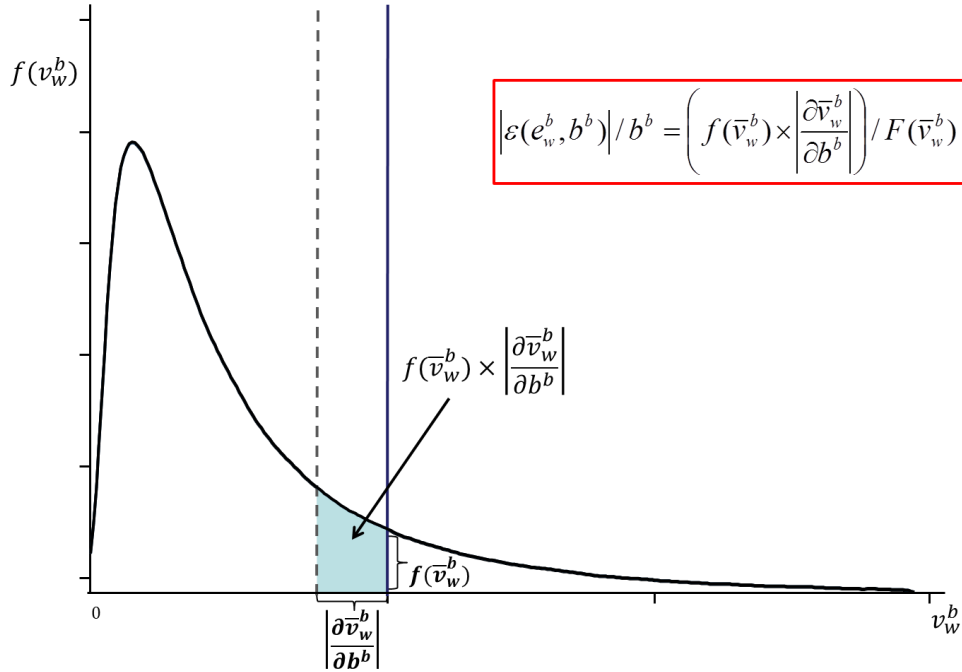
FIGURE 1

The Unaffected Spouses' Labor Force Participation Responses to Policy Changes

(a) Spousal Labor Force Participation in the Bad State



(b) The Change in Spousal Labor Force Participation in the Bad State in Response to the Policy Change

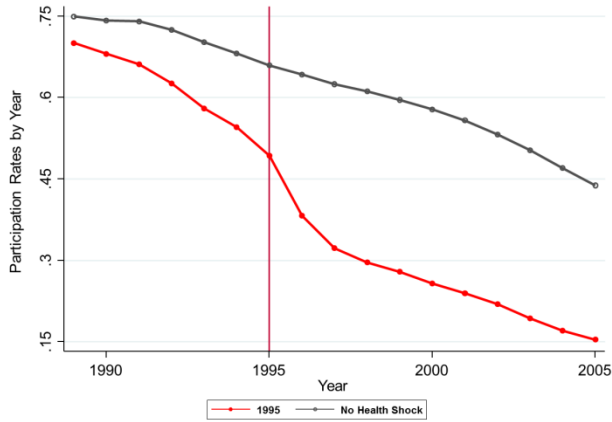


Notes: These figures plot a potential probability density function (pdf) for the labor disutility of the unaffected spouse (spouse w) in state b , v_w^b . The x-axis corresponds to v_w^b and the y-axis corresponds to the pdf, $f(v_w^b)$. In this figure, \bar{v}_w^b is the threshold value below which spouse w chooses to work in state b . Therefore, the area between 0 and \bar{v}_w^b below the pdf is the aggregate labor supply of spouses in state b , $e_w^b = F(\bar{v}_w^b)$. This is the shaded area in panel A. When government transfers locally change, the threshold changes by $\frac{\partial \bar{v}_w^b}{\partial b^b}$ and the approximated change in w 's labor supply is the shaded area in Panel B, $f(\bar{v}_w^b) \times \left| \frac{\partial \bar{v}_w^b}{\partial b^b} \right|$. Hence, the relative within-state change in labor force participation can be approximated by $\left(f(\bar{v}_w^b) \times \left| \frac{\partial \bar{v}_w^b}{\partial b^b} \right| \right) / F(\bar{v}_w^b)$, which is exactly the semi-elasticity of participation, e_w^b , with respect to benefits, b^b . That is, $\epsilon(e_w^b, b^b) / b^b = \left(f(\bar{v}_w^b) \times \left| \frac{\partial \bar{v}_w^b}{\partial b^b} \right| \right) / F(\bar{v}_w^b)$.

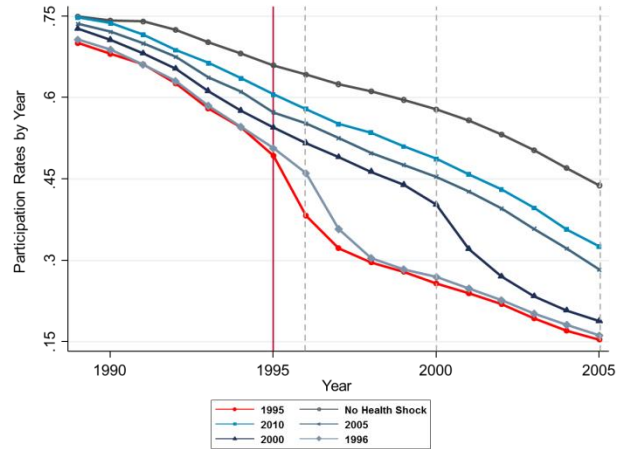
FIGURE 2

Illustration of the Empirical Research Design

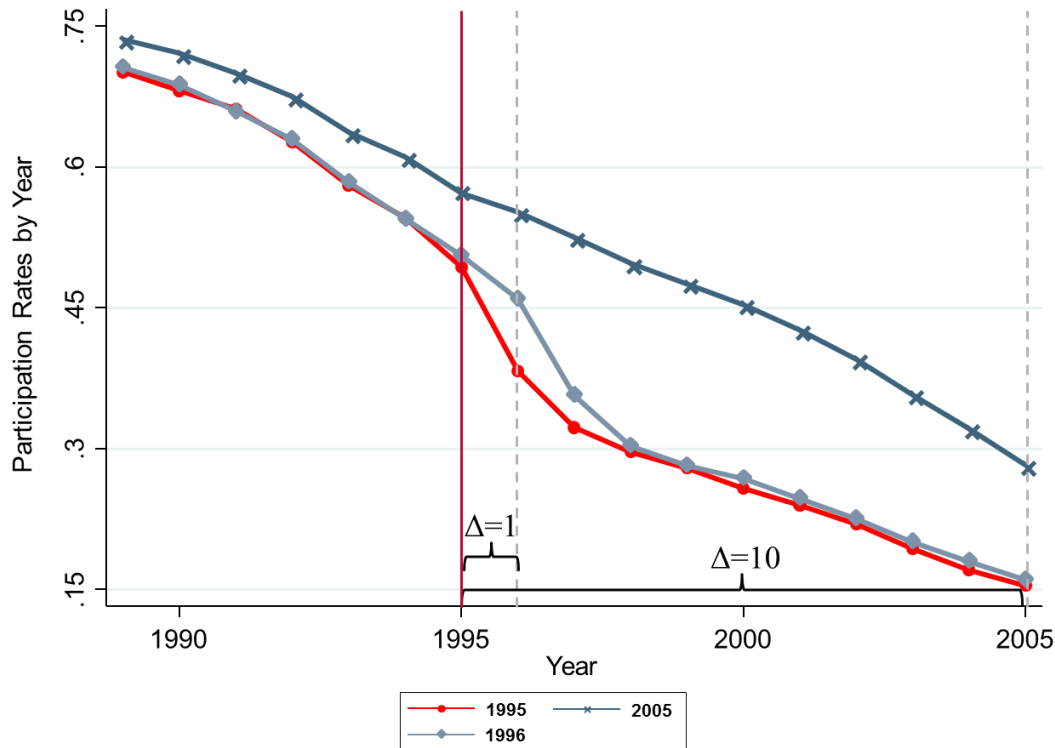
(a) Health Shocks in Year 1995 vs. No Shock



(b) Health Shocks in Different Years and No Shock



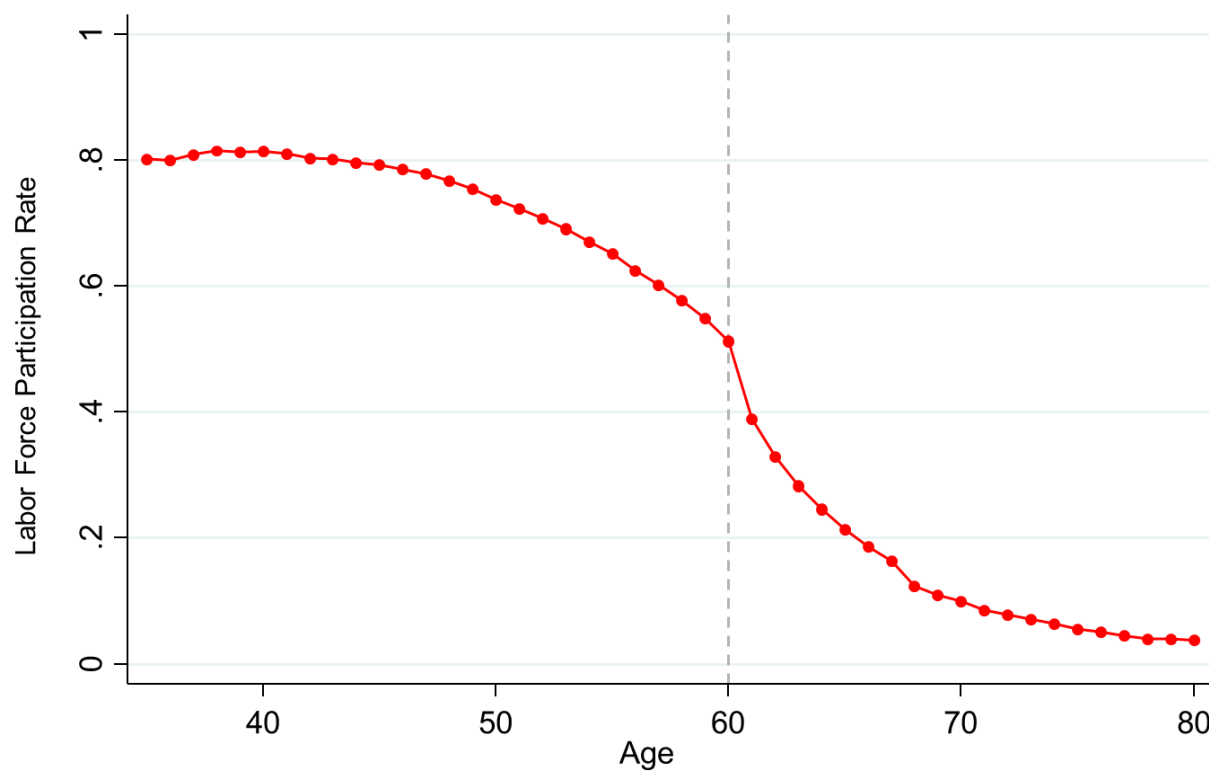
(c) Health Shocks in Years 1995, 1996 and 2005



Notes: These figures compare the labor force participation of a treatment group of individuals who were born between 1930 and 1950 and experienced a heart attack or a stroke in 1995 to that of potential control groups. Panel A compares the treatment group to those who belong to the same cohorts but did not experience a shock in our data window, years between 1985 and 2011, and shows that the pre-1995 patterns of these groups are far from parallel. Panel B adds the behavior of households that experienced the same shock but in different years, and shows that the groups are becoming increasingly comparable to the treatment group – in terms of parallel trends before 1995 – the closer the year in which the individual experienced the shock was to the year the treatment group experienced the shock (1995). The figures suggest using households that experienced a shock in year $1995+\Delta$ as a control group for households that experienced a shock in 1995. The trade-off in the choice of Δ is presented in Panel C. On the one hand, we would want to choose a smaller Δ such that the control group would be more closely comparable to the treatment group, e.g., year 1996 which corresponds to $\Delta=1$. On the other hand, we would want to choose a larger Δ in order to be able to identify longer-run effects of the shock, up to period $\Delta-1$. Using those that experienced a shock in 2005, which corresponds to $\Delta=10$, will allow us to estimate up to the 9-year effect of the shock. However, this entails a potentially greater bias since the trend in the behavior of this group is not as tightly parallel to that of the treatment group.

FIGURE 3

Life-Cycle Labor Force Participation of the Unaffected Spouses in the Death Event Sample

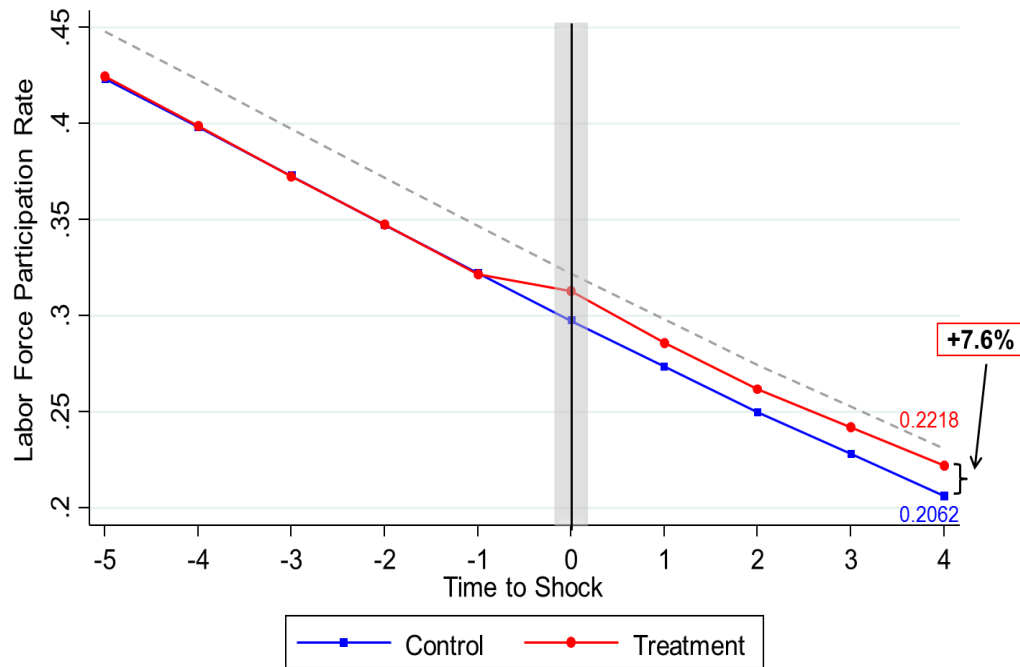


Notes: This figure displays the life-cycle labor force participation of the unaffected spouses that are included in the death event sample (i.e., individuals whose spouses died between ages 45 and 80 from 1985 to 2011). The observations include the pre-shock periods (specifically, periods -5 to -2). The sharp drop at age 60 corresponds to eligibility for the Voluntary Early Retirement Pension (VERP). The figure shows the complex life-cycle trends in labor supply and illustrates why an extrapolation based on behavior in previous years is a poor predictor of future behavior.

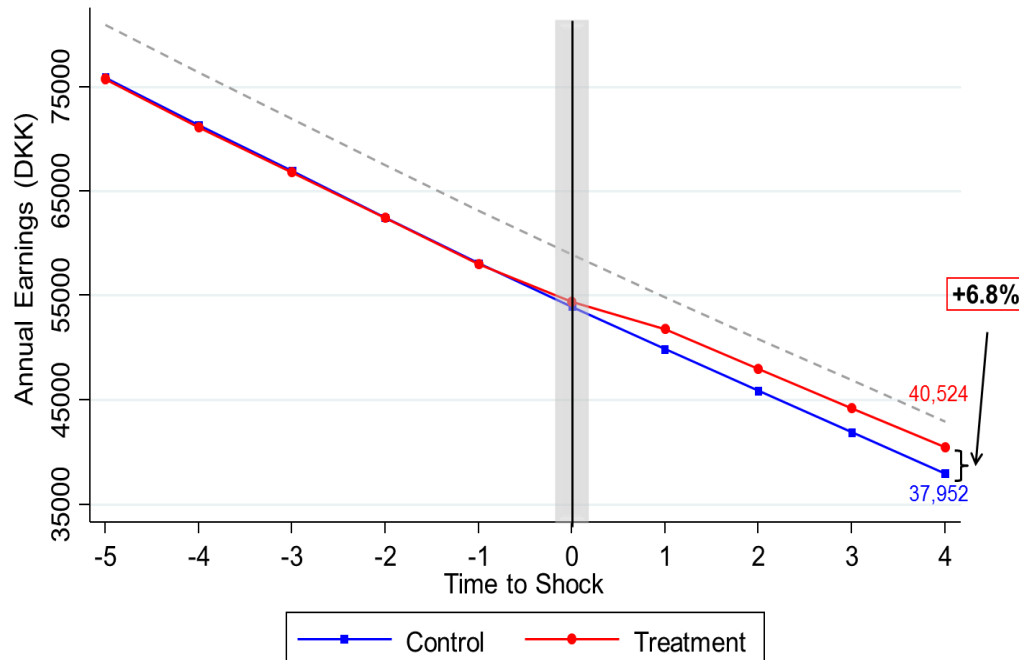
FIGURE 4

Survivors' Labor Supply Responses to the Death of Their Spouse

(a) Labor Force Participation



(b) Annual Earnings

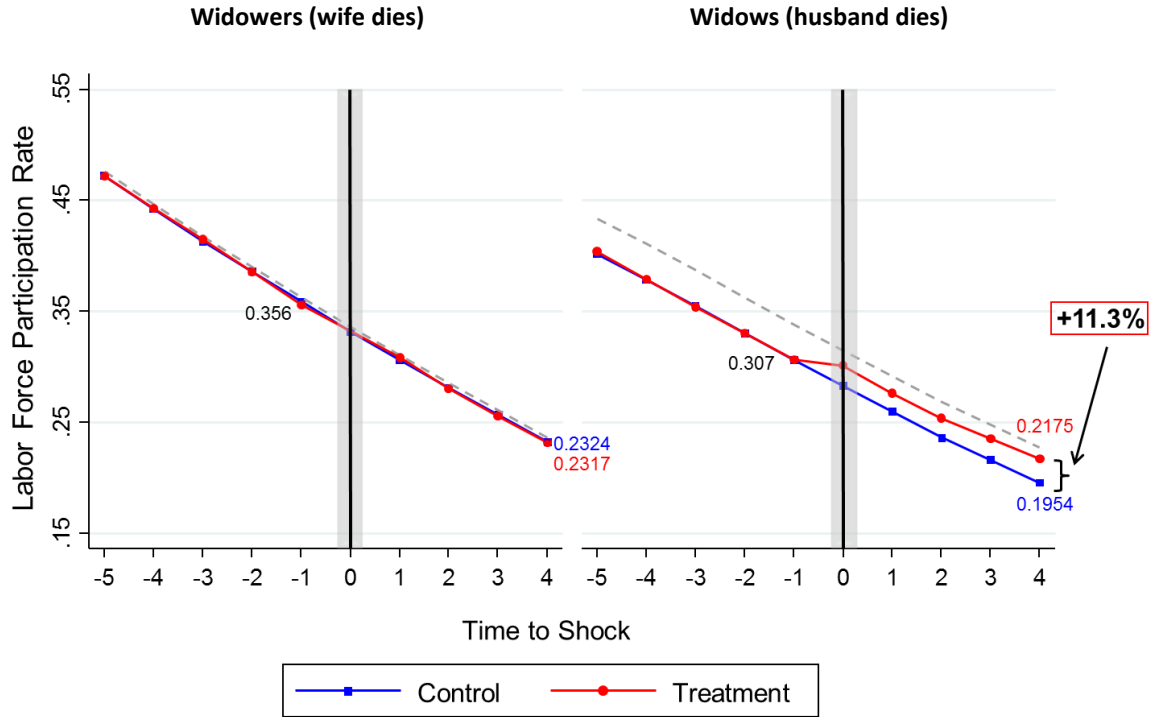


Notes: These figures plot the labor supply responses of survivors to the death of their spouse. The sample includes individuals whose spouses died between ages 45 and 80 from 1985 to 2011. Panel A depicts the behavior of labor force participation, and Panel B depicts the behavior of annual earnings. The x-axis denotes time with respect to the shock, normalized to period 0. For the treatment group, period 0 is when the actual shock occurs; for the control group period 0 is when a “placebo shock” occurs (while their actual shock occurs in period 5). The dashed gray line plots the behavior of the control group. To ease the comparison of trends, we normalize the level of the control group’s outcome to the pre-shock level of the treatment group’s outcome. This normalized counterfactual is displayed by the blue line and squares. The red line and circles plot the behavior of the treatment group.

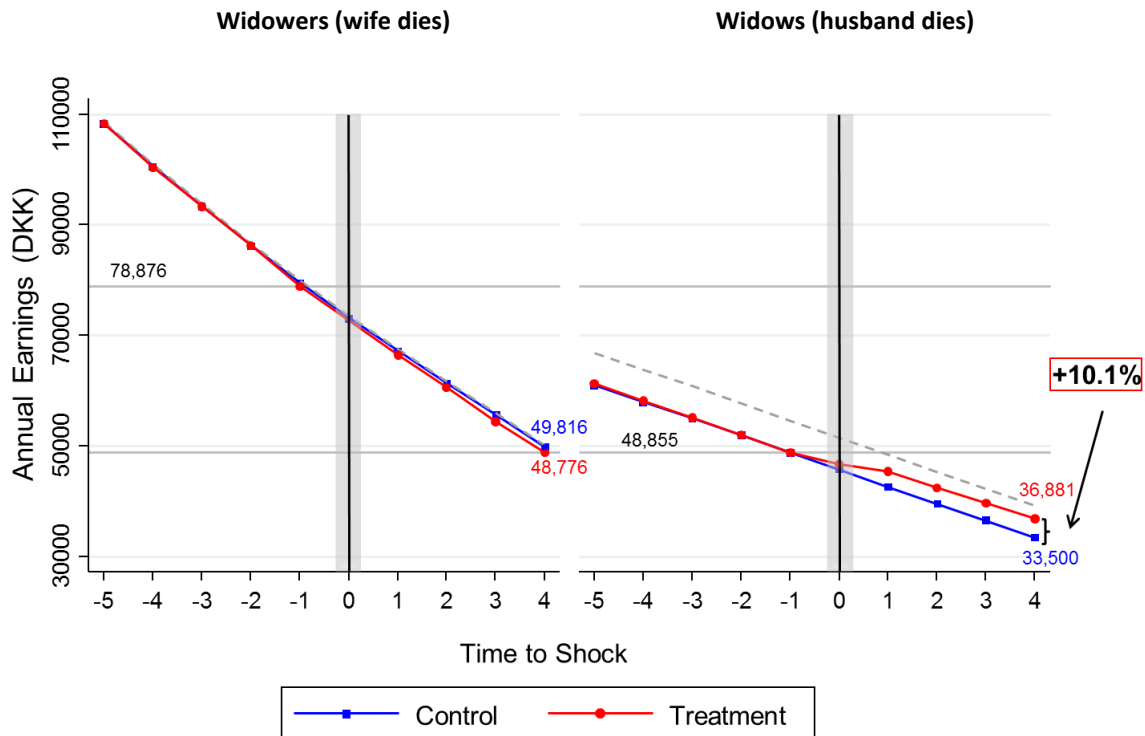
FIGURE 5

Survivors' Labor Supply Responses to the Death of Their Spouse by Gender

(a) Labor Force Participation



(b) Annual Earnings

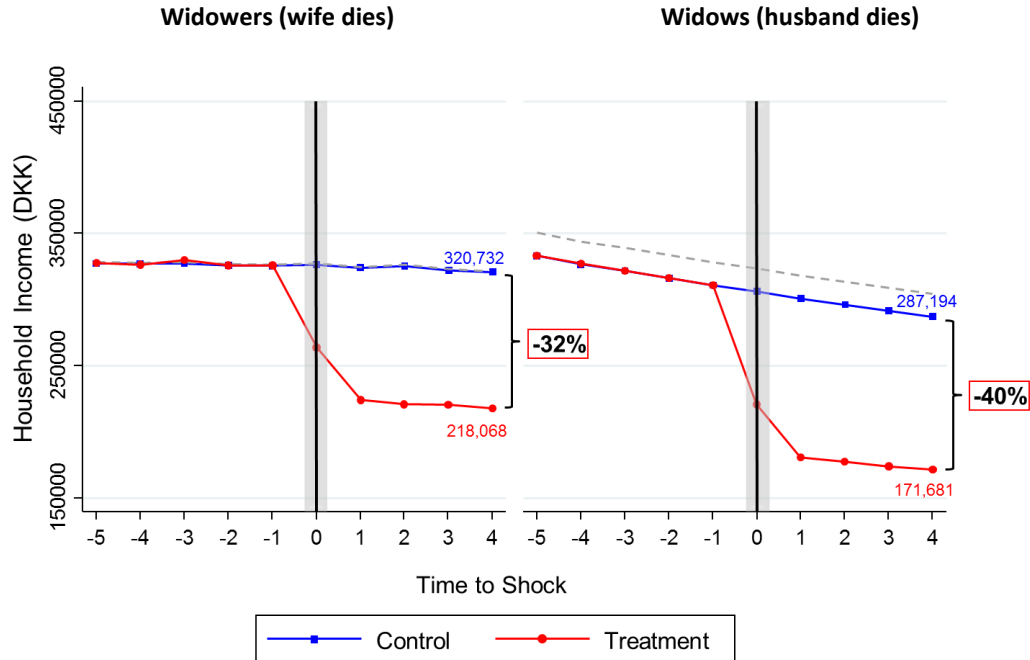


Notes: These figures plot the labor supply responses of survivors to the death of their spouse by the gender of the surviving spouse. The sample includes individuals whose spouses died between ages 45 and 80 from 1985 to 2011. Panel A depicts the behavior of labor force participation, and Panel B depicts the behavior of annual earnings. The x-axis denotes time with respect to the shock, normalized to period 0. For the treatment group period 0 is when the actual shock occurs; for the control group period 0 is when a “placebo shock” occurs (while their actual shock occurs in period 5). The dashed gray line plots the behavior of the control group. To ease the comparison of trends, we normalize the level of the control group’s outcome to the pre-shock level of the treatment group’s outcome. This normalized counterfactual is displayed by the blue line and squares. The red line and circles plot the behavior of the treatment group.

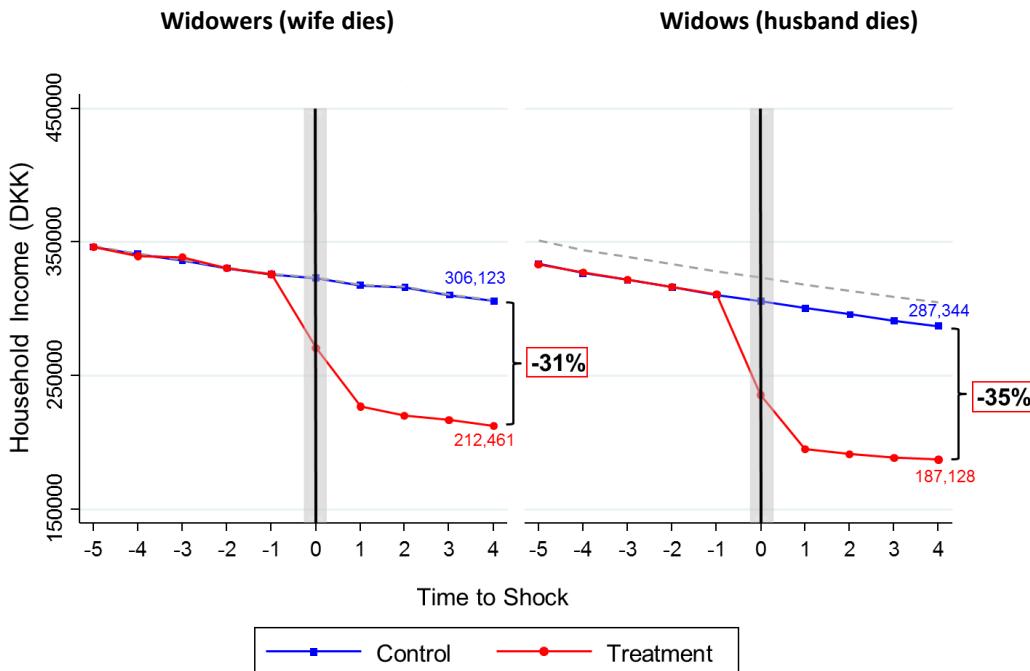
FIGURE 6

Household Income in the Death Event Study

(a) Potential Household Income



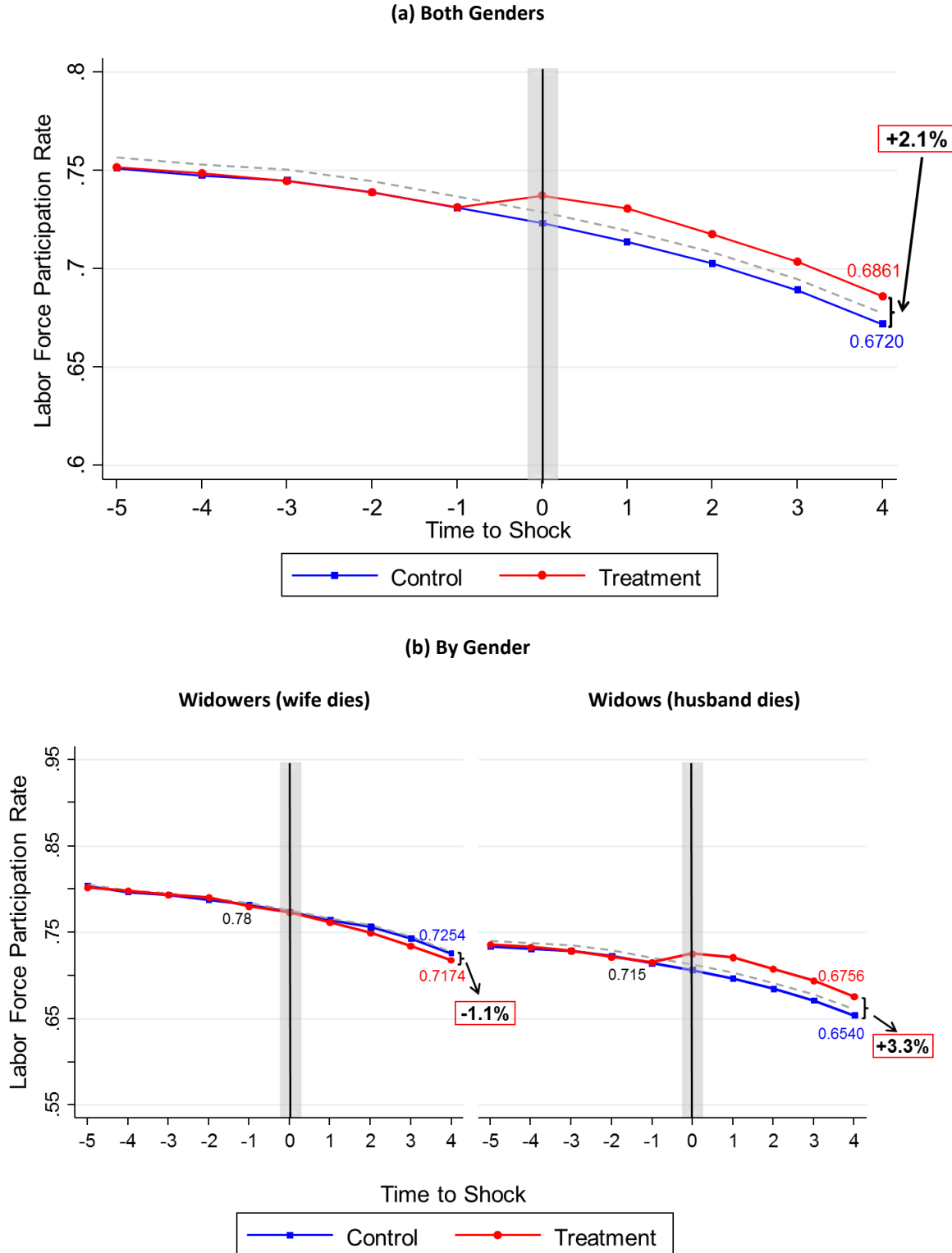
(b) Actual Household Income



Notes: These figures plot different measures of household-level income for households in the death event study by the gender of the surviving spouse. The sample includes individuals whose spouses died between ages 45 and 80 from 1985 to 2011. Panel A plots an adjusted measure of household income. Specifically, we fix the surviving spouse's labor income, Social Disability and Social Security benefits as well as sick-pay benefits at their pre-shock levels (in period -1). Hence, this measure captures the income loss that is directly attributed to the loss of a spouse. Panel B plots the actual household income that is observed in the data, which takes into account the surviving spouse's behavioral responses. The x-axis denotes time with respect to the shock, normalized to period 0. For the treatment group period 0 is when the actual shock occurs; for the control group period 0 is when a "placebo shock" occurs (while their actual shock occurs in period 5). The dashed gray line plots the behavior of the control group. To ease the comparison of trends, we normalize the level of the control group's outcome to the pre-shock level of the treatment group's outcome. This normalized counterfactual is displayed by the blue line and squares. The red line and circles plot the behavior of the treatment group.

FIGURE 7

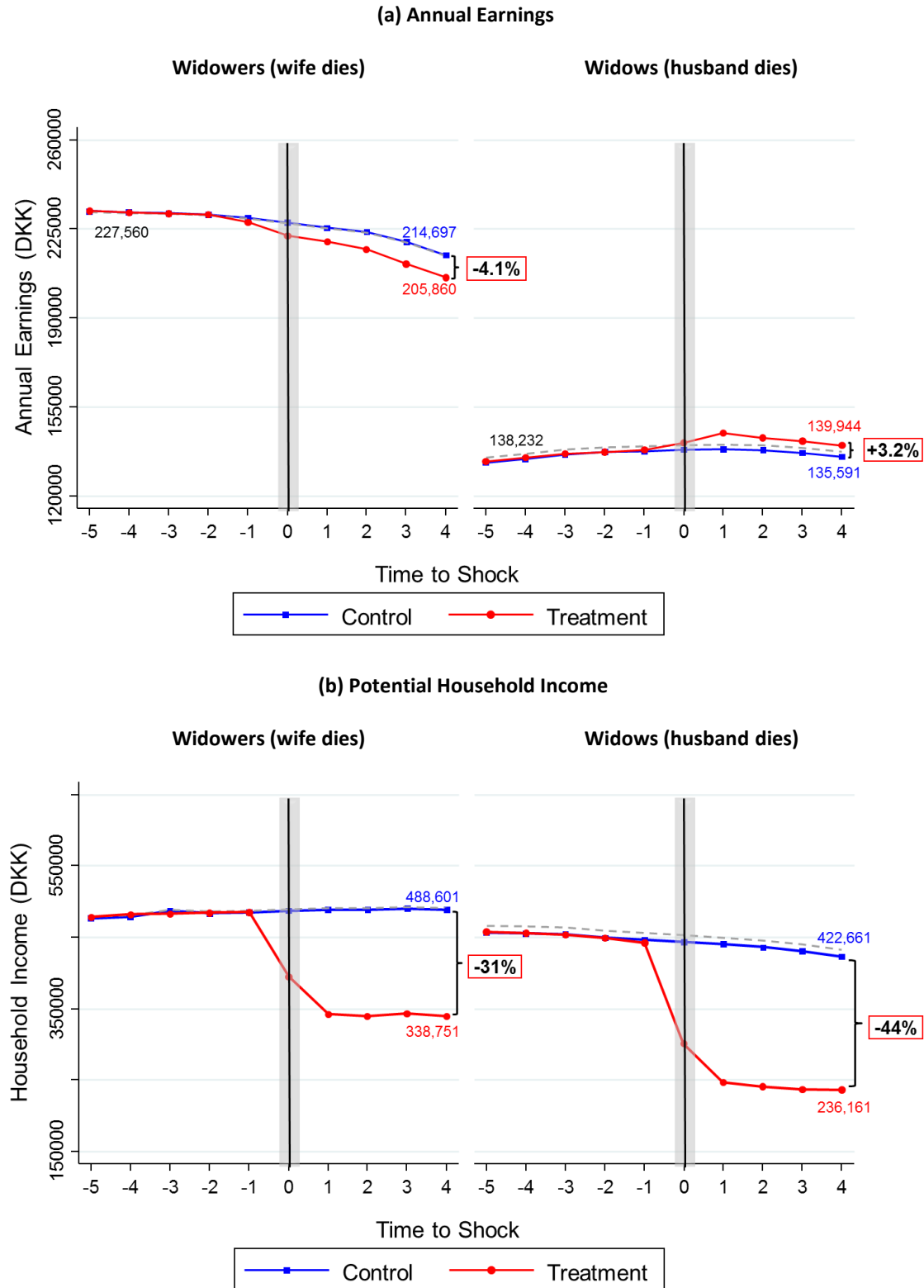
Labor Force Participation Responses of Survivors under Age 60 to the Death of Their Spouse



Notes: These figures plot the labor force participation responses of survivors under age 60 to the death of their spouse by the gender of the surviving spouse. The sample includes individuals under 60 whose spouses died between ages 45 and 80 from 1985 to 2011. Panel A depicts the behavior of the overall sample; Panel B divides the sample by the gender of the surviving spouse. The x-axis denotes time with respect to the shock, normalized to period 0. For the treatment group period 0 is when the actual shock occurs; for the control group period 0 is when a “placebo shock” occurs (while their actual shock occurs in period 5). The dashed gray line plots the behavior of the control group. To ease the comparison of trends, we normalize the level of the control group’s outcome to the pre-shock level of the treatment group’s outcome. This normalized counterfactual is displayed by the blue line and squares. The red line and circles plot the behavior of the treatment group.

FIGURE 8

Annual Earnings and Potential Household Income of Survivors under Age 60 by Gender

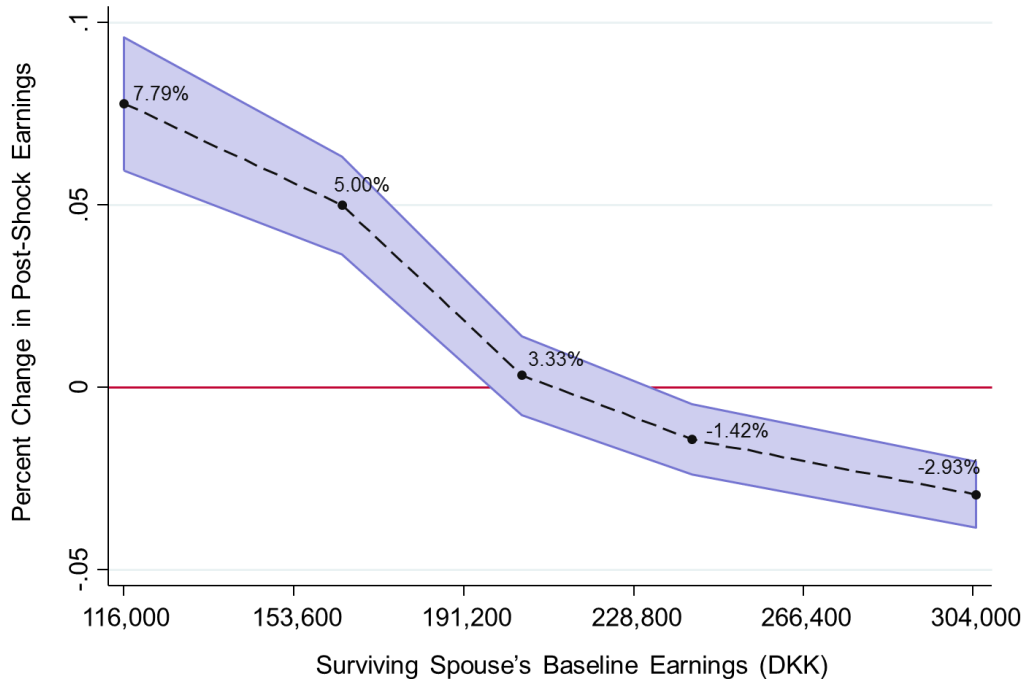


Notes: These figures plot different outcomes for survivors under age 60 around the death of their spouse by the gender of the surviving spouse. The sample includes individuals under 60 whose spouses died between ages 45 and 80 from 1985 to 2011. Panel A plots annual earnings. Panel B plots an adjusted measure of household income. Specifically, we fix the surviving spouse's labor income, Social Disability and Social Security benefits as well as sick-pay benefits at their pre-shock levels (in period -1). Hence, this measure captures the income loss that is directly attributed to the loss of a spouse. The x-axis denotes time with respect to the shock, normalized to period 0. For the treatment group period 0 is when the actual shock occurs; for the control group period 0 is when a "placebo shock" occurs (while their actual shock occurs in period 5). The dashed gray line plots the behavior of the control group. To ease the comparison of trends, we normalize the level of the control group's outcome to the pre-shock level of the treatment group's outcome. This normalized counterfactual is displayed by the blue line and squares. The red line and circles plot the behavior of the treatment group.

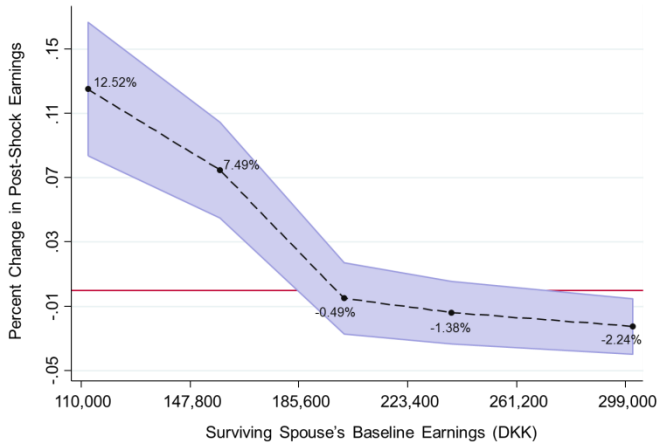
FIGURE 9

Survivors' Annual Earnings Responses to the Death of Their Spouse by the Level of their Own Pre-Shock Earnings

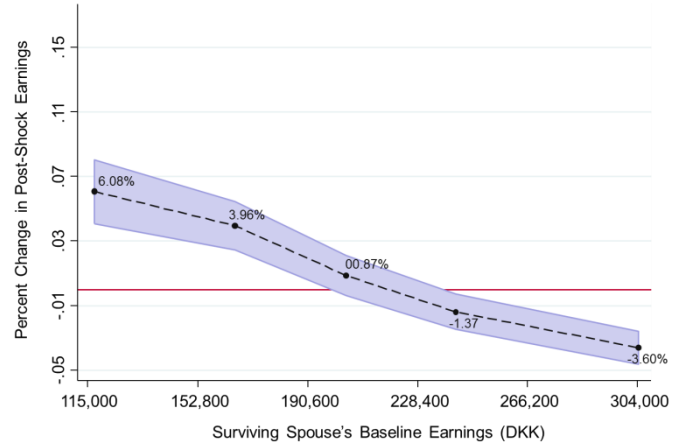
(a) All Households



(b) Households with Low-Earning Deceased Spouses



(c) Households with High-Earning Deceased Spouses

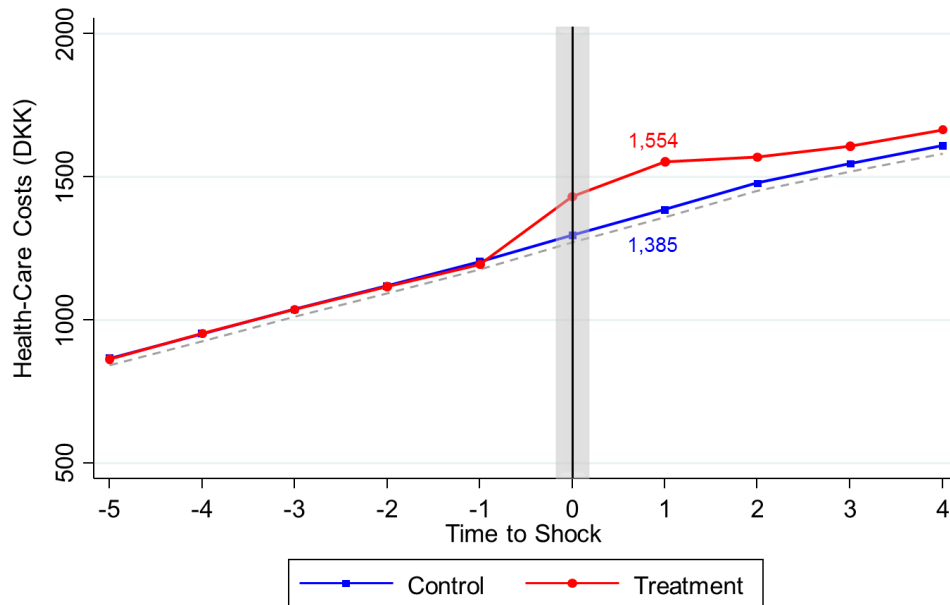


Notes: These figures include individuals whose spouses died between ages 45 and 80 from 1985 to 2011, where we constrain the sample in the following way. First, we exclude surviving spouses whose average labor income before the shock (in periods -5 to -2) was lower than their experimental-group-specific 20th percentile. Then, we calculate for each household the pre-shock labor income share of the deceased spouse out of the household's overall labor income and include only households in which both spouses were sufficiently attached to the labor force; specifically, we keep households for whom the average share was between 0.20 and 0.80. These restrictions allow us to focus on households for which there has been some loss of income due to the death of a spouse and in which the surviving spouse has earned non-negligible labor income both in levels and as a share within the household. In addition, to guarantee that our results are not driven by outliers, we exclude households with dying spouses whose mean pre-shock earnings did not fall within their group-specific 5th and 95th percentiles as well as households with unaffected spouses whose mean pre-shock earnings were higher than those of their group-specific 95th percentile. We divide the remaining sample into five equal-sized groups by their pre-shock level of earnings and plot the average labor income response as well as its 95-percent confidence interval (in which standard error are calculated using the Delta method) against the pre-shock mean earnings for each group. Panel A includes all households; Panel B includes households in which the dying spouses' pre-shock labor income fell within the bottom three quintiles of its group-specific distribution, to which we refer as "low earners"; Panel C includes households in which the dying spouses' pre-shock labor income fell within the top two quintiles, to which we refer as "high earners". The pre-shock periods include periods -5 to -3. The post-shock periods include periods 2 to 4.

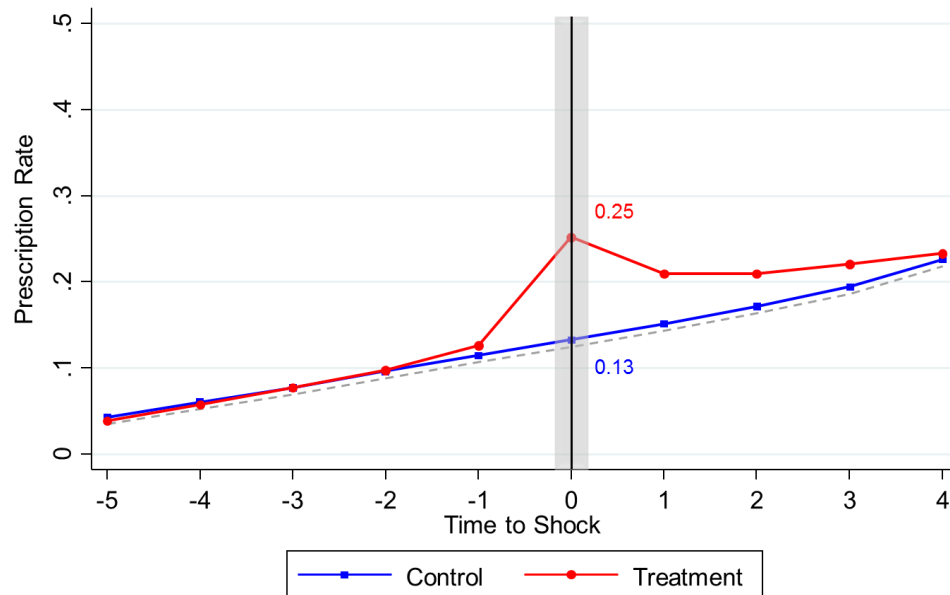
FIGURE 10

Survivors' Health-Care Utilization around the Death of Their Spouse

(a) Health-Care Costs



(b) Prescriptions for Antidepressants

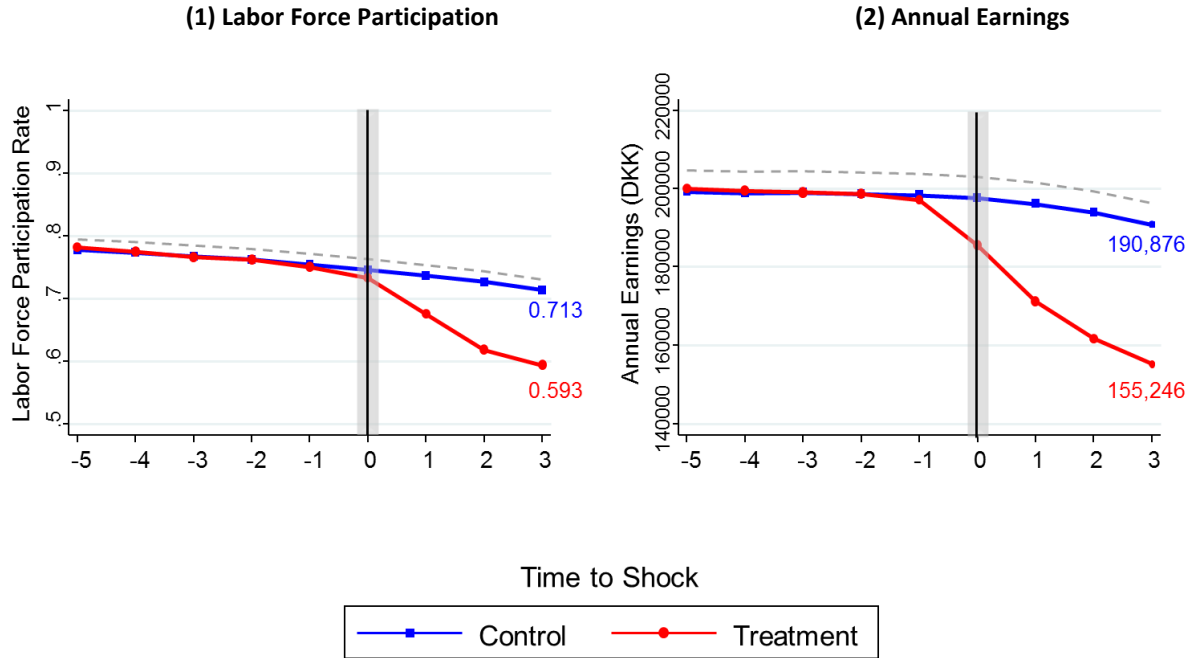


Notes: These figures plot measures of survivors' health-care use around the death of their spouse. The sample includes individuals born between 1930 and 1950 (for whom we have data on drug prescriptions) whose spouses died between ages 45 and 80 from 1985 to 2011. Panel A depicts overall expenditure on primary medical care, and Panel B depicts the prescription rate for antidepressants (Psycholeptics and Psychoanaleptics). The x-axis denotes time with respect to the shock, normalized to period 0. For the treatment group, period 0 is when the actual shock occurs; for the control group, period 0 is when a "placebo shock" occurs (while their actual shock occurs in period 5). The dashed gray line plots the behavior of the control group. To ease the comparison of trends, we normalize the level of the control group's outcome to the pre-shock level of the treatment group's outcome. This normalized counterfactual is displayed by the blue line and squares. The red line and circles plot the behavior of the treatment group.

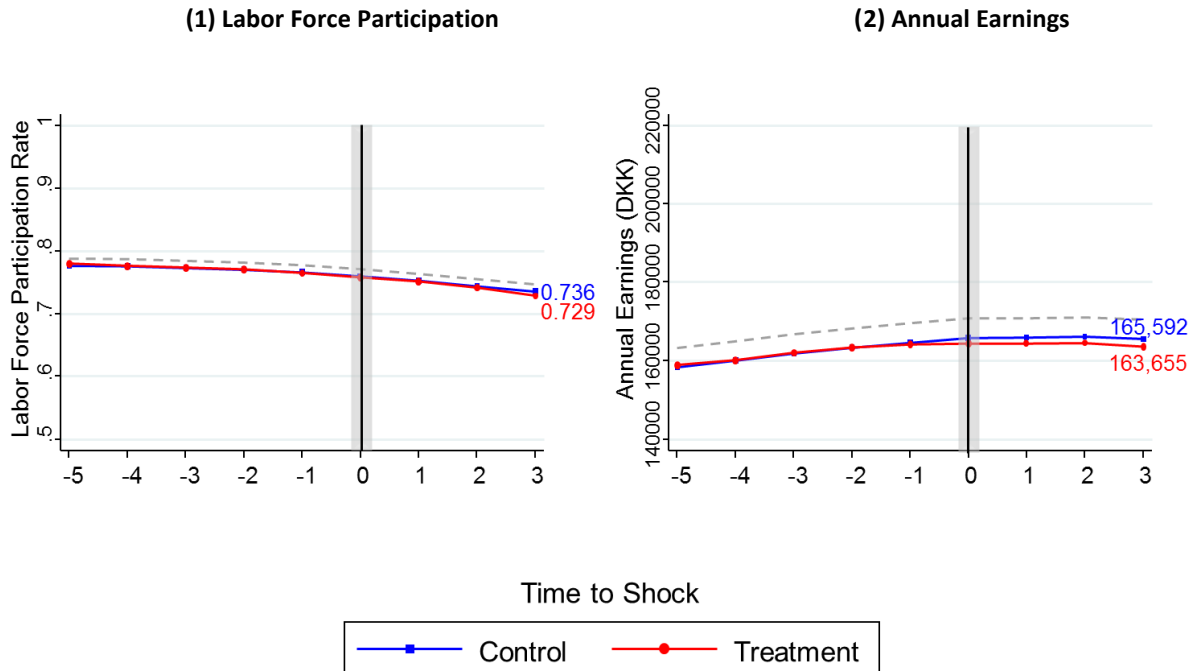
FIGURE 11

Household Labor Supply Responses to Severe Health Shocks in which the Affected Spouse Survived

(a) Affected Spouse



(b) Unaffected Spouse

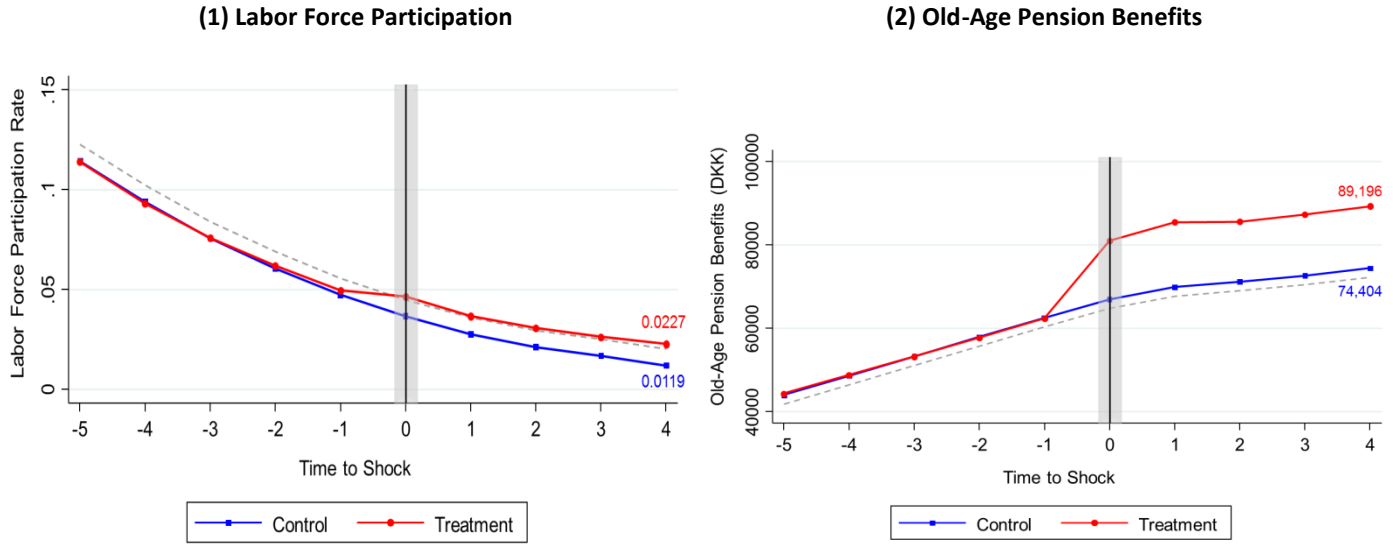


Notes: These figures plot the labor supply responses of households in which an individual experienced a heart attack or a stroke between 1985 and 2011 and survived for at least three years. The sample includes households in which both spouses were under age 60. Panels A.1 and A.2 depict the labor force participation and annual earnings of the individual that experienced the shock, respectively. Panels B.1 and B.2 depict the labor force participation and annual earnings of the unaffected spouse, respectively. The x-axis denotes time with respect to the shock, normalized to period 0. For the treatment group, period 0 is when the actual shock occurs; for the control group, period 0 is when a “placebo shock” occurs (while their actual shock occurs in period 5). The dashed gray line plots the behavior of the control group. To ease the comparison of trends, we normalize the level of the control group’s outcome to the pre-shock level of the treatment group’s outcome. This normalized counterfactual is displayed by the blue line and squares. The red line and circles plot the behavior of the treatment group.

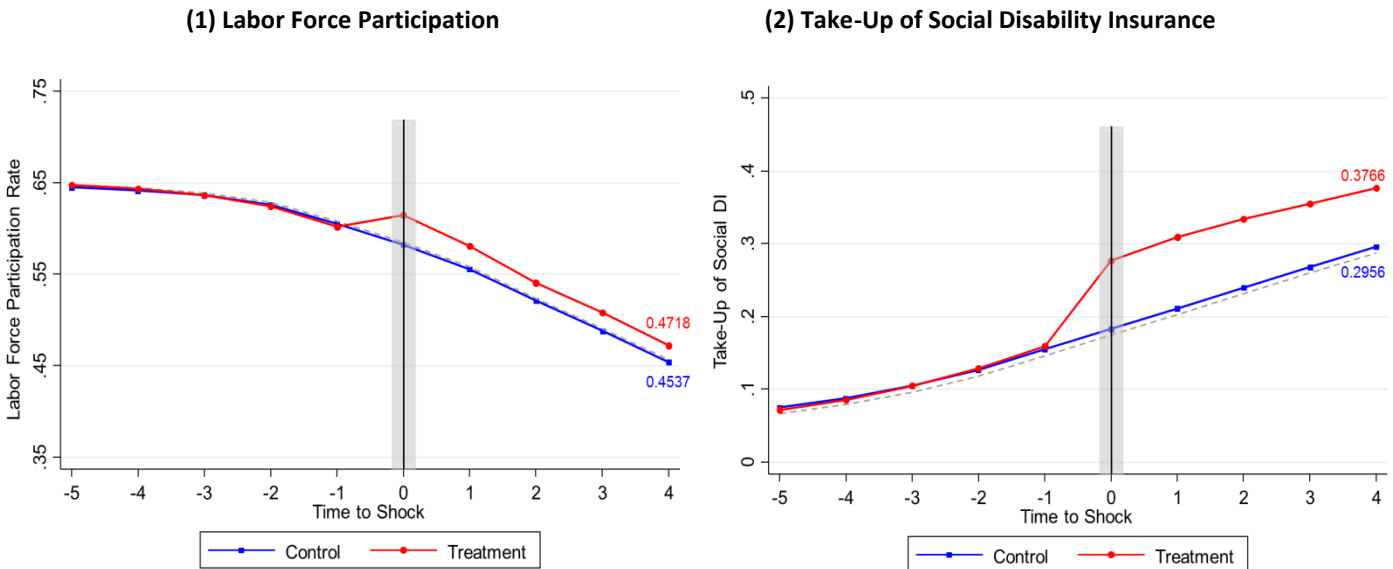
FIGURE 12

Widows' Labor Force Participation and Government Transfers around the Death of Their Spouse by Age Group

(a) Widows over Age 67



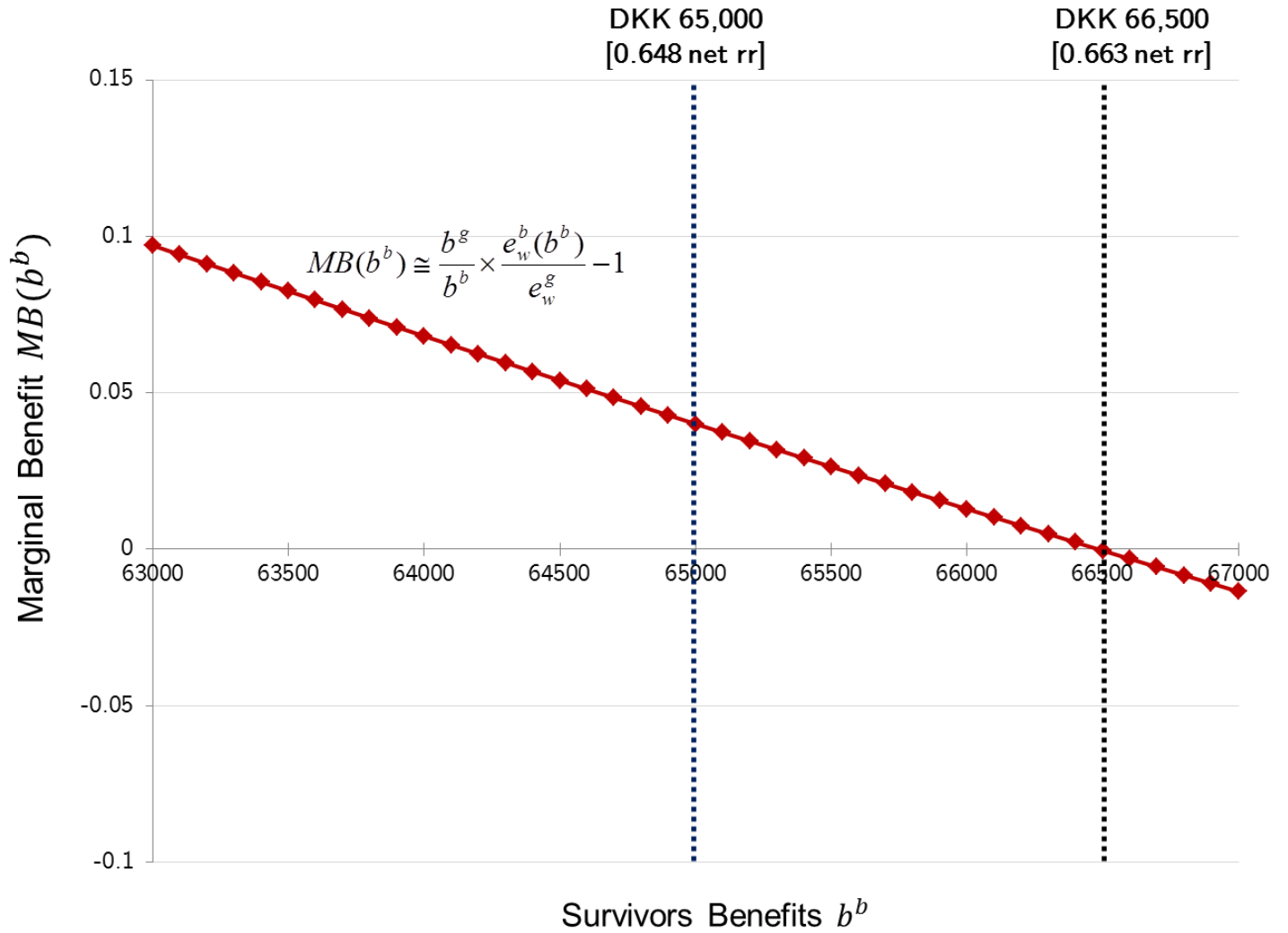
(b) Widows under Age 67



Notes: These figures plot outcomes for survivors around the death of their spouse by age group. Panel A plots outcomes for widows over age 67 whose husbands died between 1985 and 2011. Panel A.1 plots their labor force participation, and Panel A.2 plots the benefits they received from the Old-Age Pension program. Panel B plots outcomes for widows under age 67 (the age at which the Social Disability Insurance transitions into the Old-Age Pension) in years prior to 1994 (when there is a data break in the reporting method of benefits received through Social Disability Insurance) whose husbands died between 1985 and 2011. Panel B.1 plots their labor force participation, and Panel B.2 plots their take-up of the Social Disability Insurance program. The x-axis denotes time with respect to the shock, normalized to period 0. For the treatment group, period 0 is when the actual shock occurs; for the control group, period 0 is when a “placebo shock” occurs (while their actual shock occurs in period 5). The dashed gray line plots the behavior of the control group. To ease the comparison of trends, we normalize the level of the control group’s outcome to the pre-shock level of the treatment group’s outcome. This normalized counterfactual is displayed by the blue line and squares. The red line and circles plot the behavior of the treatment group.

FIGURE 13

Welfare Gains from Survivors Benefits within the Social Disability Insurance Program

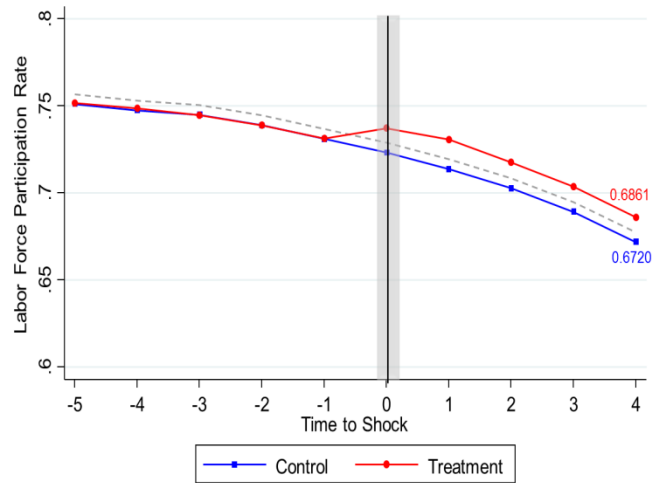


Notes: This figure plots the marginal benefit from transfers to widows within the Social Disability Insurance program. The x-axis denotes the benefit level, b^b , measured in Danish Kroner (DKK), and the y-axis denotes the marginal benefit, $MB(b^b)$. The vertical dashed line at DKK 65,000 (\$8,115) denotes the mean benefits transferred to widows who are on the program. It represents a net replacement rate (denoted by “net rr” in the figure) of 0.648 relative to the mean pre-shock annual earnings of deceased spouses who worked before they died. To convert the monetary values into net replacement rates out of the deceased spouse's pre-shock earnings, we calculate the average earnings in $t = -1$ for affected spouses who had positive earnings in the year before they died. The average is DKK 170,000 (\$21,250), which implies net wage earnings of DKK 100,300 (\$12,538) using an average labor income tax rate of 41% (OECD estimates). The vertical dashed line at DKK 66,500 (\$8,300) denotes the benefit level that sets the marginal benefit to zero. It represents a net replacement rate (denoted by “net rr” in the figure) of 0.663. This suggests that for widows under 67 the current levels are near optimal.

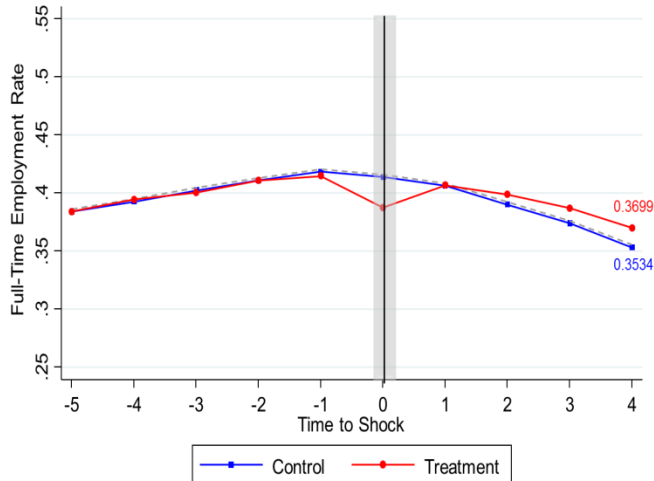
APPENDIX FIGURE 1

Labor Supply Responses of Survivors under Age 60 to the Death of Their Spouse

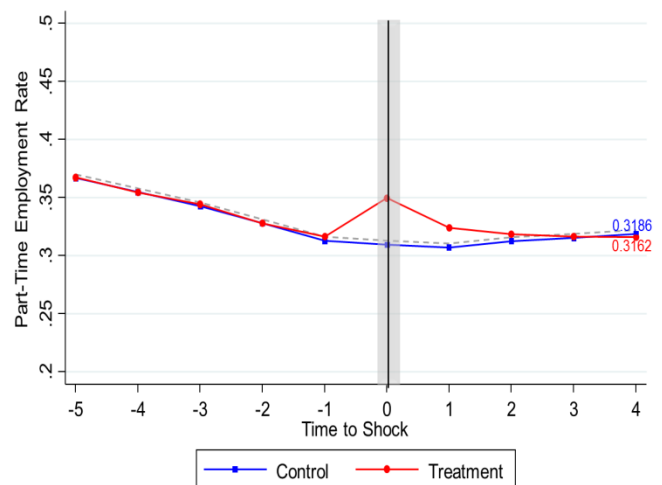
(a) Labor Force Participation



(b) Full-Time Employment



(c) Part-Time Employment



Notes: These figures plot labor supply responses of survivors under age 60 to the death of their spouse. The sample includes individuals under 60 whose spouses died between ages 45 and 80 from 1985 to 2011. Panel A depicts labor force participation; Panels B and C depict the fraction of surviving spouses who are employed full time and part time, respectively. The pictures are constructed from ATP data available for workers under 60. Full-time employment is defined as working at least 30 hours per week all 12 months of the calendar year (“full-time full-year”); part-time employment is defined as working at some point during the year, but either fewer than 30 hours per week or fewer than 12 months within the calendar year. The x-axis denotes time with respect to the shock, normalized to period 0. For the treatment group, period 0 is when the actual shock occurs; for the control group, period 0 is when a “placebo shock” occurs (while their actual shock occurs in period 5). The dashed gray line plots the behavior of the control group. To ease the comparison of trends, we normalize the level of the control group’s outcome to the pre-shock level of the treatment group’s outcome. This normalized counterfactual is displayed by the blue line and squares. The red line and circles plot the behavior of the treatment group.

Appendix A: A Dynamic Collective Model of Household Labor Force Participation

The model we analyze in this appendix generalizes our baseline model in two ways. Most importantly, it analyzes life-cycle participation decisions using a dynamic search model, which allows for endogenous savings. Second, we extend the one-shock model we analyzed in the text to include different and potentially sequential shocks. In addition, we use the generalized preference structure we analyzed in Section 2.2 and allow for additional extensions to it as we describe below.

Setup. We consider a discrete-time setting in which households live for T periods $\{0, 1, \dots, T-1\}$ (where T is allowed to go to infinity) and set both the interest rate and the agents' time discount rate to zero for simplicity. Households consist of two individuals, w and h . We assume that at time 0 households are in the "good health" state (state g) in which h is in good health and works. In each period, the household transitions with probability ρ_t to the "bad health" state (state b) in which h experiences a health shock and drops out of the labor force. Conditional on being sick, h may die in period t with probability λ_t in which case the household transitions to the state where w is a widow – state d . In what follows, the subscript $i \in \{w, h\}$ refers to the spouse and the superscript $s \in \{g, p, d\}$ refers to the state of nature.

At the beginning of the planning period, w does not work and searches for a job. When w enters period t in state s without a job she chooses search intensity, e_{wt}^s , which we normalize to equal the probability of finding a job in the same period. If w finds a job, the job begins at time t and is assumed to last until the end of the planning period once found.¹

Individual preferences. Let $u_{it}^s(c_{it}^s, l_{it}^s, l_{jt}^s)$ represent i 's flow consumption utility at time t in state s as a function of consumption, c_{it}^s , labor force participation, l_{it}^s , and the other spouse's labor force participation, l_{jt}^s , where $\frac{\partial u_{it}^s}{\partial c_{it}^s} > 0$ and $\frac{\partial^2 u_{it}^s}{\partial (c_{it}^s)^2} < 0$. We denote w 's cost of search effort at time t in state s by $\kappa^s(e_{wt}^s)$, which we assume to be strictly increasing and convex. The relative cost of time invested in search effort across states is captured by $\theta^\sigma(e_{wt}^\sigma) \equiv \kappa^{\sigma'}(e_{wt}^\sigma)/\kappa^{g'}(e_{wt}^\sigma)$, where $\sigma \in \{b, d\}$.

Household preferences. We assume that the household's per-period utility weights individual utilities according to their respective Pareto weights β_w and β_h , such that the household's flow utility at time t in state s is $\beta_w u_{wt}^s + \beta_h u_{ht}^s$ augmented by w 's weighted search cost $\beta_w \kappa^s(e_{wt}^s)$ when she is unemployed. We assume equal Pareto weights and normalize $u_{ht}^d = 0$. In the following analysis we suppress the dependence of the consumption utility on participation for ease of notation only.

Policy tools. The planner observes the state of nature as well as the employment status of each spouse. Since some spouses work and earn more than others do, the optimal policy is dependent on whether the spouse is employed. We denote the tax on spouse i 's labor income in state g by T_i^g and the benefits given to non-working spouses in state g by b^g . In state $\sigma \in \{b, d\}$, households in which the unaffected spouse, w , works receive transfers of the amount B^σ and households in which w does not work receive benefits of the amount b^σ . We denote taxes by $T \equiv (T_w^g, T_h^g)$ and benefits by $B \equiv (b^g, B^b, b^b, B^d, b^d)$, and let $B(l_{wt}^s)$ represent the actual transfers received by a household as a function of w 's participation.

Household's problem. The household's choices include the allocation of consumption to each spouse, c_{it}^s , as well as w 's search effort if she is unemployed, e_{wt}^s . In each period, w 's employment status, l_{wt}^s , determines the household's income flow, $y_t^s(l_{wt}^s)$, such that $y_t^s(l_{wt}^s) = \bar{z}_{ht}^s \times l_{ht}^s + \bar{z}_{wt}^s \times l_{wt}^s + B(l_{wt}^s)$, where z_{it} is i 's labor income and $\bar{z}_{it}^s = z_{it} - T_i^s$ is i 's labor income net of taxes in state s (with $T_i^s = 0$). This implies that each period's consumption as well as the next period's wealth – where we denote assets in period t by A_t – are functions of w 's participation, which we denote by $c_{it}^s(l_{wt}^s)$ and $A_{t+1}(l_{wt}^s)$, respectively. Therefore, the value function for households in state s who enter period t when w is without a job and with household assets A_t is

$$V_t^{s,0}(B, T, A_t) \equiv \max e_{wt}^s \left(u_h^s(c_{ht}^s(1)) + u_w^s(c_{wt}^s(1)) + W_{t+1}^{s,1}(B, T, A_{t+1}(1)) \right) + (1 - e_{wt}^s) \left(u_h^s(c_{ht}^s(0)) + u_w^s(c_{wt}^s(0)) + W_{t+1}^{s,0}(B, T, A_{t+1}(0)) \right) - \kappa_w^s(e_{wt}^s),$$

where the budget constraints satisfy

$$c_{ht}^s(l_{wt}^s) + c_{wt}^s(l_{wt}^s) + A_{t+1}(l_{wt}^s) = A_t + y_t^s(l_{wt}^s),$$

and $W_{t+1}^{s,l_{wt}^s}(B, T, A_{t+1})$ are the continuation value functions which depend on whether the job search was successful or not in time t . The continuation functions are defined by

$$W_{t+1}^{g,l_{wt}^g}(B, T, A_{t+1}) \equiv (1 - \rho_{t+1}) V_{t+1}^{g,l_{wt}^g}(B, T, A_{t+1}) + \rho_{t+1} V_{t+1}^{b,l_{wt}^g}(B, T, A_{t+1}),$$

¹This simplifies the algebra of the analysis. We later allow for job separations such that employment is absorbing within a health state but not across health states.

$$W_{t+1}^{b,l_{wt}^b}(B, T, A_{t+1}) \equiv (1 - \lambda_{t+1})V_{t+1}^{b,l_{wt}^b}(B, T, A_{t+1}) + \lambda_{t+1}V_{t+1}^{d,l_{wt}^b}(B, T, A_{t+1}),$$

$$W_{t+1}^{d,l_{wt}^d}(B, T, A_{t+1}) \equiv V_{t+1}^{d,l_{wt}^d}(B, T, A_{t+1}),$$

where $V_t^{s,1}(B, T, A_t)$ is the value of entering period t when w is employed in state s which is defined by

$$V_t^{s,1}(B, T, A_t) \equiv \max \left\{ u_h^s(c_{ht}^s(1)) + u_w^s(c_{wt}^s(1)) + W_{t+1}^{s,1}(B, T, A_{t+1}(1)) \right\}.$$

The optimal search effort is chosen according to the first-order condition

$$\left(u_h^s(c_{ht}^s(1)) + u_w^s(c_{wt}^s(1)) + W_{t+1}^{s,1}(B, T, A_{t+1}(1)) \right) - \left(u_h^s(c_{ht}^s(0)) + u_w^s(c_{wt}^s(0)) + W_{t+1}^{s,0}(B, T, A_{t+1}(0)) \right) = \kappa_w^s(e_{wt}^s), \quad (1)$$

where the effect of a \$1 increase in the benefit level b^s on search intensity in state s is

$$\frac{\partial e_{wt}^s}{\partial b^s} = -\frac{1}{\kappa_w^s(e_{wt}^s)} \left(u_w^s(e_{wt}^s(0)) + \frac{\partial W_{t+1}^{s,0}}{\partial b^s} \right). \quad (2)$$

Planner's problem. We define the household's expected utility at the beginning of the planning period by $J_0(B, T) \equiv (1 - \rho_0)V_0^{g,0}(B, T, A_0) + \rho_0 V_0^{b,0}(B, T, A_0)$. The social planner's objective is to choose the tax-and-benefit system that maximizes the household's expected utility subject to a balanced-budget constraint. For simplicity, we assume there is some expected revenue collected from each household and study the optimal redistribution of this revenue. We abstract from the specific way in which revenue is collected (or, similarly, assume a lump-sum tax that is determined outside of our problem) since our focus is on the benefits from social insurance and not its fiscal-externality costs. The perturbations we study involve increasing b^σ , $\sigma \in \{b, d\}$, by lowering b^g . Therefore, to further simplify the analysis we assume that $B^b = B^d = 0$, as well as that $b^d = 0$ when we perturb b^b and that $b^b = 0$ when we perturb b^d .

Let D^s denote the expected share of the household's life-time in state s and let \hat{e}_w^s denote the conditional probability of w being employed if she is observed in state s . To construct the budget constraint, consider randomly choosing a household at a random point in its life-cycle. The probability of choosing a household in state s is D^s and, hence, the probability of choosing a household in state s in which w is unemployed is $D^s \times (1 - \hat{e}_w^s)$. If the government collects revenues of the amount r per household, a balanced budget requires that the expected transfer to a random household is equal to this amount. That is, $D^g(1 - \hat{e}_w^g)b^g + D^b(1 - \hat{e}_w^b)b^b + D^d(1 - \hat{e}_w^d)b^d = r$. Hence, the planner chooses the benefit levels B that solve

$$\max_B J_0(B, T) \quad \text{s.t.} \quad D^g(1 - \hat{e}_w^g)b^g + D^b(1 - \hat{e}_w^b)b^b + D^d(1 - \hat{e}_w^d)b^d = r. \quad (3)$$

Optimal Social Insurance

We consider the optimal distribution of benefits to households with non-working spouses across health states $\sigma \in \{b, d\}$ and g . First, consider a \$1 increase in b^b financed by lowering b^g . The net welfare gain from this perturbation is

$$\frac{dJ_0(T, B)}{db^b} = Q_1^b + Q_2^b \frac{db^g}{db^b}, \quad (4)$$

where $Q_1^b = \left(\rho_0 \frac{\partial V_0^{b,0}}{\partial b^b} + (1 - \rho_0) \frac{\partial V_0^{g,0}}{\partial b^b} \right)$ and $Q_2^b = \left(\rho_0 \frac{\partial V_0^{b,0}}{\partial b^g} + (1 - \rho_0) \frac{\partial V_0^{g,0}}{\partial b^g} \right)$. The following proposition provides an approximated formula for the normalized version of this gain.

Proposition A1.

Under a locally quadratic approximation of the effort function $\kappa_w^g(e_{wt}^g)$ around e_{wt}^g and assuming that the ratio $\theta^b(e_{wt}^b)$ is locally constant at \hat{e}_{w0}^b , the marginal benefit from raising b^b by \$1 is

$$M_w(b^b) \cong MB(b^b) - MC(b^b),$$

with

1. $MB(b^b) \equiv L^b + M^b + S^b$, where $L^b \equiv \frac{\hat{e}_{w0}^b - e_{w0}^g}{e_{w0}^g}$, $M^b \equiv \left(\frac{|\varepsilon(\hat{e}_{w0}^b, b^b)|/b^b}{|\varepsilon(e_{w0}^g, b^g)|/b^g} - 1 \right) \frac{e_{w0}^b}{e_{w0}^g}$, $S^b \equiv (\theta^b - 1)(1 + L^b + M^b)$,
 $\varepsilon(x, y) \equiv \frac{\partial x}{\partial y} \frac{y}{x}$, $\theta^b \equiv \theta^b(\hat{e}_{w0}^b)$, e_{w0}^g is w 's participation rate at the beginning of the planning period, and \hat{e}_{w0}^b is w 's mean participation rate in households that transition to state b .
2. $MC(b^b) \equiv \beta_0^b + \beta_1^b \epsilon(1 - \hat{e}_w^g, b^p) + \beta_2^b \epsilon(1 - \hat{e}_w^p, b^p)$, where the coefficients β_0^b , β_1^b , and β_2^b are functions of the transition probabilities, average participation rates, and benefits and $\epsilon(x, y) \equiv \frac{dx}{dy} \frac{y}{x}$.²

Proof.

The general logic of the proof is to characterize the derivatives of the value functions in their sequential problem representation – that is, as a sum of derivatives over time and over different states of nature. To do so, we work backwards from period $T - 1$ to period 0. Taylor approximations then lead to our results.

We begin by providing expressions for $\frac{\partial V_0^{b,0}}{\partial b^b}$ and $\frac{\partial V_t^{g,0}}{\partial b^b}$ in order to characterize Q_1^b . First, we have that $\frac{\partial V_t^{b,0}}{\partial b^b} = (1 - e_{wt}^b) \left(u_w'(c_{wt}^b(0)) + \frac{\partial W_{t+1}^{b,0}}{\partial b^b} \right)$ and $\frac{\partial W_{t+1}^{b,0}}{\partial b^b} = (1 - \lambda_{t+1}) \frac{\partial V_{t+1}^{b,0}}{\partial b^b}$, which imply that $\frac{\partial V_t^{b,0}}{\partial b^b} = (1 - e_{wt}^b) \left(u_w'(c_{wt}^b(0)) + (1 - \lambda_{t+1}) \frac{\partial V_{t+1}^{b,0}}{\partial b^b} \right)$.

Working backwards one can show that $\frac{\partial V_t^{b,0}}{\partial b^b} = (1 - e_{wt}^b) \left(u_w'(c_{wt}^b(0)) + \sum_{i=t+1}^{T-1} \left(\prod_{j=t+1}^i (1 - e_{wj}^b)(1 - \lambda_j) \right) (u_w'(c_{wi}^b(0))) \right)$.

Next, since $\frac{\partial W_{t+1}^{g,1}}{\partial b^b} = 0$ we obtain $\frac{\partial V_t^{g,0}}{\partial b^b} = (1 - e_{wt}^g) \frac{\partial W_{t+1}^{g,0}}{\partial b^b}$, where $\frac{\partial W_{t+1}^{g,0}}{\partial b^b} = (1 - \rho_{t+1}) \frac{\partial V_{t+1}^{g,0}}{\partial b^b} + \rho_{t+1} \frac{\partial V_{t+1}^{b,0}}{\partial b^b}$. Therefore, we get that $\frac{\partial V_t^{g,0}}{\partial b^b} = (1 - e_{wt}^g)(1 - \rho_{t+1}) \frac{\partial V_{t+1}^{g,0}}{\partial b^b} + (1 - e_{wt}^g)\rho_{t+1} \frac{\partial V_{t+1}^{b,0}}{\partial b^b}$, which implies by working backwards from period $T - 1$ to period 0 that $\frac{\partial V_t^{g,0}}{\partial b^b} = (1 - e_{wt}^g) \sum_{i=t+1}^{T-1} \left(\prod_{j=t+1}^{i-1} (1 - e_{wj}^g)(1 - \rho_j) \right) \rho_i \frac{\partial V_i^{b,0}}{\partial b^b}$.

Putting the terms together, it follows that

$$Q_1^b = \left(\rho_0 \frac{\partial V_0^{b,0}}{\partial b^b} + (1 - \rho_0) \frac{\partial V_0^{g,0}}{\partial b^b} \right) = \sum_{i=0}^{T-1} \left[\prod_{j=0}^{i-1} (1 - e_{wj}^g)(1 - \rho_j) \rho_i \right] \frac{\partial V_i^{b,0}}{\partial b^b}. \quad (5)$$

Using equation (2) and $\frac{\partial V_t^{b,0}}{\partial b^b} = (1 - e_{wt}^b) \left(u_w'(c_{wt}^b(0)) + \frac{\partial W_{t+1}^{b,0}}{\partial b^b} \right)$, we get that $\frac{\partial V_t^{b,0}}{\partial b^b} = -\kappa_w^b(e_{wt}^b) \frac{\partial e_{wt}^b}{\partial b^b} (1 - e_{wt}^b)$. Plugging this expression into (5) yields the following result

$$Q_1^b = - \sum_{i=0}^{T-1} \left[\prod_{j=0}^{i-1} (1 - e_{wj}^g)(1 - \rho_j) \rho_i \right] (1 - e_{wi}^b) \kappa_w^b(e_{wi}^b) \frac{\partial e_{wi}^b}{\partial b^b}. \quad (6)$$

To understand the meaning of this formula let us break it down into its components. First, note that it is a weighted sum of a function of the change in effort (or participation rate), $\frac{\partial e_{wi}^b}{\partial b^b}$. The weight, the term in brackets, is the probability of reaching period i with w unemployed and transitioning to state b exactly in that period. For households that transition to state b in period i when w is employed, the change in effort and participation rates is zero (because they stay employed and do not engage in search effort). Therefore, dividing the probability weights by the chance of transitioning to state b at some point throughout the planning horizon, $\rho \equiv \sum_{i=0}^{T-1} \left(\prod_{j=0}^{i-1} (1 - \rho_j) \right)$, and rewriting (6) in terms of elasticities (with $\varepsilon(x, y) \equiv \frac{\partial x}{\partial y} \frac{y}{x}$) yield $Q_1^b = \rho E_b \left\{ (1 - \bar{e}_{w0}^b) \kappa_w^b(\bar{e}_{w0}^b) \left| \varepsilon(\bar{e}_{w0}^b, b^b) \right| \frac{\bar{e}_{w0}^b}{b^b} \right\} \equiv \rho E_b(g(\bar{e}_{w0}^b))$, where \bar{e}_{w0}^b denotes participation in the period the household transitions to state b and E_b is the expectation operator conditional on being in state b . By expanding $g(e)$ around w 's average participation in households in which h becomes sick – which we denote by \hat{e}_{w0}^b – such that $g(e) \cong g(\hat{e}_{w0}^b) + g'(\hat{e}_{w0}^b)(e - \hat{e}_{w0}^b)$, we approximate

²Specifically, $\beta_0^b \equiv \frac{\sigma^b D^b(1 - \hat{e}_w^b) - D^g(1 - \hat{e}_w^g)}{D^g(1 - \hat{e}_w^g)}$, $\beta_1^b \equiv \sigma^b \frac{b^g}{b^b}$, and $\beta_2^b \equiv \sigma^b \frac{D^b(1 - \hat{e}_w^b)}{D^g(1 - \hat{e}_w^g)}$, where $\sigma^b \equiv (1 - p_0)(1 - e_{w0}^g)/\rho(1 - \hat{e}_{w0}^b)$ and

$\rho \equiv \sum_{i=0}^{T-1} \left(\prod_{j=0}^{i-1} (1 - \rho_j) \right)$. Note that the elasticities in $MC(b^b)$ consist of the total effect of increasing b^p , which takes into account the effect of lowering the level of the financing tool, b^g . Also note that with forward-looking households, transfers in states not yet encountered can have effects through ex-ante responses. For example, individuals in state g can lower labor supply and savings today in response to larger benefits in state b .

$E_b(g(\hat{e}_{w0}^b)) \cong E_b(g(\hat{e}_{w0}^b)) = g(\hat{e}_{w0}^b)$ and obtain the approximation

$$Q_1^b \cong \rho(1 - \hat{e}_{w0}^b) \kappa_w''(\hat{e}_{w0}^b) |\varepsilon(\hat{e}_{w0}^b, b^b)| \frac{\hat{e}_{w0}^b}{b^b}. \quad (7)$$

We now turn to provide expressions for $\frac{\partial V_0^{b,0}}{\partial b^g}$ and $\frac{V_0^{g,0}}{\partial b^g}$ in order to characterize Q_2^b . Since households that transitioned to state b either stay in state b or transition to state d , we have that $\frac{\partial V_0^{b,0}}{\partial b^g} = 0$. In addition, $\frac{V_0^{g,0}}{\partial b^g} = (1 - e_{wt}^g) \left(u_w'(c_w^g(0)) + \frac{\partial W_{t+1}^{g,0}}{\partial b^g} \right)$, which combined with equation (2) yields $\frac{V_0^{g,0}}{\partial b^g} = -(1 - e_{wt}^g) \left(\kappa_w''(e_{wt}^g) \frac{\partial e_{wt}^g}{\partial b^g} \right)$. Put together, we get that

$$Q_2^b = (1 - \rho_0) (1 - e_{w0}^g) \kappa_w''(e_{w0}^g) |\varepsilon(e_{w0}^g, b^g)| \frac{e_{w0}^g}{b^g}. \quad (8)$$

To complete the proof we need to calculate $\frac{db^g}{db^b}$. Total differentiation of the simplified budget constraint $D^g(1 - \hat{e}_w^g) b^g + D^b(1 - \hat{e}_w^b) b^b = r$ with respect to b^b gives us

$$\frac{db^g}{db^b} = -\frac{b^g}{b^b} \epsilon(1 - \hat{e}_w^g, b^b) - \frac{D^b(1 - \hat{e}_w^b)}{D^g(1 - \hat{e}_w^g)} \epsilon(1 - \hat{e}_w^b, b^b) - \frac{D^b(1 - \hat{e}_w^b)}{D^g(1 - \hat{e}_w^g)}, \quad (9)$$

where $\epsilon(x, y) \equiv \frac{dx}{dy} \frac{y}{x}$. Plugging (7), (8) and (9) into (4), using a quadratic approximation of the effort function $\kappa^g(e_{wt}^g)$ around e_{w0}^g and assuming that the ratio $\theta^b(e_{wt}^b)$ is locally constant at \hat{e}_{w0}^b , we obtain the approximated formula for the normalized welfare gain $M_w(b^p) \equiv \frac{\frac{dJ_0(T, B)}{db^b} / \rho(1 - \hat{e}_{w0}^b)}{\frac{\partial J_0(T, B)}{\partial b^g} / (1 - \rho_0)(1 - e_{w0}^g)}$ that is stated in the proposition, which completes the proof. ■

Next, consider a \$1 increase in b^d financed by lowering b^g . We analyze this perturbation separately from the former since the sequential nature of the model requires a more careful investigation of transfers to different “bad” states (as shown in the following proof), although the approximated formulas turn out to be conceptually similar. The net welfare gain from this perturbation is

$$\frac{dJ_0(T, B)}{db^d} = Q_1^d + Q_2^d \frac{db^g}{db^d}, \quad (10)$$

where $Q_1^d = \left(\rho_0 \frac{\partial V_0^{b,0}}{\partial b^d} + (1 - \rho_0) \frac{\partial V_0^{g,0}}{\partial b^d} \right)$ and $Q_2^d = \left(\rho_0 \frac{\partial V_0^{b,0}}{\partial b^g} + (1 - \rho_0) \frac{V_0^{g,0}}{\partial b^g} \right)$. We present the approximated formula in the following proposition.

Proposition A2.

Under a locally quadratic approximation of the effort function $\kappa_w^g(e_{wt}^g)$ around e_{w0}^g and assuming that the ratio $\theta^d(e_{wt}^d)$ is locally constant at \hat{e}_{w0}^d , the marginal benefit from raising b^d by \$1 is

$$M_w(b^d) \cong MB(b^d) - MC(b^d),$$

with

1. $MB(b^d) \equiv L^d + M^d + S^d$, where $L^d \equiv \frac{\hat{e}_{w0}^d - e_{w0}^g}{e_{w0}^g}$, $M^d \equiv \left(\frac{|\varepsilon(\hat{e}_{w0}^d, b^d)|/b^d}{|\varepsilon(e_{w0}^g, b^g)|/b^g} - 1 \right) \frac{\hat{e}_{w0}^d}{e_{w0}^g}$, $S^d \equiv (\theta^d - 1)(1 + L^d + M^d)$, $\varepsilon(x, y) \equiv \frac{\partial x}{\partial y} \frac{y}{x}$, $\theta^d \equiv \theta^d(\hat{e}_{w0}^d)$, e_{w0}^g is w 's participation rate at the beginning of the planning period, and \hat{e}_{w0}^d is w 's mean participation rate in households that transition to state d .
2. $MC(b^d) \equiv \beta_0^d + \beta_1^d \epsilon(1 - \hat{e}_w^g, b^d) + \beta_2^d \epsilon(1 - \hat{e}_w^b, b^d)$, where the coefficients β_0^d , β_1^d , and β_2^d are functions of the transition probabilities, average participation rates, and benefits and $\epsilon(x, y) \equiv \frac{dx}{dy} \frac{y}{x}$.³

³Specifically, $\beta_0^d \equiv \frac{\sigma^d D^d(1 - \hat{e}_w^d) - D^g(1 - \hat{e}_w^g)}{D^g(1 - \hat{e}_w^g)}$, $\beta_1^d \equiv \sigma^d \frac{b^g}{b^d}$, and $\beta_2^d \equiv \sigma^d \frac{D^d(1 - \hat{e}_w^d)}{D^g(1 - \hat{e}_w^g)}$, where $\sigma^d \equiv (1 - \rho_0)(1 - e_{w0}^g)/\lambda(1 - \hat{e}_{w0}^d)$, $\lambda \equiv \sum_{i=0}^{T-1} \mu_i^d$, and μ_i^d is the probability of transitioning to state d in period i .

Proof.

We first find expressions for $\frac{\partial V_0^{b,0}}{\partial b^d}$ and $\frac{\partial V_0^{g,0}}{\partial b^d}$ in order to characterize Q_1^d . With $\frac{\partial V_t^{b,0}}{\partial b^d} = (1 - e_{wt}^b) \left(\frac{\partial V_{t+1}^{b,0}}{\partial b^d} \right)$ and $\frac{\partial V_{t+1}^{b,0}}{\partial b^d} = (1 - \lambda_{t+1}) \frac{\partial V_{t+1}^{b,0}}{\partial b^d} + \lambda_{t+1} \frac{\partial V_{t+1}^{d,0}}{\partial b^d}$ we have that $\frac{\partial V_t^{b,0}}{\partial b^d} = (1 - e_{wt}^b) \left((1 - \lambda_{t+1}) \frac{\partial V_{t+1}^{b,0}}{\partial b^d} + \lambda_{t+1} \frac{\partial V_{t+1}^{d,0}}{\partial b^d} \right)$. Working backwards from period $T-1$ to period 0 one can show that $\frac{\partial V_t^{b,0}}{\partial b^d} = \sum_{i=t+1}^{T-1} \prod_{j=t}^{i-1} (1 - e_{wj}^b) \prod_{j=t+1}^{i-1} (1 - \lambda_j) \lambda_j \frac{\partial V_i^{d,0}}{\partial b^d}$.

In state g we have $\frac{\partial V_t^{g,0}}{\partial b^d} = (1 - e_{wt}^g) \left(\frac{\partial V_{t+1}^{g,0}}{\partial b^d} \right)$ and $\frac{\partial V_{t+1}^{g,0}}{\partial b^d} = \rho_{t+1} \frac{\partial V_{t+1}^{b,0}}{\partial b^d} + (1 - \rho_{t+1}) \frac{\partial V_{t+1}^{g,0}}{\partial b^d}$, which imply that $\frac{\partial V_t^{g,0}}{\partial b^d} = (1 - e_{wt}^g) \left(\rho_{t+1} \frac{\partial V_{t+1}^{b,0}}{\partial b^d} + (1 - \rho_{t+1}) \frac{\partial V_{t+1}^{g,0}}{\partial b^d} \right)$. Define the probability of transitioning to state d exactly at time i while w is unemployed by $\mu_i^{d,0}$ (which takes into account all the possible transition paths). Then, combining the results so far one can show by working backwards that $Q_1^d = \left(\rho_0 \frac{\partial V_0^{b,0}}{\partial b^d} + (1 - \rho_0) \frac{\partial V_0^{g,0}}{\partial b^d} \right) = \sum_{i=0}^{T-1} \mu_i^{d,0} E_{\mu_i^{d,0}} \left[\frac{\partial V_i^{d,0}}{\partial b^d} \right]$, where $E_{\mu_i^{d,0}}$ is the expectation operator conditional on arriving at period i with w unemployed and transitioning to state d then (taken over all possible paths).

Since $\frac{\partial V_t^{d,1}}{\partial b^d} = 0$ we have that $\frac{\partial V_t^{d,0}}{\partial b^d} = (1 - e_{wt}^d) \left(u_w'(c_{wt}^d(0)) + \frac{\partial V_{t+1}^{d,0}}{\partial b^d} \right)$. Combined with (2) it can be expressed as $\frac{\partial V_t^{d,0}}{\partial b^d} = -(1 - e_{wt}^d) \kappa_w^d(e_{wt}^d) \frac{de_{wt}^d}{db^d}$. Putting the terms together we obtain

$$Q_1^d = \sum_{i=0}^{T-1} \mu_i^{d,0} E_{\mu_i^{d,0}} \left[(1 - e_{wi}^d) \kappa_{wi}^d(e_{wi}^d) | \varepsilon(e_{wi}^d, b^d) | \frac{e_{wi}^d}{b^d} \right]. \quad (11)$$

Define the probability of transitioning to state d in period i by μ_i^d and note that for those households who arrive at this period with w employed the change in participation is zero. Dividing the probabilities in (11) by the chance of transitioning to state d at some point, $\lambda \equiv \sum_{i=0}^{T-1} \mu_i^d$, we can rewrite Q_1^d as $Q_1^d = \lambda E_\lambda \left\{ (1 - \bar{e}_{w0}^d) \kappa_w^d(\bar{e}_{w0}^d) | \varepsilon(e_{w0}^d, b^d) | \frac{e_{w0}^d}{b^d} \right\} \equiv \lambda E_\lambda(g(\bar{e}_{w0}^d))$, where \bar{e}_{w0}^d denotes participation in the period the household transitions to state d and E_λ is the expectation operator conditional on being in state d . Expanding $g(e)$ around w 's average participation upon the transition to state d – which we denote by \hat{e}_{w0}^d – we can approximate Q_1^d by

$$Q_1^d \cong \lambda (1 - \hat{e}_{w0}^d) \kappa_w^d(\hat{e}_{w0}^d) | \varepsilon(\hat{e}_{w0}^d, b^d) | \frac{\hat{e}_{w0}^d}{b^d}. \quad (12)$$

In addition, as in the proof of Proposition A1

$$Q_2^d = \left(\rho_0 \frac{\partial V_0^{b,0}}{\partial b^g} + (1 - \rho_0) \frac{\partial V_0^{g,0}}{\partial b^g} \right) = (1 - \rho_0) (1 - e_{w0}^g) \kappa_w^g(e_{w0}^g) | \varepsilon(e_{w0}^g, b^g) | \frac{e_{w0}^g}{b^g}. \quad (13)$$

To complete the proof we differentiate the budget constraint with respect to b^d which yields

$$\frac{db^g}{db^d} = -\frac{b^g}{b^d} \epsilon(1 - \hat{e}_w^g, b^d) - \frac{D^d(1 - \hat{e}_w^d)}{D^g(1 - \hat{e}_w^g)} \epsilon(1 - \hat{e}_w^d, b^d) - \frac{D^d(1 - \hat{e}_w^d)}{D^g(1 - \hat{e}_w^g)}. \quad (14)$$

Plugging (12), (13) and (14) into (10), using a quadratic approximation of the effort function $\kappa^g(e_{wt}^g)$ around e_{w0}^g and assuming that the ratio $\theta^d(e_{wt}^d)$ is locally constant at \hat{e}_{w0}^d , we obtain the approximated formula for the normalized welfare gain $M_w(b^d) \equiv \frac{\frac{dJ_0(T, B)}{db^d} / \lambda(1 - \hat{e}_{w0}^d)}{\frac{dJ_0(T, B)}{db^g} / (1 - \rho_0)(1 - e_{w0}^g)}$ that is stated in the proposition, which completes the proof. ■

Extension: Exogenous Separations

One natural extension of our search model is to allow for w 's employment status to change at state transitions. For example, a working w in state g may want to decrease her labor supply in state b to take care of the ill h and may decide to quit her job and start searching for a job again in a year or two after the shock occurs. We can extend the model such that employment is only absorbing within each health state, but can be exogenously terminated at rate δ_t at health-state transitions. To demonstrate how to include this sort of separation, let us reconsider the value of entering period t in state g when w is unemployed. In this case, the household's value function is

$$V_t^{g,0}(B, T, A_t) \equiv \max e_{wt}^g \left(u_h^g(c_{ht}^g(1)) + u_w^g(c_{wt}^g(1)) + W_{t+1}^{g,1}(B, T, A_{t+1}(1)) \right) + (1 - e_{wt}^g) \left(u_h^g(c_{ht}^g(0)) + u_w^g(c_{wt}^g(0)) + W_{t+1}^{g,0}(B, T, A_{t+1}(0)) \right) - \kappa_w^g(e_{wt}^g),$$

where as before

$$W_{t+1}^{g,0}(B, T, A_{t+1}) \equiv (1 - \rho_{t+1})V_{t+1}^{g,0}(B, T, A_{t+1}) + \rho_{t+1}V_{t+1}^{b,0}(B, T, A_{t+1}),$$

but with the adjustment that now

$$W_{t+1}^{g,1}(B, T, A_{t+1}) \equiv \rho_{t+1} \left((1 - \delta_{t+1})V_{t+1}^{b,1}(B, T, A_{t+1}) + \delta_{t+1}V_{t+1}^{b,0}(B, T, A_{t+1}) \right) + (1 - \rho_{t+1})V_{t+1}^{g,1}(B, T, A_{t+1}).$$

That is, if h becomes sick when w works, there is a probability of δ_{t+1} that w stops working and then renews her search effort. In this case, it is no longer true that $\frac{\partial W_{t+1}^{g,1}}{\partial b^b} = 0$, but rather $\frac{\partial W_{t+1}^{g,1}}{\partial b^b} = \rho_{t+1}\delta_{t+1}\frac{\partial V_{t+1}^{b,0}}{\partial b^b}$. In turn, this implies that in equation (5) one needs to take into account additional paths to reach period i with w unemployed and transition to state b exactly in that period. It is no longer merely the probability of becoming exactly sick in period i and staying unemployed until that period. Rather, it is also the probability of being employed before period i and then transitioning into state b and becoming unemployed in that period (with probability δ_t). However, recall that our final formulas include expected values and averages. Before, those who were employed contributed a value of zero to the integrals. But, now, with a positive probability they contribute a non-zero value (because a fraction δ_t responds on the effort margin as for them employment is not absorbing). Therefore, our formulas remain the same under this extension such that welfare is still identified by the means stated in our formulas. The change is that conceptually these means include additional individuals that respond. The sample moments that one needs to calculate to recover welfare remain the same.

Appendix B: A Collective Intensive-Margin Model of Household Labor Supply

In this appendix we present a baseline static model that is the intensive-margin counterpart to the participation model in the text. The analysis of the dynamic version of the model follows the logic of the analysis in Appendix A and is available from the authors on request. The general conclusion of the dynamic model in the intensive-margin case is similar to that in the extensive-margin case – the labor supply responses that identify the marginal benefits from social insurance are replaced by average labor supply responses. For completeness, we describe the full setup of the model although it has close similarities to the model of Section 2.1.

Setup. Households consist of two individuals, w and h . We consider a world with two states of nature: a “good state” (state g) in which h is in good health, and a “bad state” (state b) in which h experiences a shock. Households spend a share of μ^g of their adult life in state g and a share of μ^b in state b ($\mu^g + \mu^b = 1$). In what follows, the subscript $i \in \{w, h\}$ refers to the spouse and the superscript $s \in \{g, b\}$ refers to the state of nature.

Individual preferences. Let $U_i(c_i^s, l_i^s)$ represent i 's utility as a function of consumption, c_i^s , and labor supply, l_i^s , in state s . We assume that $\frac{\partial U_i}{\partial c_i^s} > 0$, $\frac{\partial^2 U_i}{\partial (c_i^s)^2} < 0$, $\frac{\partial U_i}{\partial l_i^s} < 0$ and $\frac{\partial^2 U_i}{\partial (l_i^s)^2} < 0$.

Household preferences. We follow the collective approach to household behavior and assume that household decisions are Pareto efficient and can be characterized as solutions to the maximization of $\beta_w U_w(c_w^s, l_w^s) + \beta_h U_h(c_h^s, l_h^s)$, where β_w and β_h are the Pareto weights on w and h , respectively. For simplicity, we assume equal Pareto weights ($\beta_w = \beta_h = 1$), which is without loss of generality as long as the spouses' relative bargaining power is stable across states of nature.

Policy tools. Households in state b receive transfers of the amount B , which are financed by a linear tax rate τ_i^s on i 's labor income in state s . We denote taxes by $T \equiv (\tau_w^g, \tau_h^g, \tau_w^b, \tau_h^b)$ and actual transfers by B^s such that $B^g = 0$ and $B^b = B$.

Household's problem. In each state s the household solves the following problem

$$\begin{aligned} V^s(B, T, A) &\equiv \max_{c_i^s, l_i^s} U_h(c_h^s, l_h^s) + U_w(c_w^s, l_w^s) \\ \text{s.t.: } c_h^s + c_w^s &= A + w_h^s (1 - \tau_h^s) l_h^s + w_w (1 - \tau_w^s) l_w^s + B^s, \end{aligned}$$

where A is the household's wealth, w_h^s is h 's wage rate in state s and w_w is w 's wage rate. The household's first-order conditions imply that $\frac{\partial U_h}{\partial c_h^s} = \frac{\partial U_w}{\partial c_w^s} = -\frac{\partial U_w}{\partial l_w^s} \frac{1}{w_w(1 - \tau_w^s)}$. Importantly, note that we allow h to be at a corner solution in state b – that is, $l_h^b = 0$ – and use only w 's labor supply first-order conditions.

Planner's problem. The social planner's objective is to choose the tax-and-benefit system that maximizes the

household's expected utility, $J(B, T) \equiv \mu^g V^g(B, T, A) + \mu^b V^b(B, T, A)$, subject to the requirement that expected benefits paid, $\mu^b B$, equal expected taxes collected, $\mu^g(\tau_h^g w_h^g l_h^g + \tau_w^g w_w l_w^g) + \mu^b(\tau_h^b w_h^b l_h^b + \tau_w^b w_w l_w^b)$. Hence, the planner chooses the benefit level B and taxes T that solve

$$\max_{B, T} J(B, T) \quad \text{s.t.} \quad \mu^b B = \mu^g(\tau_h^g w_h^g l_h^g + \tau_w^g w_w l_w^g) + \mu^b(\tau_h^b w_h^b l_h^b + \tau_w^b w_w l_w^b). \quad (15)$$

Optimal Social Insurance

Consider a \$1 increase in B financed by an appropriate increase in taxes, e.g., through τ_h^g . To simplify notation we assume that $\tau_w^g = \tau_h^b = \tau_w^b = 0$, which allows us to obtain concise welfare formulas.⁴ The welfare gain from this perturbation is $\frac{dJ(B, T)}{dB} = \mu^b \frac{\partial V^b}{\partial B} + \mu^g \frac{\partial V^g}{\partial \tau_h^g} \frac{d\tau_h^g}{dB}$, which we normalize by the welfare gain from raising h 's net-of-tax labor income in state g by \$1 (scaled by the targeted population) to gain a cardinal interpretation.⁵ Exploiting the Envelope theorem (in the differentiation of the household's value functions) and using the household's first-order conditions, we obtain $\frac{\partial V^g}{\partial \tau_h^g} = -w_h^g l_h^g \frac{\partial U_w}{\partial c_w^g}$ and $\frac{\partial V^b}{\partial B} = \frac{\partial U_w}{\partial c_w^b}$. Differentiating the budget constraint with respect to B

we get $\frac{d\tau_h^g}{dB} = \frac{\mu^b}{\mu^g z_h^g} \left(1 + \frac{\varepsilon(z_h^g, 1 - \tau_h^g) \frac{\tau_h^g}{1 - \tau_h^g}}{1 - \varepsilon(z_h^g, 1 - \tau_h^g) \frac{\tau_h^g}{1 - \tau_h^g}} \right)$, where $z_h^g \equiv w_h^g l_h^g$ is h 's taxable income and $\varepsilon(z_h^g, 1 - \tau_h^g) \equiv \frac{\partial z_h^g}{\partial (1 - \tau_h^g)} \frac{1 - \tau_h^g}{z_h^g}$

is the commonly estimated net-of-tax taxable income elasticity.⁶ Put together, it follows that the normalized welfare gain from a marginal increase in B is $M_W(B) = MB(B) - MC(B)$, where $MB(B) \equiv \frac{\frac{\partial U_w}{\partial c_w^b} - \frac{\partial U_w}{\partial c_w^g}}{\frac{\partial U_w}{\partial c_w^g}}$ and

$$MC(B) \equiv \frac{\varepsilon(z_h^g, 1 - \tau_h^g) \frac{\tau_h^g}{1 - \tau_h^g}}{1 - \varepsilon(z_h^g, 1 - \tau_h^g) \frac{\tau_h^g}{1 - \tau_h^g}}.$$

Identifying the benefits from social insurance. The identification of the gap in marginal utilities of consumption using the unaffected spouse's labor supply responses in the intensive margin model is summarized in the following proposition.

Proposition B1. *Assuming consumption-leisure separability,⁷ the marginal benefit from raising B in \$1 is approximately*

$$MB(B) \cong L^b + M^b, \quad (16)$$

where $L^b \equiv \frac{l_w^b - l_w^g}{l_w^g}$, $M^b \equiv (\varphi - 1) \frac{l_w^b - l_w^g}{l_w^g}$, and $\varphi \equiv \frac{\partial^2 U_w / (\partial l_w^g)^2}{\partial U_w / \partial l_w^g} l_w^g$.

Proof. Recall that the household's first-order conditions imply that $\frac{\partial U_h}{\partial c_h^g} = \frac{\partial U_w}{\partial c_w^g} = -\frac{\partial U_w}{\partial l_w^g} \frac{1}{w_w}$. This allows us to map i 's marginal utility from consumption to the unaffected spouse's marginal disutility from labor, such that

$MB(B) = \frac{\left| \frac{\partial U_w}{\partial l_w^b} \right| - \left| \frac{\partial U_w}{\partial l_w^g} \right|}{\left| \frac{\partial U_w}{\partial l_w^g} \right|}$. Following Gruber's (1997) analysis for estimating the consumption representation of the welfare formulas (see also Chetty and Finkelstein 2013), we take a second-order approximation of w 's labor disutility function around l_w^g . The consumption-leisure separability assumption yields the result. ■

⁴Relaxing this assumption results in additional elasticities in $MC(B)$ which is defined below. See Footnote 6.

⁵The formula for the normalized gain is $M_W(B) \equiv \frac{\frac{dJ(B, T)}{dB} / \mu^b}{\frac{\partial J(B, T)}{\partial z_h^g} / \mu^g}$, where $z_h^g \equiv w_h^g l_h^g$.

⁶Note that when calculating the change in government revenues, we need to take into account *any* possible margin that can respond to the change *and* is being taxed. For example, if we added taxes on w , we would need to include her labor supply responses to changes in h 's tax rate.

⁷Recent research finds supportive evidence for consumption-leisure separability – e.g., Aguilu, Attanasio, and Meghir (2011) who find no change in consumption (defined as non-durable expenditure) around retirement. However, complementarities between consumption and leisure can be handled by estimating the cross-partial using the technique in Chetty (2006).

Identification of φ

In this section we derive a relationship between φ and observable labor supply elasticities. The analysis uses a similar strategy as that introduced by Chetty (2006) to recover risk aversion – i.e., we recover the curvature of the labor disutility function in the same way that Chetty (2006) recovers the curvature of the consumption utility function. The intuition for the method is that the extent to which an individual responds to changes in economic incentives (wages and income) is directly linked to the rate at which preferences change (over consumption or labor). To conduct the analysis at the individual level, we use the “sharing-rule” interpretation of the collective model as defined by Chiappori (1992). That is, we assume that non-labor income in state s , denoted by y^s , is shared between the members such that $y_w^s \equiv \pi_w^s(w_w, w_h^s, A)$ is the amount received by w and $y_h^s \equiv y^s - \pi_w^s(w_w, w_h^s, A)$ is the amount received by h . With these definitions, one can write w ’s program in state g as

$$\begin{aligned} \max_{c_w^g, l_w^g} & U_w(c_w^g, l_w^g) \\ \text{s.t.: } & c_w^g = y_w^g + w_w l_w^g. \end{aligned}$$

Since we are focusing on the analysis of spouse w in state g , we drop spouse subscripts and state superscripts for convenience.

The first-order conditions of this program imply that $wU_c(y + wl, l) = -U_l(y + wl, l)$, where U_x denotes the partial derivative of U with respect to x . Partially differentiating the latter equation with respect to y and w yields $\frac{\partial l}{\partial y} = -\frac{wU_{cc} + U_{cl}}{w^2U_{cc} + U_{ll} + 2wU_{cl}}$ and $\frac{\partial l}{\partial w} = -\frac{U_c + wU_{cc} + U_{cl}}{w^2U_{cc} + U_{ll} + 2wU_{cl}}$.⁸ It follows that $\varphi \equiv \frac{U_{ll}}{U_l}l = \frac{1+\varepsilon(l,y)\frac{wl}{y}}{\varepsilon^c(l,w)} + \varepsilon(U_c, l)$, where $\varepsilon(l, y) \equiv \frac{\partial l}{\partial y}\frac{y}{l}$, $\varepsilon(l, w) \equiv \frac{\partial l}{\partial w}\frac{w}{l}$, $\varepsilon(U_c, l) \equiv \frac{U_{cl}}{U_c}l$ and $\varepsilon^c(l, w) \equiv \varepsilon_{l,w} - \varepsilon_{l,y}\frac{wl}{y}$. With consumption-leisure separability the formula reduces to $\varphi = \frac{1+\varepsilon(l,y)\frac{wl}{y}}{\varepsilon_{l,w} - \varepsilon_{l,y}\frac{wl}{y}}$.

Appendix C: Heterogeneity in θ^b

In this section we return to our participation model of Section 2.2 and provide an approximated formula for the case in which the labor disutility state dependence is heterogeneous. Denote the joint distribution of the vector of w ’s labor disutility and labor disutility state dependence, (v_w, θ^b) , by $\Gamma(v_w, \theta^b)$, the marginal distribution of θ^b by $K(\theta^b)$ and the marginal distribution of v_w by $F(v_w)$ as before. In addition, denote the distribution of v_w conditional on θ^b by $F_{\theta^b}(v_w)$ and the corresponding probability density function by $f_{\theta^b}(v_w)$. Define $y^s \equiv \theta^s v_w$ (where $\theta^g = 1$ by normalization) and denote its distribution by $G^s(y^s)$ for $s \in \{g, b\}$ with a probability density function $g^s(y^s)$. Using this notation, w works in state s whenever $y^s < \bar{y}^s$ where

$$\bar{y}^s \equiv [u_h^s(c_h^s(1)) + u_w^s(c_w^s(1))] - [u_h^s(c_h^s(0)) + u_w^s(c_w^s(0))].$$

It follows that we can rewrite the marginal benefit in labor disutility terms as $MB(b^b) = \frac{|\frac{\partial \bar{y}^b}{\partial b^b}| - |\frac{\partial \bar{y}^g}{\partial b^g}|}{|\frac{\partial \bar{y}^g}{\partial b^g}|}$. Define participation by $e_w^s \equiv G^s(\bar{y}^s)$ and note that $\frac{\partial e_w^b}{\partial b^b} = g^b(\bar{y}^b) \frac{\partial \bar{y}^b}{\partial b^b}$. To continue, we would want to express $g^b(\bar{y}^b)$ in terms of the marginal distribution of v_w . Since $G^b(y^b) = \int_0^\infty k(\theta^b) \left[\int_0^{y^b/\theta^b} f_{\theta^b}(v_w) dv_w \right] d\theta^b$ we have that $g^b(y^b) = \int_0^\infty \left[f_{\theta^b}(\frac{y^b}{\theta^b}) \frac{1}{\theta^b} \right] k(\theta^b) d\theta^b = E_{\theta^b} \left[f_{\theta^b}(\frac{y^b}{\theta^b}) \frac{1}{\theta^b} \right]$. Next, consider approximating $g^b(\bar{y}^b)$. Define $\mu(\theta^b) \equiv f_{\theta^b}(\frac{\bar{y}^b}{\theta^b}) \frac{1}{\theta^b}$ and take a first-order Taylor expansion around $E\theta^b$ to get $\mu(\theta^b) \cong \mu(E\theta^b) + \mu'(E\theta^b)(\theta^b - E\theta^b)$. Hence, to a first approximation $g^b(\bar{y}^b) = E_{\theta^b} [\mu(\theta^b)] \cong \mu(E\theta^b) = f_{E\theta^b}(\frac{\bar{y}^b}{E\theta^b}) \frac{1}{E\theta^b}$. Define \bar{v}^b to be v_w which satisfies $v_w E\theta^b = \bar{y}^b$. This implies that $g^b(\bar{y}^b) \cong \frac{1}{E\theta^b} f_{E\theta^b}(\bar{v}^b)$ and hence that $\frac{\partial e_w^b}{\partial b^b} = g^b(\bar{y}^b) \frac{\partial \bar{y}^b}{\partial b^b} \cong \frac{1}{E\theta^b} f_{E\theta^b}(\bar{v}^b) \frac{\partial \bar{y}^b}{\partial b^b}$. If, for example, v_w is distributed independently of θ^b , such that $f_{E\theta^b}(\bar{v}^b) = f(\bar{v}^b)$, a first-order approximation of F in the threshold region $(\bar{v}_w^g, \bar{v}_w^b)$ will yield the same approximated formula for $MB(b^b)$ as in Proposition 2 where θ^b is replaced by its mean value, $E\theta^b$.

⁸Note the subtlety that we focus on *partial* derivatives of the unaffected spouse’s behavior with respect to y and w . In particular, y is held fixed when we change w .

Appendix D: Calibration of θ^b

In this section we provide a proof for the Lemma in the text (Section 5.2). We begin with the baseline model and then provide a proof for the dynamic model. Similar analysis can be conducted for the intensive-margin case and is available from the authors on request.

Static Extensive Margin Model

Recall that $V^s(y^s(l_w^s)) \equiv \max u_w^s(c_w^s) + u_h^s(c_h^s)$ s.t. $c_w^s + c_h^s = y^s(l_w^s)$, where $y^s(l_w^s) \equiv A + \bar{z}_h^s \times l_h^s + \bar{z}_w \times l_w^s + B(l_w^s)$. Since we are interested in analyzing steady-state equivalence scales we account for transitory labor income shocks and later employ conditions under which the scales we study are not sensitive to these shocks. We decompose w 's net labor income, \bar{z}_w , into its permanent component, \tilde{z}_w , and its transitory component, ς_w , such that $\bar{z}_w = \tilde{z}_w + \varsigma_w$ and $y^s(l_w^s) = A + \bar{z}_h^s \times l_h^s + (\tilde{z}_w + \varsigma_w) \times l_w^s + B(l_w^s)$.

Next, recall that w works when $v_w^s < \bar{v}_w^s \equiv V^s(y^s(1)) - V^s(y^s(0))$, where $v_w^g = v_w$ and $v_w^b = \theta^b \times v_w^g$. In equilibria in which w 's participation rate in state g and in state b are the same it must be that $\bar{v}_w^g = \bar{v}_w^b / \theta^b$, or: $V^g(y^g(1)) - V^g(y^g(0)) = \frac{1}{\theta^b} [V^b(y^b(1)) - V^b(y^b(0))]$. This implies a necessary condition that the household income flows $-y^g(0)$, $y^g(1)$, $y^b(0)$, and $y^b(1)$ must satisfy when labor supply is unchanged across states of nature. In a steady state, this equality is insensitive to local income shocks. By equating the derivative of both sides with respect to the transitory income shock, ς_w , we get the relationship

$$V^{g'}(y^g(1)) = \frac{1}{\theta^b} \{V^{b'}(y^b(1))\}. \quad (17)$$

Let $\theta^u \equiv V^{b'}(y^b(1)) / V^{g'}(y^g(1))$ denote the change in the marginal value of household income, and let $\gamma \equiv -[V^{g''}(y^g(1)) / V^{g'}(y^g(1))] \times y^g(1)$ denote the household-level pre-shock relative risk aversion. A second-order expansion of the value function V^b on the right-hand side of (17) around $y^g(1)$ yields the result in the Lemma

$$\theta^u(1 + \gamma(1 - r^{eq})) \cong \theta^b, \quad (18)$$

where $r^{eq} \equiv y^b(1) / y^g(1)$ is the steady state replacement rate that satisfies this relationship.

Dynamic Search Model

The notation and definitions we use here are described in Appendix A. To simplify the analysis we assume two states of nature as in the baseline model, $s \in \{g, b\}$. Recall from Appendix A that $c_{ht}^s(l_{wt}^s) + c_{wt}^s(l_{wt}^s) + A_{t+1}(l_{wt}^s) = A_t + y_t^s(l_{wt}^s)$ and $y_t^s(l_{wt}^s) \equiv \bar{z}_{ht}^s \times l_{ht}^s + \bar{z}_{wt} \times l_{wt}^s + B(l_{wt}^s)$. As in the baseline case, we decompose w 's net labor income, \bar{z}_{wt} , into its permanent component, \tilde{z}_{wt} , and its transitory component, ς_{wt} , such that $\bar{z}_{wt} = \tilde{z}_{wt} + \varsigma_{wt}$ and $y_t^s(l_{wt}^s) = \bar{z}_{ht}^s \times l_{ht}^s + (\tilde{z}_{wt} + \varsigma_{wt}) \times l_{wt}^s + B(l_{wt}^s)$. For each period in which w is not working define the flow consumption utility at the optimal choices as a function of the period's wealth and income by

$$U^s(A_t, y_t^s(l_{wt}^s)) \equiv u_h^s(c_{ht}^{s*}(l_{wt}^s)) + u_w^s(c_{wt}^{s*}(l_{wt}^s)),$$

where

$$(c_{wt}^{s*}, c_{ht}^{s*}(l_{wt}^s), c_{wt}^{s*}(l_{wt}^s), A_{t+1}^s(l_{wt}^s)) \equiv \arg \max_{e_{wt}^s, c_{ht}^s, c_{wt}^s, A_{t+1}} \left\{ \begin{aligned} &e_{wt}^s \left(u_h^s(c_{ht}^s(1)) + u_w^s(c_{wt}^s(1)) + W_{t+1}^{s,1}(B, T, A_{t+1}(1)) \right) + \\ &(1 - e_{wt}^s) \left(u_h^s(c_{ht}^s(0)) + u_w^s(c_{wt}^s(0)) + W_{t+1}^{s,0}(B, T, A_{t+1}(0)) \right) - \kappa_w^s(e_{wt}^s) \end{aligned} \right\}.$$

We can, therefore, rewrite the first-order condition for w 's effort as

$$\left(U^s(A_t, y_t^s(1)) + W_{t+1}^{s,1}(B, T, A_{t+1}^s(1)) \right) - \left(U^s(A_t, y_t^s(0)) + W_{t+1}^{s,0}(B, T, A_{t+1}^s(0)) \right) = \kappa_w^{s'}(e_{wt}^{s*}). \quad (19)$$

In equilibria in which w 's participation rate in state g and state b are the same it must be that $e_{wt}^{g*} = e_{wt}^{b*}$. For a

given period, which we normalize to 0, define $\theta^b \equiv \kappa^b'(e_{w0}^{b*})/\kappa^g'(e_{w0}^{b*})$, which implies that

$$\left(U^g(A_0, y_0^g(1)) + W_1^{g,1}(B, T, A_1^*(1)) \right) - \left(U^g(A_0, y_0^g(0)) + W_1^{g,0}(B, T, A_1^*(0)) \right) = \frac{1}{\theta^b} \left\{ \left(U^b(A_0, y_0^b(1)) + W_1^{b,1}(B, T, A_1^*(1)) \right) - \left(U^b(A_0, y_0^b(0)) + W_1^{b,0}(B, T, A_1^*(0)) \right) \right\}. \quad (20)$$

Differentiating both sides with respect to the transitory shock ς_{w0} yields $U_y^g(A_0, y_0^g(1)) = \frac{1}{\theta^b} U_y^b(A_0, y_0^b(1))$, where U_x^s is the partial derivative of U^s with respect to x . Let $\theta^u \equiv U_y^b(A_0, y_0^b(1))/U_y^g(A_0, y_0^g(1))$ denote the change in the marginal value of household income, and let $\gamma \equiv -[U_{yy}^g(A_0, y_0^g(1))/U_y^g(A_0, y_0^g(1))] \times y_0^g(1)$ denote the household-level pre-shock relative risk aversion. A second-order expansion of the consumption flow “value function” U^b around $y_0^g(1)$ yields the result in the Lemma

$$\theta^u(1 + \gamma(1 - r^{eq})) \cong \theta^b, \quad (21)$$

where $r^{eq} \equiv y_0^b(1)/y_0^g(1)$ is the steady state replacement rate that satisfies this relationship.

Appendix E: Implications for Health-State Dependence of the Household’s Preferences

In this section we formalize the discussion in Section 5.3 on health-state dependence. Since we found the unaffected spouse’s labor supply response to spousal health shocks to be on the intensive margin, we refer to the intensive-margin model of the household behavior developed in Appendix B. We generalize preferences such that each spouse’s preferences in state s can be represented by the utility function $U_i^s(c_i^s, l_i^s)$, where c_i^s and l_i^s are spouse i ’s consumption and labor supply in state s , respectively. Efficiency requires the marginal utility of h ’s consumption, $\frac{\partial U_h^s}{\partial c_i^s}$, to equal w ’s marginal disutility of labor, $-\frac{\partial U_w^s}{\partial l_w^s} \frac{1}{w_w}$. This is the basic logic behind the welfare result for the intensive margin case, which implies that $\left(\frac{\partial U_h^b}{\partial c_i^b} - \frac{\partial U_h^g}{\partial c_i^g} \right) / \frac{\partial U_h^g}{\partial c_i^g} = \left(\frac{\partial U_w^b}{\partial l_w^b} - \frac{\partial U_w^g}{\partial l_w^g} \right) / \frac{\partial U_w^g}{\partial l_w^g}$. Define $\theta^u \equiv \frac{\partial U_h^b}{\partial c_h^b} / \frac{\partial U_h^g}{\partial c_h^g}$ at c_h^b and $\theta^b \equiv \frac{\partial U_w^b}{\partial l_w^b} / \frac{\partial U_w^g}{\partial l_w^g}$ at l_w^b to be the local consumption utility and labor disutility state dependence parameters, respectively. With consumption-leisure separability it follows that $\theta^u \gamma \frac{\Delta c_h}{c_h} + \theta^b \varphi \frac{\Delta l_w}{l_w} \cong \theta^b - \theta^u$, where $\gamma \equiv -\frac{\partial^2 U_h^g / \partial (c_h^g)^2}{\partial U_h^g / \partial c_h^g} c_h^g$ is h ’s risk aversion parameter, $\varphi \equiv \frac{\partial^2 U_w^g / \partial (l_w^g)^2}{\partial U_w^g / \partial l_w^g} l_w^g$ is the curvature of w ’s disutility from labor, and $\frac{\Delta x}{x} = \frac{x^g - x^b}{x^g}$.⁹ Since we find that $\frac{\Delta l_w}{l_w} > 0$, since $\theta^u, \theta^b, \gamma, \varphi > 0$, and if $\frac{\Delta c_h}{c_h} > 0$ due to the small income loss the household experiences, it must be that $0 < \theta^u \gamma \frac{\Delta c_h}{c_h} + \theta^b \varphi \frac{\Delta l_w}{l_w} \cong \theta^b - \theta^u$. This implies that $\frac{\theta^b}{\theta^u} > 1$, which includes the extreme cases of $\theta^u = 1$ with $\theta^b > 1$ and $\theta^b = 1$ with $\theta^u < 1$. More generally, our results imply that labor disutility state dependence is greater than the potential state dependence in the sick spouse’s consumption utility.

⁹This is achieved by taking a Taylor expansion of $\theta^u \frac{\partial U_h^g}{\partial c_h^g}$ around c_h^g and of $\theta^b \frac{\partial U_w^g}{\partial l_w^g}$ around l_w^g .

Appendix F: An Empirical Model of Labor Force Participation

In this section we estimate an empirical counterpart to the theoretical model of household labor force participation in order to provide suggestive estimates for $\varepsilon(e_w^b, b^b)$ and $\varepsilon(e_w^g, b^g)$. We model w 's participation such that in the years before the event her decision is conditional on h 's behavior. Specifically, the income h contributes to the household – whether through transfers or through labor income – is perceived as non-labor income in w 's decision making.¹⁰ We constrain the sample to individuals who are younger than 60 to avoid retirement transitions that are due to eligibility for early retirement benefits and Social Security.

Labor force participation. We let w 's labor supply depend on her potential wage if she decides to work, on the potential transfers she would receive if she decides not to work, as well as on her unearned income. Denote the participation decision and the latent index of spouse w in household i at time t in state s by $l_{w,i,t}^s$ and $I_{w,i,t}^s$, respectively. Then, $l_{w,i,t}^s = 1$ if $I_{w,i,t}^s > 0$ and $l_{w,i,t}^s = 0$ otherwise. We assume the following linear form for the participation latent index

$$I_{w,i,t}^s = \delta_0 + \delta_1 z_{w,i,t}^s + \delta_2 b_{w,i,t}^s + \delta_3 y_{i,t}^s + \delta_4 wealth_{i,t} + controls + \varepsilon_{i,t}^s, \quad (22)$$

where

$$\begin{aligned} \delta_0 &= \delta_{00} + \delta_{01} treat_i + \delta_{02} post_{i,t} + \delta_{03} treat_i \times post_{i,t}, \\ \delta_k &= \delta_{k0} + \delta_{k1} treat_i \times post_{i,t} \quad k = 1, \dots, 4. \end{aligned}$$

In this specification $z_{w,i,t}^s$ denotes w 's potential labor income in state s , $b_{w,i,t}^s$ denotes her potential government transfers if she decides not to work in state s , $y_{i,t}^s$ denotes w 's unearned income as well as any income (earned or unearned) that is attributed to h before his death, and $wealth_{i,t}$ denotes the household's net wealth. The coefficients are allowed to freely change across states of nature, since $treat_i \times post_{i,t}$ is the differences-in-differences interaction variable. The controls include dummies for w 's age, calendar year, and municipality of residence before the shock occurs.

Wage equations. Following Blundell, Chiappori, Magnac, and Meghir (2007), we take the standard human capital approach to wages and additionally allow for the relative prices of education to change over time. In particular, we assume¹¹

$$\begin{aligned} z_{w,i,t}^s &= \pi_{0t} + \pi_{1t} educ_i + \pi_{2t} educ_i^2 + \pi_{3t} gender_i + \pi_{4t} age_{i,t} \\ &\quad + \pi_{5t} local\ labor\ market_{i,t} + \pi_{6t} health_{i,t} + \pi_{7t} X_{i,t} + \kappa_{i,t}^s. \end{aligned}$$

This assumes that wage offers are a function of calendar year, education (and its square), gender, age indicators, local labor market conditions (which include municipality fixed-effects and municipality-level unemployment rate and average labor income), health (current and lagged hospitalization), and additional characteristics $X_{i,t}$ in which we include a dummy variable for whether the person is a native or an immigrant and indicators for the number of children (of any age). The coefficients on education are allowed to vary over time. To account for selection into the labor force in the imputation of wage offers, we employ the (two-stage) Heckman correction (1979). The analysis is repeated separately for each combination of timing (before/after the shock) and experimental group (treatment/control).

Potential transfers. In the same manner we need to impute the expected potential government transfers in the case an individual chooses not to work. The labor-supply-dependent transfers are Social Disability Insurance (Social DI) benefits, which are awarded in Denmark for medical reasons as well as for social reasons. Recall that Social DI is a state-wide means-tested program that is locally administered (at the municipality level). Hence, we model expected benefits as a function of calendar year dummies (which capture overall national trends in benefits), municipality fixed effects, and interactions of municipality dummies with year dummies. The source of variation we use to identify the effect of potential transfers on participation is within municipalities over time since we include municipality and calendar year fixed effects as controls in the participation equation (22). We also include deciles of gross wealth, liabilities, and home value since some portion of DI is asset-tested, as well as age dummies, gender,

¹⁰This is a common practice in the empirical literature on married women's labor force participation (see, e.g., a review in Keane, Todd, and Wolpin 2011) and is in-line with the sharing-rule representation of the collective model (in Chiappori 1992).

¹¹For expositional reasons we use the notation that whenever the variable is multidimensional (e.g., $age_{i,t}$, which denotes a complete set of age dummies), the corresponding coefficient is a vector of the same dimension (e.g., π_4 has as many entries as the number of unique ages observed in our sample).

and health indicators (hospitalization and lagged hospitalization). We use the following specification

$$b_{w,i,t}^s = \sigma_0 t + \sigma_1 municipality_i + \sigma_2 municipality_i \times year_{i,t} + \sigma_3 age_{i,t} + \sigma_4 gender_i + \sigma_5 health_{i,t} + \sigma_6 gross\ wealth_{i,t} + \sigma_7 liabilities_{i,t} + \sigma_8 home\ value_{i,t} + \omega_{i,t}^s.$$

We estimate this equation using the sample of individuals that do not participate in the labor force, separately for different combinations of timing (before/after the shock) and experimental groups (treatment/control). In this way we construct the transfers an agent who decides not to work expects to receive at time t in state s .

Non-labor income and net-wealth. We want a measure for non-labor income that is exogenous to other decisions such as take-up of social benefits (beyond direct government transfers that are captured by $b_{w,i,t}^s$), withdrawals from savings accounts, claims from private insurance policies, etc. Therefore, we treat w 's component of unearned income $y_{i,t}^s$ as endogenous (following Blundell, Chiappori, Magnac and Meghir 2007), and use predictions based on reduced-form projections, which we run for each combination of timing and experimental group for the effective unearned income on a series of pre-shock household economic variables and characteristics.¹² We then construct non-labor income $y_{i,t}^s$ as the sum of h 's income and w 's predicted non-labor income. To account for potential endogeneity in household-level net wealth (excluding home value), we use pre-shock wealth levels as the right-hand side variable for wealth.

Stochastic specification and estimation. We estimate the model as a probit and hence assume that the error in the latent index, $\varepsilon_{i,t}^s$, is normally distributed with unit variance. The participation equation is estimated using the imputed wages, the expected government benefits, the household-level non-labor income, pre-shock net wealth, and the additional controls (age, year, and municipality dummies).

Elasticity Estimates

The estimation of the model above provides us with the following elasticities, evaluated at sample means: $\varepsilon(e_w^d, b^d) = -0.1937$ with a confidence interval of $[-0.2031, -0.1842]$ and $\varepsilon(e_w^g, b^g) = -0.1409$ with a confidence interval of $[-0.1468, -0.1350]$. The estimate for their ratio is $\varepsilon(e_w^d, b^d)/\varepsilon(e_w^g, b^g) = 1.375$ with a confidence interval of $[1.292, 1.457]$.

¹²To improve the fit of this reduced-form we included a rich set of predictors. These include age and year dummies as well as their interaction, deciles of pre-shock wealth, liabilities, and home value, pre-shock income flows from different private and social sources available in the register-based data, occupation, employment and earnings history, health indicators, education, cohort dummies, as well as gender and municipality fixed effects.

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