Incomplete Intertemporal Consumption Smoothing and Incomplete Risksharing*

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Abstract

This paper develops a method to estimate jointly the degree of (possibly incomplete) intertemporal consumption smoothing and the degree of (possibly incomplete) international/interregional risksharing. This approach generalizes and improves upon studies that either examine only intertemporal consumption smoothing, or analyze risksharing by making an extreme assumption on intertemporal consumption smoothing, or by adopting a purely empirical framework. The method is applied to the US states and OECD and EU countries to analyze how the degrees of risksharing and intertemporal consumption smoothing differ within a country and across countries. The empirical results suggest that: 1) regardless of the assumption on the degree of intertemporal consumption smoothing, the degree of risksharing within a country is larger than across countries 2) the degree of intertemporal consumption smoothing within a country is also larger than across countries, contrary to the findings of past channel studies. Finally, this paper also provides some foundations and suggests limitations of the empirical literature on channels of risksharing and intertemporal consumption smoothing.

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1. Introduction

Empirical studies on risksharing have grown rapidly in recent years. The formal literature started by testing the null hypothesis of full risksharing at various aggregation levels, such as among individuals in a village (Townsend, 1994), among households (Mace, 1991, Cochrane, 1991, Altug and Miller, 1990, Hayashi, Altonji and Kotlikoff, 1996), among countries (Canova and Ravn, 1996, Lewis, 1996).[1] These seminal papers, which were essentially based on regressions of consumption on income (and possibly on other idiosyncratic variables), often controlling for aggregate consumption, originated two strands of macroeconomic literature. One line of research — firmly based on theoretical foundations — has allowed for the possibility of incomplete risksharing and has focused on its precise measurement (e.g. Obstfeld, 1994, Crucini, 1999, Athanasoulis and van Wincoop, 2001, Crucini and Hess, 2000). These studies usually focus on the degree of risksharing across regions (mutual insurance across states of nature against idiosyncratic regional risks, ex ante), but many of them pay less attention to the degree of intertemporal consumption smoothing of the region (diversification of idiosyncratic consumption changes across time, ex post). For example, Athanasoulis and van Wincoop (2001) have performed estimations of the degree of risksharing, assuming away intertemporal consumption smoothing. Other studies have assumed an extreme degree of intertemporal consumption smoothing, either by taking the permanent income hypothesis to hold fully (Crucini, 1999 and Crucini and Hess, 2000), or by postulating no intertemporal consumption smoothing altogether (Obstfeld, 1994, 1995).

A second line of work has concentrated on measuring the contribution to risksharing — possibly incomplete — of various risksharing channels (Asdrubali, Sørensen and Yosha, 1996, Del Negro, 1998, Sørensen and Yosha, 1998, Mélitz and Zumer, 1999, Dedola, Usai and Vannini, 1999, Asdrubali and Kim, 2004.) An important contribution of these papers has been the distinction between risksharing and intertemporal smoothing. However, by adopting a purely empirical framework, these analyses have not provided explicit theoretical underpinnings to their empirical estimations. In addition, these studies require data on several income measures, one after each stage of risksharing or intertemporal consumption smoothing; yet such data might be unavailable.[2]

This paper links together these two major strands of the empirical risksharing literature, by developing a method that jointly estimates the (possibly incomplete) degree of risksharing and the (possibly incomplete) degree of intertemporal consumption smoothing, and that is consistent with risksharing and intertemporal consumption smoothing theory. The paper also identifies the major econometric differences between the two approaches, and provides rationales for either choice. Like many other papers of both lines of research, we apply our method to three regions — the US states, the OECD countries, and the EU members — in order to provide a possible rationalization for the failure of the full risksharing hypothesis by comparing intra

[1] Informal tests of full risksharing using cross-country income and consumption correlations were pioneered by Backus, Kehoe and Kydland (1992), and spurred a vast "cross-correlations" literature.

[2] Refer to the discussion in Sections 2 and 3.

vs. international risksharing and intertemporal consumption smoothing, and to shed a light on the cost of the European monetary unification process.

Our methodology also improves upon each line of research. As for the former strand of the literature, a method of estimating the degree of risksharing without paying much attention to the degree of intertemporal consumption smoothing is likely to be biased, since the two mechanisms are inter-related and the estimate of the degree of risksharing may depend on the assumption on the degree of intertemporal smoothing. Second, by paying attention to intertemporal consumption smoothing as well as to risksharing we contribute to the clarification of such practical issues as the costs of a monetary union. In a monetary union, not only does the role of automatic stabilization mechanisms — such as risksharing ex ante through portfolio diversification or via fiscal stabilizers — but also of intertemporal consumption smoothing mechanisms — like international lending and borrowing — become crucial; hence their precise measurement bears paramount implications for the design of EU institutions. Assuming an extreme degree of intertemporal smoothing thus obscures the true costs and benefits of monetary unification. As for the latter strand of the literature, we provide a theoretical foundation of studies on channels of risksharing and consumption smoothing (e.g., Asdrubali, Sørensen, and Yosha, 1996, Sørensen and Yosha, 1998, and Mélitz and Zumer, 1999), which — albeit widely recognized as a useful first cut to smoothing measurement — have not as yet been based on explicit links to theory. We suggest some theoretical limitations encountered by those studies and we further propose an empirical method that does not necessarily require data on national or disposable income (that is, income after risksharing), which is useful if such data is not available or has a poor quality.

Finally, there is much work that focuses on intertemporal consumption smoothing, for example, Hall (1978), Campbell and Deaton (1989), Campbell and Mankiw (1990), Deaton (1992), and Østergaard, Sørensen, and Yosha (2002). Among them, just few recent studies such as Sørensen and Yosha (2000) and Bayoumi and Klein (1997) have investigated the degree of intertemporal consumption smoothing within a country vs. across countries. From the viewpoint of these analyses, we develop a method to estimate the degree of risksharing, as a complement to the degree of intertemporal consumption smoothing.

The test of intertemporal consumption smoothing and the test of risksharing often involve a similar set of variables, for example, consumption as a dependent variable and income as an independent variable. As a result, it is likely that estimating one side often turns out to be actually estimating the other side also. For example, sometimes a study intends to estimate the degree of intertemporal consumption smoothing, but the estimate may reflect in part the degree of risksharing.[3] This study offers one way to disentangle intertemporal consumption smoothing from risksharing in a unified framework.

The rest of the paper is organized as follows. Section 2 develops a method to estimate the degree of risksharing and the degree of intertemporal consumption smooth-

[3] For example, as argued by Sørensen and Yosha (2000), Bayoumi and Klein (1997) intended to estimate the degree of intertemporal consumption smoothing only, but they ended up with a measure of the degree of intertemporal consumption smoothing and risksharing combined.

ing. Section 3 extends the framework to provide a connection with the channel literature. Section 4 reports the estimation results. Finally, Section 5 concludes with a summary of findings.

2. Incomplete Risk Sharing and Incomplete Intertemporal Consumption Smoothing

Since risksharing is arranged ex-ante while consumption is intertemporally smoothed ex-post, we first model risksharing arrangements, and then model intertemporal consumption smoothing on top of the risksharing arrangements. Consider possibly incomplete risksharing among J countries in an international organization, that to fix ideas we will call EU (or among J regions in a country, which we will call the US).[4] As in Crucini's (1999) model, we posit that each country j sells a fraction λ of its income stream Y_j in exchange for a claim to the pooled income streams of all J countries, so that λ can be naturally interpreted as the degree of risk sharing achieved by the country.

The average date t amount in the pool of the EU is $Y_t \equiv \frac{1}{J}\sum_{j=1}^{J} Y_{jt}$. The flow of domestic income after risk pooling is

$$\overline{Y}_{jt} \equiv \lambda Y_t + (1-\lambda) Y_{jt}. \tag{2.1}$$

Domestic income after risksharing (or "disposable income") is equal to its own income stream when λ is 0 (no risksharing), and to the income stream of the pool when λ is 1 (full risksharing).[5] When λ is between 0 and 1 (partial risksharing), a country's disposable income is a weighted average of its own income stream and of the income stream of the pool.[6]

While complete risksharing implies full intertemporal consumption smoothing — in the sense that an Euler equation for intertemporal consumption allocation is satisfied — on the contrary partial risksharing does not necessarily imply full intertemporal consumption smoothing. Therefore, we will consider possibly incomplete intertemporal consumption smoothing of each country j. When consumption is perfectly smoothed intertemporally, the country consumes its permanent (disposable) income.[7] When consumption is not smoothed intertemporally at all, the country consumes its current (disposable) income. We define γ, the degree of intertemporal consumption smoothing achieved by the country, as the fraction of its permanent disposable income used to smooth its consumption. When a fraction, γ, of its permanent disposable income is used to smooth its consumption (and hence the remaining fraction $1-\gamma$ is

[4]For simplicity, we follow the standard practice of assuming that all countries in the EU (or all regions in the US) are identical ex ante.

[5]In this section, we do not separate risksharing achieved by private and public sectors, but we will do it in section 3.

[6]Risksharing may be incomplete if markets are incomplete, if transaction costs in the goods markets are non-negligible, if contracts are costly to enforce or informational asymmetries exist that induce moral hazard.

[7]We assume that each country smooths consumption by borrowing or lending at a possibly different but constant exogenous real interest rate.

consumed out of its current disposable income), the change in consumption of country j is

$$\triangle C_{jt} = \mu_j + (1-\gamma)\triangle\overline{Y}_{jt} + \gamma\overline{\varepsilon}_{jt} \tag{2.2}$$

where $\overline{\varepsilon}_{jt} \equiv (1-\beta)\sum_{k=0}^{\infty}\beta^k\left[E_t\overline{Y}_{jt+k} - E_{t-1}\overline{Y}_{jt+k}\right]$ is the change in consumers' estimate of their permanent (disposable) income from $t-1$ to t, which we will call the innovation in permanent (disposable) income. The consumption change is equal to the current disposable income change when γ is 0 (no intertemporal consumption smoothing), and to the innovation in permanent disposable income when γ is 1 (full intertemporal consumption smoothing). When γ is between 0 and 1 (partial intertemporal consumption smoothing), a country's consumption change is a weighted average of its current disposable income change and the innovation in permanent disposable income.[8] Observe that, in characterizing incomplete intertemporal consumption smoothing, equation (2.2) allows for both excess sensitivity of consumption and excess smoothness, as well as "rule of thumb" behavior, as documented by Flavin (1981), Campbell and Deaton (1989) and Campbell and Mankiw (1989, 1990), respectively. The change in the consumption average of all countries leads to the expression for the change in the corresponding aggregate consumption of the EU.

$$\triangle C_t \equiv \frac{1}{J}\sum_{j=1}^{J}\triangle C_{jt} = \mu + (1-\gamma)\triangle Y_t + \gamma\varepsilon_t \tag{2.3}$$

where $\mu \equiv \frac{1}{J}\sum_{j=1}^{J}\mu_j$ and $\varepsilon_t \equiv \frac{1}{J}\sum_{j=1}^{J}\overline{\varepsilon}_{jt}$.

Using equations (2.1), (2.2), and (2.3), the change in country consumption becomes

$$\triangle C_{jt} = \widetilde{\mu} + \lambda\triangle C_t + (1-\gamma)(1-\lambda)\triangle Y_{jt} + \eta_{jt} \tag{2.4}$$

where the intercept $\widetilde{\mu} \equiv \mu_j - \lambda\mu$, the error $\eta_{jt} \equiv \gamma(\overline{\varepsilon}_{jt} - \lambda\varepsilon_t) = \gamma(1-\lambda)\varepsilon_{jt}$ and the innovation $\varepsilon_{jt} \equiv (1-\beta)\sum_{k=0}^{\infty}\beta^k\left[E_tY_{jt+k} - E_{t-1}Y_{jt+k}\right]$. The change in country consumption is a weighted average of the changes in aggregate consumption, the changes in domestic income, and the innovation in permanent income. λ shows the degree of international risksharing while γ indicates the degree of intertemporal consumption smoothing of the country. As λ goes to 1, the change in country consumption is closer to the change in aggregate consumption and risksharing is larger. As γ goes to 1 when λ is less than 1, the change in country consumption depends more on the innovations in its permanent income and intertemporal consumption smoothing is larger. When λ and γ both go to 0, the consumption change is closer to the change in current domestic

[8] Intertemporal consumption smoothing can be incomplete, and the permanent income hypothesis may not hold, due to market imperfections, such as liquidity constraints. Other reasons why the permanent income hypothesis may not hold include a rate of impatience different from the gross real interest rate, the existence of precautionary savings, changing real interest rates (Michener 1984), home production (Baxter and Jermann 1999), non-additive utility and consumption-leisure non-separabilities (Mankiw, Rotemberg and Summers 1985).

income, which implies that both risk sharing and consumption smoothing are closer to null. Observe that full risksharing ($\lambda = 1$) implies that intertemporal consumption smoothing is automatically achieved in the sense that the Euler condition is satisfied regardless of the value of γ;[9] consequently, γ does not show up in (2.4) when $\lambda = 1$ (because the third term disappears). On the contrary, full intertemporal consumption smoothing ($\gamma = 1$) does not imply that risksharing is automatically achieved, in the sense that country consumption is not necessarily proportional to aggregate consumption; this is why λ still shows up in (2.4) when $\gamma = 1$ (the second term). Taking account of this asymmetry between risksharing and intertemporal smoothing is a value added of our formulation.

Since income and consumption series do not follow exactly linear homoskedastic processes, an empirical test of an equation like (2.4) — which is cast in level-differences — is not entirely appropriate. Thus we follow the literature in taking the log approximation of the equation, along the lines suggested by Campbell and Mankiw (1989, 1990), Obstfeld (1994) and Crucini (1999), so that our results will be comparable with theirs. Hence our estimating relation will be

$$\triangle c_{jt} = \widetilde{\mu} + \lambda \triangle c_t + (1-\gamma)(1-\lambda)\triangle y_{jt} + u_{jt} \tag{2.5}$$

where lowercase letters indicate logs. The above formulation represents not only a parsimonious way of jointly characterizing partial risksharing and partial intertemporal smoothing. It is also quite general, in the sense that it can be derived in a full-fledged model as an approximation either from a standard quadratic utility function, or from an isoelastic utility function with log-normally distributed consumption.[10]

Equation (2.5) can be viewed as an advanced form of risksharing test that allows partial intertemporal consumption smoothing. In this sense, it encompasses previous studies on both risksharing and intertemporal consumption smoothing as special cases. Obstfeld (1994, 1995) examined a variant of the $\gamma = 0$ case (no intertemporal consumption smoothing), by including the change in current income as a regressor without considering the innovations in permanent income. Obstfeld (1994) estimated the following type of equation:

$$\triangle c_{jt} = \alpha + \alpha_1 \triangle c_t + \alpha_2 \triangle y_{jt} + e_{jt} \tag{2.6}$$

Note that by assuming $\gamma = 0$ (no intertemporal consumption smoothing), equation (2.5) reduces to the following equation.

$$\triangle c_{jt} = \widetilde{\mu} + \lambda \triangle c_t + (1-\lambda)\triangle y_{jt} \tag{2.7}$$

which is the same as (2.6) with the additional condition $\alpha_1 + \alpha_2 = 1$.[11]. Therefore, Obstfeld (1994) essentially assumed no intertemporal consumption smoothing.

[9] See, for example, Sørensen and Yosha (1998) for a formal proof.

[10] See Kimball (2003) for a defense of the certainty equivalence approximation to uncertainty.

[11] e_{jt} can be interpreted as a country-specific preference shocks.

On the other hand, Crucini (1999) and Crucini and Hess (2000) examined the case of $\gamma = 1$ (perfect intertemporal consumption smoothing) by including the innovation in permanent income without considering the change in current income. Crucini (1999) estimated the following type of equation:

$$\triangle c_{jt} = \alpha_1 \triangle c_t + (1 - \alpha_1) \triangle y_{jt}^P + e_{jt} \tag{2.8}$$

where $\triangle y_{jt}^P$ $(= \varepsilon_{jt})$ is the innovation in permanent income. Note that equation (2.5) reduces to this equation by assuming $\gamma = 1$ (and $\widetilde{\mu} = 0$). By assuming and estimating various stochastic processes for y_{jt}, Crucini (1999) constructs y_{jt}^P, and then estimates equation (2.8) by OLS.

If y_{jt} follows a random walk so that $\triangle y_{jt} = \nu_{jt}$ where ν_{jt} is i.i.d., then all methods are similar (when estimating the degree of risksharing) since permanent income changes and current income changes are equal and it does not matter whether we use the former, the latter or a weighted average of the two as regressors. Specifically, all equations reduce to[12]

$$\triangle c_{jt} = \alpha + \alpha_1 \triangle c_t + (1 - \alpha_1) \triangle y_{jt} + e_{jt}. \tag{2.9}$$

In this case, it becomes difficult to empirically distinguish an economy with full intertemporal smoothing from an economy with no intertemporal smoothing. However, realistically, y_{jt} may follow a more general process. First, changes in domestic income may depend on its own past changes. In fact, several studies, such as Campbell and Mankiw (1990), Campbell and Deaton (1989), and Deaton (1992), suggested that income changes do depend on past income changes. In this regard, we estimate the auto-correlation of y_{jt} for each state in the US and for each country in the OECD and EU. The average of the estimated auto-correlation of income is 0.31 for the US states, 0.29 for OECD countries, and 0.30 for EU members; the dependence is not trivial. Second, changes in domestic income may be affected by other variables, like changes in aggregate income.

As an illustration, let us assume an AR-1 process for domestic income changes, that is, $\triangle y_{jt} = \rho \triangle y_{jt-1} + \nu_{jt}$, where $0 < \rho < 1$, and examine how equations (2.5) and (2.8) diverge. Under the assumed income process, $\Delta y_{jt}^P = \varepsilon_{jt} = \frac{1}{1-\rho} \triangle y_{jt}$; therefore, equation (2.5) becomes

$$\triangle c_{jt} = \widetilde{\mu} + \lambda \triangle c_t + (1 - \lambda) \left[(1 - \gamma) + \frac{\gamma}{1 - \rho} \right] \triangle y_{jt} \tag{2.10}$$

Thus assuming full intertemporal consumption smoothing ($\gamma = 1$) as in Crucini (1999) and Crucini and Hess (2000) is likely to provide a different estimate of λ than our model allowing for partial intertemporal consumption smoothing (that is, without restricting the value of γ to 1). Notice that our specification remains the same, regardless of the stochastic process followed by domestic income.

[12] The condition $\alpha_1 + \alpha_2 = 1$ is additionally needed for equation (2.6). Equations (2.5) and (2.8) are obtained by respectively imposing $e_{jt} = 0$ and $\alpha = 0$ in (2.9).

At this point, it is easy to show that our model also embeds the baseline specification of intertemporal consumption smoothing in Campbell and Mankiw (1990) as a special case. Their model

$$\triangle c_{jt} = \mu_j + (1-\gamma)\triangle \overline{y}_{jt} + \gamma \varepsilon_{jt} \tag{2.11}$$

correctly uses disposable income as a regressor, but it is silent on its determinants. In other words, it assumes risksharing away, and thus corresponds to our specification (2.2).

Equation (2.5) can be estimated by an instrumental variables (IV) approach. The error term u_{jt}, a function of the innovations in permanent income, is orthogonal to lagged variables but not necessarily to current independent variables such as $\triangle y_{jt}$ and $\triangle c_t$. The change in domestic income, $\triangle y_{jt}$, is likely to be correlated to u_{jt} when the changes in domestic income are persistent. The change in aggregate consumption, $\triangle c_t$ may be correlated with u_{jt}; both aggregate consumption and domestic permanent income are likely to be correlated with aggregate permanent income.

We use lagged values of $\triangle y_{jt}$, $\triangle y_t$, $\triangle c_{jt}$, $\triangle c_t$, as well as of measures of country savings s_{jt} and aggregate savings s_t — as instruments. Own lagged variables are good predictors. In addition, as Campbell (1987) and Campbell and Mankiw (1990) suggested, the history of consumption may be a good predictor for income, and income and consumption may be cointegrated. Therefore, we use lagged values of $\triangle c_{jt}$ and s_{jt}. On the other hand, since lagged income and saving may be good predictors for consumption, lagged values of $\triangle y_t$ and s_t are also used. We include at least the second and the third lags of the instruments, but avoid using the first lags to guard against time aggregaton bias. Following Crucini (1999), the model is estimated for each region, and the averages of the point estimates and their standard errors are reported; a pooled regression would give a near zero estimate of the coefficient on the aggregate consumption since the aggregate consumption (or the average consumption) is regressed on individual consumption. In each estimation, the values of λ and γ are restricted to be no larger than 1 and no smaller than 0.[13]

3. Alternative Method and Connections to the Channels Literature

The previous section shows a useful way to estimate the degree of risksharing and intertemporal consumption smoothing jointly when data on only domestic (before-risksharing) income and consumption are available. In this section, we discuss an alternative procedure to jointly estimate the degree of risksharing and intertemporal consumption smoothing when data on additional measures of income is available. We will take advantage of data on domestic income (e.g., GDP), national income (e.g., GNI) and disposable income (e.g., GDI), in order to measure income before

[13] In very few cases, we found implausibly large and small values that change the average dramatically, so we restrict the values of λ and γ. We also experimented by restricting the values between -1 and 2, but the results are not much different.

risksharing, income after private risksharing (through financial markets), and income after both private and public risksharing (through financial markets and fiscal stabilization), respectively.[14] We thus connect our method to studies on channels of risksharing and consumption smoothing, like Asdrubali, Sørensen, and Yosha (1996) and Sørensen and Yosha (1998), that exploited such types of data.

From equation (2.1),

$$\left(\triangle Y_{jt} - \triangle Y_t\right) - \left(\triangle \overline{Y}_{jt} - \triangle Y_t\right) = \lambda \left(\triangle Y_{jt} - \triangle Y_t\right). \tag{3.1}$$

By using equations (2.2) and (2.3),

$$\left(\triangle \overline{Y}_{jt} - \triangle Y_t\right) - \left(\triangle C_{jt} - \triangle C_t\right) = \gamma \left(\triangle \overline{Y}_{jt} - \triangle Y_t\right) - \eta_{jt}. \tag{3.2}$$

where $\eta_{jt} = \gamma \left(\overline{\varepsilon}_{jt} - \varepsilon_t\right) = \gamma \left(1 - \lambda\right) \left(\varepsilon_{jt} - \varepsilon_t\right)$. Therefore, if data on disposable income ($\overline{Y}_{jt}$) is available, λ and γ can be gauged by estimating equations (3.1) and (3.2). Equations (3.1) and (3.2) can be estimated by an OLS and an IV approach, respectively.

In addition to the degree of intertemporal consumption smoothing, studies such as Asdrubali, Sørensen and Yosha (1996), Sørensen and Yosha (1998), and Athanasoulis and van Wincoop (2001) analyzed the role of two risksharing channels — financial diversification and fiscal stabilizers — by constructing a measure of income after only capital market risksharing (by using net factor income data) and a measure of income after both types of risksharing or disposable income (by using government net transfers data). The current framework can be extended to multiple channels of risksharing if data on various measures of income are available.

Assume that $\lambda = \lambda_1 + \lambda_2$, where λ_1 is the degree of risksharing achieved by the financial market and λ_2 is the degree of risksharing achieved by fiscal policy. Then, the flow of disposable income is

$$\overline{Y}_{jt} \equiv \left(\lambda_1 + \lambda_2\right) Y_t + \left(1 - \lambda_1 - \lambda_2\right) Y_{jt}. \tag{3.3}$$

We can also define the flow of national income as

$$\widetilde{Y}_{jt} \equiv \lambda_1 Y_t + \left(1 - \lambda_1\right) Y_{jt}. \tag{3.4}$$

From the above two equations,

$$\overline{Y}_{jt} \equiv \widetilde{Y}_{jt} + \lambda_2 \left(Y_t - Y_{jt}\right). \tag{3.5}$$

[14] National income is a good measure of income after private risksharing because it includes net factor income flows, that is, rent, dividend, interest and wage payments accruing to people who have diversified abroad their financial and human portfolios. In turn, disposable income is a good measure of income after both private and public risksharing because it adds to national income the net current transfers received from abroad, typically composed of fiscal funds. For further details, see Asdrubali, Sørensen, and Yosha (1996) for a discussion of regional measures and Sørensen and Yosha (1998) for national measures.

Then, from equations (3.4) and (3.5),

$$\begin{aligned} (\triangle Y_{jt} - \triangle Y_t) - \left(\triangle \widetilde{Y}_{jt} - \triangle Y_t\right) &= \lambda_1 (\triangle Y_{jt} - \triangle Y_t) \\ \left(\triangle \widetilde{Y}_{jt} - \triangle Y_t\right) - \left(\triangle \overline{Y}_{jt} - \triangle Y_t\right) &= \lambda_2 (\triangle Y_{jt} - \triangle Y_t) \end{aligned} \tag{3.6}$$

Therefore, channels of risksharing can be estimated sequentially, as in Asdrubali, Sørensen, and Yosha (1996) or Sørensen and Yosha (1998).

Now we compare the current method to that in Asdrubali, Sørensen, and Yosha (1996) and Sørensen and Yosha (1998). They estimated the following equation system, in logs.

$$\begin{aligned} \triangle y_{jt} - \triangle \widetilde{y}_{jt} &= \alpha_{1,t} + \beta_1 \triangle y_{jt} + e_{1,jt} \\ \triangle \widetilde{y}_{jt} - \triangle \overline{y}_{jt} &= \alpha_{2,t} + \beta_2 \triangle y_{jt} + e_{2,jt} \\ \triangle \overline{y}_{jt} - \triangle c_{jt} &= \alpha_{3,t} + \beta_3 \triangle y_{jt} + e_{3,jt} \\ \triangle c_{jt} &= \alpha_{4,t} + \beta_4 \triangle y_{jt} + e_{4,jt}. \end{aligned} \tag{3.7}$$

where $\alpha_{\cdot,t}$ is a time fixed effect. Then, they interpreted $\beta_1$and β_2 as the degree of risksharing provided by financial markets and by fiscal stabilization, and β_3 as the degree of intertemporal consumption smoothing.

Our corresponding system of equations (from (3.6) and (3.2)) in log approximation is:

$$\begin{aligned} (\triangle y_{jt} - \triangle y_t) - (\triangle \widetilde{y}_{jt} - \triangle y_t) &= \lambda_1 (\triangle y_{jt} - \triangle y_t) \\ (\triangle \widetilde{y}_{jt} - \triangle y_t) - \left(\triangle \overline{y}_{jt} - \triangle y_t\right) &= \lambda_2 (\triangle y_{jt} - \triangle y_t) \\ \left(\triangle \overline{y}_{jt} - \triangle y_t\right) - (\triangle c_{jt} - \triangle c_t) &= \gamma \left(\triangle \overline{y}_{jt} - \triangle y_t\right) + \eta_{jt}. \end{aligned} \tag{3.8}$$

After reorganizing,

$$\begin{aligned} \triangle y_{jt} - \triangle \widetilde{y}_{jt} &= -\lambda_1 \triangle y_t + \lambda_1 \triangle y_{jt} \\ \triangle \widetilde{y}_{jt} - \triangle \overline{y}_{jt} &= -\lambda_2 \triangle y_t + \lambda_2 \triangle y_{jt} \\ \triangle \overline{y}_{jt} - \triangle c_{jt} &= (1-\gamma) \triangle y_t - \triangle c_t + \gamma \triangle \overline{y}_{jt} - \eta_{jt} \\ &= -\gamma \triangle y_t + \gamma \triangle \overline{y}_{jt} - \eta_{jt}, \text{ if } \triangle y_t = \triangle c_t \end{aligned} \tag{3.9}$$

where $\eta_{jt} = \gamma (\overline{\varepsilon}_{jt} - \varepsilon_t) = \gamma (1-\lambda) (\varepsilon_{jt} - \varepsilon_t)$.

By comparing equations (3.7) with equations (3.8) or equations (3.9), we can see that the procedure to estimate the degree of risksharing is very similar.[15] The main

[15] The aggregate income change in equations (3.9), can be captured with the time-fixed effect in equations (3.7). In fact, Asdrubali, Sorensen, and Yosha (1996) stated that the time fixed effect is introduced to control the aggregate effect.

difference comes from the procedure to estimate the degree of intertemporal consumption smoothing. First, in past studies $\triangle y_{jt}$ is used as a regressor, whereas $\triangle \overline{y}_{jt}$ is used as a regressor in the current setup. Intuitively, consumers smooth consumption given disposable income, rather than given domestic income. Therefore, past studies' estimates of β_3 can be regarded as the correct estimate of the degree of intertemporal consumption smoothing only if risksharing is null ($\lambda = 0$). To infer how the results would be biased if we used domestic income instead of disposable income, we further modify the third equation in (3.9) by using equation (2.1).

$$\begin{aligned} \triangle \overline{y}_{jt} - \triangle c_{jt} &= (1 - \gamma + \gamma\lambda) \triangle y_t - \triangle c_t + \gamma (1 - \lambda) \triangle y_{jt} - \eta_{it} \\ &= (-\gamma + \gamma\lambda) \triangle y_t + \gamma (1 - \lambda) \triangle y_{jt} - \eta_{it}, \text{ if } \triangle y_t = \triangle c_t. \end{aligned} \tag{3.10}$$

The above equation suggests that the results would be biased downward if there was non-zero risksharing; the more risksharing there is, the larger the downward bias. Second, in the current set up, IV estimation may be more appropriate since the error terms may be correlated with the regressor. In other words, past studies did not allow for the possibility that consumption might depend on permanent income or for the possibility that current income might be different from permanent income.[16]

We estimate equations (3.8) by running a pooled regression. The first two equations are estimated by OLS while the last equation is estimated by IV methods. As instruments, we use own lagged variables, lagged values of $\triangle c_{jt} - \triangle c_t$, lagged values of $\triangle y_{jt} - \triangle y_t$, lagged values of $\triangle \widetilde{y}_{jt} - \triangle y_t$, and lagged values of saving, $s^1_{jt} - s^1_t$ (where $s^1_{jt} = \widetilde{y}_{jt} - c_{jt}$). We include at least the second and the third lags of the instruments.

The two methods of estimating the degree of risksharing and the degree of intertemporal consumption smoothing are complementary. The single equation method, represented by equation (2.5), can be implemented without data on national or disposable income, but might be subject to a multi-collinearity problem (if $\triangle c_t$ and $\triangle y_{jt}$ are correlated). In addition, if aggregate domestic income shocks generate a positive comovement of aggregate income and individual income, individual consumption and aggregate consumption can be correlated and λ can be positive even without any risksharing. On the other hand, the channel method, represented by equations (3.8), can avoid the multi-collinearity issue but is problematic in the absence or poor quality of data on national and disposable income.

4. Empirical Results

We estimate both models by using data for 50 US states (1963-1990, annual data) and 22 OECD and 15 EU countries (1960-1990, annual data).[17] For data sources and details on data construction, refer to Asdrubali, Sørensen, and Yosha (1996) and Asdrubali and Kim (2004).

[16] On the other hand, channels studies were typically based on an accounting identity that yielded parsimonious restrictions, very useful as a first approximation to a decomposition of smoothing channels.

[17] OECD data are limited to 1990 to avoid issues related to the German unification structural break.

Region	Instruments	$\widetilde{\boldsymbol{\mu}}$	γ	$\boldsymbol{\lambda}$	$\boldsymbol{\gamma = 1}$	$\boldsymbol{\gamma = 0}$	$\boldsymbol{\lambda = 1}$	$\boldsymbol{\lambda = 0}$
US	2,3 lags	-0.02 (0.10)	0.41 (0.23)	0.53 (0.18)	10	23	10	11
US	2,3 lags		0.45 (0.27)	0.65 (0.17)	16	14	14	1
US	2-4 lags	-0.05 (0.42)	0.40 (0.25)	0.63 (0.19)	10	17	11	5
US	2-4 lags		0.34 (0.20)	0.64 (0.18)	9	21	9	1
US	2-5 lags	0.02 (0.21)	0.36 (0.21)	0.62 (0.22)	10	18	7	2
US	2-5 lags		0.32 (0.20)	0.64 (0.19)	9	22	8	0
OECD	2,3 lags	0.003(.010)	0.17 (0.08)	0.51 (0.15)	0	12	2	1
OECD	2,3 lags		0.16 (0.15)	0.50 (0.12)	1	7	2	0
OECD	2-4 lags	0.004(.008)	0.22 (0.10)	0.46 (0.15)	1	10	1	0
OECD	2-4 lags		0.11 (0.08)	0.46 (0.10)	0	9	2	0
OECD	2-5 lags	0.006(.005)	0.21 (0.13)	0.38 (0.15)	0	6	1	1
OECD	2-5 lags		0.10 (0.07)	0.45 (0.10)	0	9	1	0
EU	2,3 lags	-0.004 (0.024)	0.21 (0.12)	0.58 (0.12)	1	7	2	1
EU	2,3 lags		0.13 (0.09)	0.51 (0.13)	1	7	0	0
EU	2-4 lags	0.006 (0.007)	0.19 (0.13)	0.43 (0.16)	0	6	1	1
EU	2-4 lags		0.16 (0.07)	0.53 (0.10)	0	7	1	0
EU	2-5 lags	0.004 (0.006)	0.19 (0.09)	0.41 (0.12)	0	6	2	0
EU	2-5 lags		0.15 (0.10)	0.52 (0.09)	0	5	2	0

Table 4.1: Model 1 (single equation method, equation (2.5)). IV estimates of the degree of intertemporal smoothing γ (column 4), the degree of risksharing λ (column 5), the intercept $\widetilde{\mu}$ (column 3), with number of lags of the instruments in column 2. Also reported are estimates when $\widetilde{\mu} = 0$. Last four columns indicate the number of times the restrictions $\gamma = 1$, $\gamma = 0$, $\lambda = 1$, $\lambda = 0$ are binding, respectively.

4.1. Single-equation method

Table 4.1 shows the results of the single equation method, estimating equation (2.5). We report the results of using 2-3 lags, 2-4 lags, and 2-5 lags of the instruments (for saving, only the second lag is used in all cases) in Table 4.1. Since the constant term, $\widetilde{\boldsymbol{\mu}}$, often turns out to be statistically insignificant, we also estimate the model by assuming $\widetilde{\boldsymbol{\mu}} = 0$. The table also reports the number of cases that the restrictions on γ and λ are binding.

The first noteworthy result is that the degree of risksharing is higher among the US states than across the OECD countries; the estimated λ is 0.53–0.65 for US states but 0.38–0.51 for the OECD countries and 0.41–0.58 for the EU countries. This result is consistent with studies that found a higher degree of risksharing within a country than across countries, such as Sørensen and Yosha (1998), Asdrubali and Kim (2004), Crucini and Hess (2000), and Crucini (1999).

Second, the degree of intertemporal consumption smoothing is also higher in the US states than in the OECD and EU countries; the estimated $\boldsymbol{\gamma}$ is 0.32–0.45 for the US but 0.10–0.22 for the OECD and 0.13–0.21 for the EU.

To compare our method to those used by others, we estimate equation (2.7) ("Ob-

	Obstfeld	**Crucini, RW**	**Crucini, AR-1**	**General, AR-1**
US	0.74 (0.21)	0.73 (0.20)	0.86 (0.12)	0.77 (0.11)
OECD	0.52 (0.14)	0.49 (0.14)	0.69 (0.10)	0.54 (0.08)
EU	0.52 (0.15)	0.49 (0.15)	0.69 (0.10)	0.54 (0.10)

Table 4.2: Model 2 (single equation methods, equations (2.7), (2.9) with $\alpha = 0$, (2.10) with $\gamma = 1$, and (2.10) with $0 \leq \gamma \leq 1$): comparison of λ estimates

stfeld"), equation (2.7) with $\widetilde{\mu} = 0$ or equation ("Crucini, RW"), equation ("Crucini, AR-1"), and equation ("General, AR-1"). For the last two estimations, we first estimate ρ, then use the estimate in the main regression. Table 4.2 reports the estimate for $\boldsymbol{\lambda}$ in each case.

The method assuming no intertemporal consumption smoothing ("Obstfeld" or "Crucini, RW") tends to give a higher estimate of $\boldsymbol{\lambda}$ for both, and more for the US state case. The method assuming full intertemporal consumption smoothing ("Crucini, RW" and "Crucini, AR-1") also gives a higher estimate for both. The method allowing possibility of partial intertemporal consumption smoothing under the assumption that domestic income follows an AR-1 process ("General, AR-1") also provides a higher estimate of λ for both, and slightly more for the US state case. Overall, all these methods suggest that the degree of risksharing in the US states is larger than in the OECD (EU) countries. That is, although different assumptions on the degree of intertemporal consumption smoothing yield different estimates of λ, the relative ranking of the degree of intertemporal consumption smoothing within the US states and within the OECD (and EU) countries is the same.

4.2. Channels method

Table 4.3 reports the results of the channels method, which we apply by estimating equations (3.8). As documented by other channel studies, we find that the extent of risksharing is far larger in the US states than in the OECD and EU countries. Interestingly, the estimated value of γ is 0.64–0.78 for the US states, but only 0.57–0.61 for OECD countries and 0.30–0.46 for EU countries, which implies that the degree of intertemporal consumption smoothing is larger in the US states than in the OECD and in the EU countries, consistently with the results of our previous regression. However, this result is different from past channel studies that report a higher degree of intertemporal consumption smoothing in the OECD or EU countries than in the US states (Sørensen and Yosha, 1998 and Asdrubali and Kim, 2004), while it agrees with other studies (such as Sørensen and Yosha, 2000) that use consumption regressions developed by Hall (1978), Campbell and Deaton (1989), Deaton (1992), Østergaard, Sørensen, and Yosha (2002).

One reason that other channel studies often found the opposite result might lie in their use of domestic income (GDP), instead of disposable income (GDI), as a regressor, although consumers should smooth consumption intertemporally based on the latter. A high degree of risksharing within a country would bias the estimated degree of intertemporal smoothing significantly downward, driving to a conclusion

	$\boldsymbol{\lambda}_1$	$\boldsymbol{\lambda}_2$	**γ, 2,3 lags**	**γ, 2-4 lags**	**γ, 2-5 lags**
US	0.41 (0.01)	0.12 (0.01)	1.04 (0.29)	1.17 (0.23)	0.98 (0.20)
OECD	0.02 (0.02)	0.00 (0.01)	0.27 (0.20)	0.23 (0.19)	0.15 (0.18)
EU	0.05 (0.02)	0.00 (0.01)	0.86 (0.25)	0.47 (0.18)	0.40 (0.16)

Table 4.3: Model 3 (channels method, equations (3.8)). Estimates of risksharing through portfolio diversification λ_1 (column 2), risksharing through fiscal stabilizers λ_2 (column 3), intertemporal consumption smoothing γ (columns 4, 5, 6)

	$\triangle\mathbf{y}_{jt}$	$\triangle\overline{y}_{jt}$
US	0.30 (0.03)	0.64 (0.04)
OECD	0.43 (0.03)	0.53 (0.02)
EU	0.42 (0.04)	0.55 (0.03)

Table 4.4: Model 4 (channels models, third equation in (3.8)): comparison of OLS estimates of γ when regressor is $\triangle y_{jt}$ (GDP) (column 2) and $\triangle\overline{y}_{jt}$ (GDI) (column 3)

that the degree of intertemporal consumption smoothing within a country is low. Another reason for the discrepancy might be that other channel studies considered only current income changes, even though intertemporal consumption smoothing is related to permanent income changes that are often different from current income changes.[18]

To explore the issue, we run some pooled OLS regressions that modify the third equation in (3.8), and report the results in Table 4.4. The second and the third columns report the pooled OLS estimate of $\boldsymbol{\gamma}$ when the regressor is $\triangle y_{jt}$ (GDP) and $\triangle\overline{y}_{jt}$ (GDI), respectively. When the instrument is not used and GDP is adopted as a regressor, the γ estimate is higher for OECD (EU) countries than for US states. When the regressor changes to GDI, the γ estimate for US states becomes far larger, and the opposite result is found: the γ estimate is lower for OECD (EU) countries than for US states. These results are consistent with the above conjecture that using domestic income may cause the significant downward bias in the U.S. estimate. On the other hand, using disposable income, without considering permanent income by estimating the equation by OLS, still yields a different estimate for each case. This result is consistent with the other point we have made that permanent income changes are relevant for intertemporal consumption smoothing but may be different from current income changes.

An interesting econometric issue arises from the fact that the exact estimates of γ and λ tend to be different for the two empirical methods (the single equation method, estimating equation (2.5) and the channel method, estimating equations (3.8); the estimate of λ is higher but the estimate of γ is lower in the former than in the latter. Aggregate income shocks may generate a positive comovement of country and aggregate consumption even without risksharing, which implies that λ may be positively

[18]Del Negro (1998) and Athanasoulis and van Wincoop (2001) are exceptions.

Region	**instruments**	$\widehat{\boldsymbol{\lambda}}$
US	2-4 lags	0.47 (0.16)
US	2-5 lags	0.48 (0.17)
OECD	2-4 lags	0.40 (0.11)
OECD	2-5 lags	0.33 (0.13)
EU	2-4 lags	0.39 (0.10)
EU	2-5 lags	0.33 (0.11)

Table 4.5: Model 5 (single equation method, equation (4.1)): test of the role of aggregate shocks by estimation of $\widehat{\lambda}$

biased in the former.[19] On the other hand, the problem of the data on disposable income, in particular, omissions of some risksharing income flows, may generate a negatively biased estimate of λ in the latter. Further, given consumption and income movements, an underestimated role of risksharing would imply an overestimated role of intertemporal consumption smoothing, that is, a positively biased estimate of γ in the latter.[20] Despite these possible problems, both methods converge on the relative degree of risksharing and intertemporal consumption smoothing for the intra vs. the international dimension: the degree of risksharing and the degree of intertemporal consumption smoothing are higher within countries than across countries.

To further explore whether a possible comovement of country and aggregate consumption due to aggregate shocks (and possibly multi-collinearity problems) leads to a significantly biased estimate of λ in the single equation method, we estimate the following equation.

$$\triangle c_{jt} = \mu^* + \widehat{\lambda}\triangle\widehat{c}_t + \widehat{\gamma}\triangle y_{jt} + \eta_{jt}. \tag{4.1}$$

where $\widehat{c}_t$ is the estimated residual in the regression: $\triangle c_t = a + b\triangle y_{jt} + e_{jt}$. That is, we replace aggregate consumption changes with aggregate consumption changes that are not correlated to changes in individual income. In this way, we exclude the correlation between $\triangle c_t$ and $\triangle y_{jt}$ — including the correlation generated by aggregate income shocks — in estimating the degree of risksharing $(\widehat{\lambda})$. In addition, the multi-collinearity problem disappears. We report the estimate in Table 4.5.[21]

The results from this modification to the single equation estimation method still show that the degree of risksharing is higher in the US than in the OECD (and EU). The estimated $\widehat{\lambda}$'s tend to be lower than the estimated λ's in the original single equation method but still quite high. Especially, the estimated $\widehat{\lambda}$'s for OECD and EU

[19] We do not find any typical symptom of multi-collinearity problems in the results of the first method.

[20] Such a bias is likely to be more severe in the case of international data; international data on capital market smoothing (using the difference between GNI and GDP) does not include capital gains and losses on net foreign assets. To be consistent, the discrepancy is more severe for the OECD and EU estimates.

[21] The same set of instruments as in the original regression is used except for replacing c with $\widehat{c}$ and changing the definition of aggregate saving correspondingly.

countries (that is, for international data) are still quite higher than the estimated λ's in the channel method. This result may suggest that aggregate shocks (and possible multi-collinearity problems) in the single equation method may not be very serious, and that the inaccuracy of the international data in the channel method may be a more important reason for the discrepancy between the estimates of the two methods.

5. Conclusion

Models of consumption smoothing in open economies have typically assumed two extreme international financial structures: the "bonds only" and the "complete markets" framework (see Baxter and Crucini, 1995 and Baxter, 1995 for a comparison of the two modeling strategies in business cycle studies). In the former, only ex post international borrowing and lending is available to smooth consumption, whereas, in the latter, complete markets in contingent claims allow for consumption buffering through full risksharing of income shocks. Since the evidence seemed to point away from full risksharing or optimal intertemporal smoothing, recent work in empirical open economy macroeconomics has tried estimation either of possibly incomplete risksharing, or of possibly incomplete intertemporal smoothing.

This paper develops a method to estimate a possibly incomplete degree of intertemporal consumption smoothing and a possibly incomplete degree of risksharing jointly, consistently with the theories of risksharing and intertemporal consumption smoothing. This method improves upon past risksharing work featuring extreme assumptions on intertemporal consumption smoothing, as well as on studies that focus only on intertemporal consumption smoothing. In addition, the paper provides some foundations and limitations of empirical analyses on channels of risksharing and consumption smoothing, and suggests a theoretically sounder estimation method as a foundation of the channel literature. The two suggested empirical methods are complementary. By applying both frameworks to US states, OECD and EU countries, we try to draw a robust conclusion on the degree of risksharing and intertemporal consumption smoothing both across countries and within a country.

The main findings are as follows. First, even after allowing for the possibility of partial intertemporal consumption smoothing, the degree of risksharing within a country is larger than across countries, in line with the findings of past studies. Although methods with different assumptions on the degree of intertemporal consumption smoothing provide different estimates for the degree of risksharing in the US states and OECD (EU) countries, all methods predict a higher degree of risksharing in the US states than in the OECD (EU) countries. Second, the degree of intertemporal consumption smoothing within a country is also larger than across countries. Although channel studies often found the opposite, such results may have been obtained as a consequence of improperly measuring the degree of risksharing, and of overlooking the importance for intertemporal consumption smoothing of the difference between permanent income and current income changes.

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