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Fundamentals, information, and international capital flows: A welfare analysis

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Abstract

In the recent discussion surrounding the design of a new international financial architecture, enhancing transparency has widely been proposed as a policy essential for increasing the efficiency of international capital markets. This paper uses a simple two-country (two-agent) general equilibrium model with incomplete markets and production to explore the welfare consequences of an increase in public information about country-specific fundamentals (increase in transparency). An improvement in the quality of information has two effects on the ex ante welfare of individual countries: A direct effect that increases the efficiency of global capital allocation and welfare, and an indirect general equilibrium effect that increases asset price volatility and may decrease welfare. When the degree of risk-aversion is low, at least one country will gain from an increase in information quality. If the degree of risk-aversion is high, then there are robust examples of economies for which an increase in information hurts all countries. The paper also discusses how certain institutional arrangements (international derivative markets, international agency) could ensure that all countries gain from better information by providing insurance against information-induced asset price risk.

JEL classification: D52; D60; G15

Keywords: Information; Welfare; International capital markets; Incomplete markets

1. Introduction

Beginning in the early 1970s, there has been a worldwide trend towards integration of national financial markets resulting in a strong increase in cross-border financial transactions and capital flows. More recently, capital flows from industrial countries

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to emerging market economies have dramatically surged.[1] In the wake of the recent financial market crises, policy makers and prominent academics have made several proposals for a "new international financial architecture". Although opinions on the exact nature of this new architecture differ, there seems to be almost unanimous agreement on at least one point: Information about country-specific fundamentals (transparency) has to be improved.[2] This unanimous agreement seems somewhat surprising since it is well-known that with incomplete markets more information may decrease the ex ante welfare of all agents because of its negative impact on risk sharing (Hirshleifer, 1971).[3] However, the previous formal literature on the welfare effect of public information in general equilibrium models has focused on exchange economies, and the neglect of production might have led this literature to overstate the case against information. This paper therefore explores the welfare implications of an increase in the quality of public information within the context of a two-country (two-agent) general equilibrium model with production and incomplete asset markets.

The model is a one-good economy with exponential (CARA) utility functions and normally distributed random variables. Each country has access to a country-specific linear production function with capital as the only input factor. In addition, countries have the opportunity to trade a risk-free bond in competitive markets (international borrowing and lending without default). There are country-specific shocks to economic fundamentals (technology and/or fiscal policy shocks), and countries make investment decisions after they have received a public signal about the future shock realization. This paper derives a closed-form solution for all endogenous variables and uses this solution to discuss how a change in the precision of the signal variable affects the equilibrium values of the bond price (interest rate), capital flows (investment), and welfare (ex ante expected utility of each country).

The analysis shows that an improvement in information quality (more transparency) always leads to an increase in the volatility of capital flows and the bond price (interest rate). In other words, a decrease in the conditional variance of future fundamentals increases the unconditional variance of equilibrium prices and quantities. The net effect on the welfare of individual countries is in general ambiguous since there are two opposing effects: A positive direct effect due to a more efficient global capital allocation, and an indirect general equilibrium effect due to the change in the mean and volatility of the bond price. The indirect effect on welfare may or may not be negative. This paper shows that when agents are not too risk averse, at least one country will gain

[1] See the latest issues of the IMF's World Economic Outlook for a general discussion, and in particular IMF (1995) for more details.

[2] See, for example, Rogoff (1999) and IMF (1999). In accordance with this general view, the IMF and other international organizations have recently taken several concrete steps to increase the availability and quality of information about the fiscal position and other economic fundamentals of individual countries. For example, the IMF has established a general data dissemination standard (GDDS), has developed a "Code of Good Practices of Fiscal Transparency", and is in the process of developing a "Code on Good Practices on Transparency in Monetary and Financial Policies". Moreover, up-to-date information on major macroeconomic variables of 49 countries is now available on the Internet, and the IMF has made strong efforts to increase the transparency of its own operation.

[3] This Hirshleifer effect relies on the assumption that asset markets are incomplete in the sense that they do not provide complete insurance against information-induced asset price movements.

from an increase in information quality. In other words, for low degree of risk-aversion the negative welfare result stressed by the previous general equilibrium literature is not possible. However, if agents are risk-averse enough, then it is still possible that an increase in information quality makes all countries worse off, that is, there is an open set of economies for which more information decreases the welfare of all countries. The proof of this result relies on the fact that for high degree of risk-aversion, the increase in bond price volatility is sufficiently strong to wipe out all potential gains from more information. Thus, even though the explicit treatment of the capital allocation decision strengthens the case in favor of more transparency (more information), policy makers are still well-advised to take into account the possibly harmful general-equilibrium effects of enhanced transparency.

There is a simple economic rationale for the increase in the volatility of international bond prices and capital flows. Consider a basic neoclassical model of the world economy and suppose that the future amount of fiscal spending is the only uncertain macroeconomic variable determining the future economic performance of individual countries. Suppose further that each country's level of fiscal spending is drawn from an i.i.d. process with distribution known to all agents (the rational expectations hypothesis). If in each period only the current level of fiscal spending is observed, then expectations about future economic fundamentals do not vary over time. Thus, investors' demand for internationally traded bonds is constant implying constant values for equilibrium bond prices and capital flows – the case of zero volatility. If, however, the government of a particular country releases in each period some information about its projected future fiscal position, then investors' expectations, and therefore the equilibrium values of financial market prices and capital flows, will vary over time – the case of positive volatility. Hence, the decision of the government to increase fiscal transparency has led to an increase in the volatility of bond prices and capital flows.

The preceding welfare discussion assumes that agents cannot fully insure against information-induced bond-price risk: With full insurance, agents do not worry about bond-price movements, and the welfare effect of more information is always positive. Although this paper is mainly concerned with the consequences of increases in information quality when markets for information-induced risk are incomplete, it also discusses how certain institutional arrangements could ensure that all countries will gain from an increase in information by providing the missing insurance opportunities. One such arrangement is an international financial system in which all agents have the opportunity to trade a complete set of securities with news-contingent payoffs before the arrival of news. Clearly, in reality there are few, if any, securities whose payoffs vary directly with news about economic fundamentals of a country. Moreover, the number of securities must be in general very large, namely as large as the number of possible news realizations. For the economy considered in this paper, however, a few derivative contracts suffice even though there are "many" (a continuum of) news realizations. More precisely, it is shown that if all countries have the opportunity to trade three securities whose payoffs depend in a non-linear but differentiable fashion on the bond price (interest rate), then all countries will gain from enhanced transparency. Finally, this paper shows that even without derivative markets, all countries gain from an increase in information quality if an international agency makes transfer payments (provides concessional loans) to countries experiencing news-induced capital outflows.

Following the early contribution by Hirshleifer (1971), several papers have studied the welfare effects of public information in general equilibrium models (Berk and Uhlig, 1993; Danthine and Moresi, 1993; Eckwert and Zilcha, 2003; Green, 1981; Orosel, 1996; Schlee, 2001).[4] However, with the exception of Eckwert and Zilcha (2003) this literature has confined attention to pure exchange economies, and has therefore ruled out by assumption any positive effect of information on the allocation of capital. Eckwert and Zilcha (2003) consider an economy in which all tradable assets are priced in a risk neutral way, and show that information about non-tradable risk always has a positive social value. In contrast, this paper follows the macroeconomic asset pricing literature (Lucas, 1978; Mehra and Prescott, 1985)[5] and assumes that agents are risk averse. As shown in this paper, the assumption of risk averse asset pricing implies that information about non-tradable risk (productivity or fiscal policy risk) might have a negative effect on social (world) welfare since it increases asset price volatility.

2. The model

The structure of the model is as follows. There is one good which can be used for consumption or production purposes. There are two countries each of which has access to a country-specific constant returns to scale technology. Capital is the only factor of production so that production functions are simply linear.[6] There are two periods. There is no first-period production and no first-period consumption. The only choice to be made in the first period is to decide how much of the initial endowment of the good (the initial capital stock) should be invested domestically and how much should be used to buy a risk-free bond (international borrowing and lending without default, currency, or inflation risk). Bonds are in zero net supply so that in equilibrium one country's decision to buy bonds is another country's decision to sell bonds. First-period decisions are made after information about total factor productivity of the home country is made public.[7] In the second period, each country consumes the output produced domestically, the domestic capital stock, and the net factor payments from abroad

[4] There is also related work on allocational efficiency in rational expectations models with private information (Citanna and Villanacci, 2000; Krebs, 1999a; Laffont, 1985; Messner and Vives, 2001) and on insider trading (Leland, 1992; Dow and Rahi, 2001; Medrano and Vives, 2002). Morris and Shin (2002) study the value of public information in a game-theoretic context with private information. Finally, Calvo and Mendoza (2000) analyze the effect of public information on international capital flows in a model with exogenous interest rate (asset prices).

[5] See, for example, Constantinides (2002) for a recent survey of the literature.

[6] This linear production function is best interpreted as the reduced form of a more sophisticated model of production (for example with physical and human capital). See also Obstfeld (1994) for one example how a simple stochastic "AK-model" allows for a fruitful analysis of international financial integration.

[7] To streamline the analysis, the formal model disregards (random) fiscal spending. The model laid out in this chapter is isomorphic to a model with random productivity shocks and random fiscal spending shocks if fiscal spending is proportional to the second-period capital stock. In this case, A_i has to be interpreted as total factor productivity net of fiscal spending (as a fraction of K_i).

(which can be negative). All random variables are normally distributed and preference are of the CARA-type.[8]

2.1. Choice set and information structure

The two countries are called Home and Foreign. Home's variables are indexed by h and Foreign's variables are indexed by f. Each country is endowed with a first-period capital stock K_{0i}, $i=\mathrm{h},\mathrm{f}$. Second-period capital is denoted by K_i and we assume no depreciation so that $K_i = X_i + K_{0i}$, where X_i is gross domestic investment of country i. Second-period production is given by $Y_i = A_i K_i$, where total factor productivity A_i is a random variable whose realization is not observed in the first period. The two random variables A_h and A_f are normally and independently distributed with (unconditional) means $\bar{\mu}_\mathrm{h}$, $\bar{\mu}_\mathrm{f}$ and (unconditional) variances $\bar{\sigma}_\mathrm{h}^2$, $\bar{\sigma}_\mathrm{f}^2$.

In the first period, both countries make their investment decisions after receiving public information about Home's future productivity. More formally, we assume that both countries observe the realization, s, of a normally distributed random variable, S, that is correlated with A_h but uncorrelated with A_f. The exact joint distribution of S and A_h will be specified below.

Let the quantity of bonds purchased by country i be denoted by B_i. Of course, B_i is simply the current account balance. Further, denote the private consumption of country i by C_i and the interest rate (the inverse of the bond price minus one) by r. Using this notation, the first- and second-period budget constraints of each country read

$$X_i(s) + B_i(s) = 0,$$

$$C_i(s, A_i) = (1 + A_i)(K_{0i} + X_i(s)) + (1 + r(s))B_i(s). \tag{1}$$

Combining the first- and second-period budget constraint yields

$$C_i(s, z_i) = (1 + z_i)(K_{0i} - B_i(s)) + (1 + r(s))B_i(s). \tag{2}$$

For the sake of concreteness, we assume that the signal S is the sum of two random variables: The deviation of A_h from its mean plus a normally distributed noise term

$$S = (A_\mathrm{h} - \bar{\mu}_\mathrm{h}) + \varepsilon, \qquad \mathrm{E}\varepsilon = 0, \qquad \mathrm{E}[(A_\mathrm{h} - \bar{\mu}_\mathrm{h})\varepsilon] = 0, \tag{3}$$

where $\mathrm{E}[X]$ stands for the expected value of the random variable X. The specification (3) implies that S and A_h are jointly normally distributed with mean vector and variance/covariance matrix given by

$$\mu = \begin{pmatrix} 0 \\ \bar{\mu}_\mathrm{h} \end{pmatrix}, \qquad \Sigma = \begin{pmatrix} \bar{\sigma}_\mathrm{h}^2 + \sigma_\varepsilon^2 & \bar{\sigma}_\mathrm{h}^2 \\ \bar{\sigma}_\mathrm{h}^2 & \bar{\sigma}_\mathrm{h}^2 \end{pmatrix}. \tag{4}$$

[8] The assumption of CARA-utility function and normally distributed returns is frequently employed when closed-form solutions are desired, but has its obvious drawbacks: Any non-negativity constraint is violated with some positive probability and individual demand functions for risky assets are wealth independent.

For the derivation of Home's investment decision, the conditional mean, $\mu_{\mathrm{h}}(s) \equiv \mathrm{E}[A_{\mathrm{h}} \mid s]$, and variance, $\sigma_{\mathrm{h}}^2 \equiv var[A_{\mathrm{h}} \mid s]$, will be of importance (see below). From (4) we can calculate these conditional moments:

$$\mu_{\mathrm{h}}(s) = \bar{\mu}_{\mathrm{h}} + \frac{\bar{\sigma}_{\mathrm{h}}^2}{\bar{\sigma}_{\mathrm{h}}^2 + \sigma_{\varepsilon}^2} s, \qquad \sigma_{\mathrm{h}}^2 = \frac{\bar{\sigma}_{\mathrm{h}}^2 \sigma_{\varepsilon}^2}{\bar{\sigma}_{\mathrm{h}}^2 + \sigma_{\varepsilon}^2}. \tag{5}$$

Notice that even though the conditional variance differs from the unconditional variance, it does not vary with the signal s. The variance of the noise term, σ_{ε}^2, is a measure of the informational content of the information variable S. The smaller the noise term σ_{ε}^2, the more informative the signal variable, that is, the smaller the forecast error σ_{h}^2. In the limit $\sigma_{\varepsilon}^2 \to 0$, countries have perfect foresight about Home's output at the time of decision making (no uncertainty), $\sigma_{\mathrm{h}}^2 \to 0$, but there are still random fluctuations in Home's output.

We denote the conditional mean and variance of Foreign's variables by μ_{f} and σ_{f}^2, respectively. Since there is no information about Foreign's variables forthcoming, in this case conditional and unconditional moments are the same: $\mu_{\mathrm{f}} = \bar{\mu}_{\mathrm{f}}$, $\sigma_{\mathrm{f}}^2 = \bar{\sigma}_{\mathrm{f}}^2$.

2.2. Preferences

There is one representative agent for each country. The representative agent of each country has preferences defined over random consumption streams which allow for an expected utility representation with CARA utility function:

$$\mathrm{E}[U_i] = \mathrm{E}\left[-\frac{1}{\phi}\mathrm{e}^{-\phi C_i}\right],$$

$$\mathrm{E}[U_i \mid s] = \mathrm{E}\left[-\frac{1}{\phi}\mathrm{e}^{-\phi C_i} \mid s\right]. \tag{6}$$

For simplicity, the coefficient of absolute risk aversion, ϕ, is assumed to be common across countries. We will call $\mathrm{E}[U_i \mid s]$ the interim expected utility (welfare) of country i and $\mathrm{E}[U_i]$ the ex ante expected utility (welfare) of country i.

2.3. Equilibrium

Each country chooses a signal-dependent bond trading plan $B_i = B_i(s)$ which maximizes ex ante expected utility (6) subject to the (sequential) budget constraint (2). Of course, the maximization problem of each individual country is simply a static two-asset portfolio choice problem with normally distributed returns and CARA utility function. The optimal bond-trading and capital-allocation plan for each country is therefore

$$B_h(s) = K_{0h} - \frac{\mu_h(s) - r(s)}{\phi\sigma_h^2}, \quad K_h(s) = K_{0h} - B_h(s),$$

$$B_f(s) = K_{0f} - \frac{\mu_f - r(s)}{\phi\sigma_f^2}, \quad K_f(s) = K_{0f} - B_f(s) \tag{7}$$

and the resulting consumption plan is

$$C_h(s, A_h) = \frac{(A_h - r(s))(\mu_h(s) - r(s))}{\phi\sigma_h^2} + (1 + r(s))K_{0h},$$

$$C_f(s, A_f) = \frac{(A_f - r(s))(\mu_f - r(s))}{\phi\sigma_f^2} + (1 + r(s))K_{0f}. \tag{8}$$

In equilibrium all markets must clear. Because of Walras' law, bond market clearing implies goods market clearing. Thus, when analyzing equilibrium in the world economy we can focus attention on international capital markets – international competitive equilibrium is equivalent to international financial market equilibrium. Bond market equilibrium simply requires

$$B_h(s) + B_f(s) = 0. \tag{9}$$

Because asset demand functions are linear, calculation of an equilibrium is straightforward.[9] Using the demand functions (7) and the market clearing condition (9), we find the following expression for the equilibrium interest rate function (the inverse of the bond price function):

$$r(s) = \frac{\sigma_f^2\mu_h(s) + \sigma_h^2\mu_f}{\sigma_f^2 + \sigma_h^2} - \phi(K_{0h} + K_{0f})\frac{\sigma_h^2\sigma_f^2}{\sigma_h^2 + \sigma_f^2}. \tag{10}$$

The equilibrium bond holdings and capital allocation are given by (7) using expression (10). Moreover, equilibrium consumption is determined by (8) using (10). In short, (7), (8), and (10) constitute an equilibrium of the economy. The next proposition summarizes the preceding discussion:

Proposition 1. *An international financial market equilibrium is given by the equilibrium interest rate* (10) *in conjunction with an equilibrium allocation that is determined by* (7) and (8) *using* (10).

At this stage, a comment regarding modeling strategy seems in order. The subsequent welfare analysis heavily relies on the closed-form solution for an equilibrium as specified in the Proposition 1, and this closed-form solution is derived exploiting the joint assumption of exponential utility functions and normally distributed random variables. Although such a framework has been widely used by the literature on rational

[9] Uniqueness of equilibrium is an issue not addressed in this paper. Clearly, the equilibrium analyzed here is the only linear equilibrium.

expectations equilibrium with private information, the particular specification of the model used here is new in the sense that the previous literature has either focused on exchange economies (Grossman and Stiglitz, 1980; Hellwig, 1980)[10] or assumed the existence of one risk-neutral agent pinning down the price of all traded assets (Kyle, 1985; Rahi, 1995).[11] As already discussed in Section 1, either assumption rules out the type of welfare effect that lies at the heart of the current analysis. More specifically, in an exchange economy there is no investment decision, and therefore no effect of information on the capital allocation. Moreover, if traded assets are priced in a risk-neutral way, then information about the return on one asset cannot affect the return volatility of another asset.

3. Information and welfare

In the model, an increase in information means a reduction in the noise term σ_ε^2, holding the unconditional first and second moments fixed. Since $\sigma_{\mathrm{h}}^2 = \bar{\sigma}_{\mathrm{h}}^2\sigma_\varepsilon^2/(\bar{\sigma}_{\mathrm{h}}^2 + \sigma_\varepsilon^2)$, a reduction in σ_ε^2 amounts to a reduction in the forecast error σ_{h}^2. For simplicity, the comparative statics results are immediately stated in terms of changes in the forecast error σ_{h}^2.

As a first step towards the final goal of a comprehensive welfare analysis, we will compute the volatility of interest rates and capital flows. From (10) we conclude that the interest rate volatility, $\sigma_r^2 \doteq \mathrm{var}[r(s)]$, is given by

$$\sigma_r^2 = \frac{\sigma_{\mathrm{f}}^2}{(\sigma_{\mathrm{h}}^2 + \sigma_{\mathrm{f}}^2)^2}\,\sigma_\mu^2, \tag{11}$$

where the volatility

$$\sigma_\mu^2 \doteq \mathrm{var}[\mu_{\mathrm{h}}(s)] = \bar{\sigma}_{\mathrm{h}}^4\left(\bar{\sigma}_{\mathrm{h}}^2 + \frac{\sigma_{\mathrm{h}}^2}{1 - \sigma_{\mathrm{h}}^2/\bar{\sigma}_{\mathrm{h}}^2}\right)^{-1} \tag{12}$$

is derived from (5). Using (7), we find the following expression for the capital flow volatility:

$$\sigma_{\mathrm{b}}^2 \doteq \mathrm{var}[B_{\mathrm{f}}(s)] = \mathrm{var}[B_{\mathrm{h}}(s)] = \frac{1}{\phi^2\sigma_{\mathrm{f}}^4}\sigma_r^2. \tag{13}$$

[10] The literature on exchange economies (Grossman and Stiglitz, 1980; Hellwig, 1980) has usually made the additional assumption that the endowment (output) vector lies in the span of traded assets. This spanning assumption implies that the equilibrium allocation for the corresponding no-information economy is Pareto efficient if preferences exhibit linear risk tolerance (Magill and Quinzii, 1996), which in turn implies that for the original economy with information the ex ante Pareto efficient allocations are information-independent (Schlee, 2001).

[11] Wang (1994) analyzes a model with exogenous interest rate, one risky investment opportunity (production), and one traded asset with risky payoffs (stocks). An extended version of his model could be used to study how information about country-specific shocks affects stock price volatility and welfare. Such an analysis, however, is complicated by the fact that the equilibrium stock price is determined by a non-linear equation.

Eqs. (11) and (13) express the interest rate volatility and capital flow volatility as functions of information quality: $\sigma_r^2 = \sigma_r^2(\sigma_\mathrm{h}^2)$ and $\sigma_\mathrm{b}^2 = \sigma_\mathrm{b}^2(\sigma_\mathrm{h}^2)$. Straightforward differentiation of (11) taking into account (12) shows that $\mathrm{d}\sigma_r^2/\mathrm{d}\sigma_\mathrm{h}^2 < 0$. From (13) it then immediately follows that $\mathrm{dvar}[B_\mathrm{h}]/\mathrm{d}\sigma_\mathrm{h}^2 < 0$. Hence, better information leads to higher interest rate (bond price) and capital flow volatility.

We now turn to the calculation of interim and ex ante expected utility, which is somewhat cumbersome, but still possible without approximation (the results are exact given the assumptions already made). In order to derive the expression for interim expected utility, one uses direct integration or, equivalently, the formula for the moment generating function of a normal distribution. This yields

$$\mathrm{E}[U_\mathrm{h}\,|\,s] = -\frac{1}{\phi}\exp\left(-\phi K_{0\mathrm{h}}(1+r(s)) - \frac{1}{2\sigma_\mathrm{h}^2}(\mu_\mathrm{h}(s)-r(s))^2\right),$$

$$\mathrm{E}[U_\mathrm{f}\,|\,s] = -\frac{1}{\phi}\exp\left(-\phi K_{0\mathrm{f}}(1+r(s)) - \frac{1}{2\sigma_\mathrm{f}^2}(\mu_\mathrm{f}-r(s))^2\right). \tag{14}$$

Finally, ex ante expected utility is calculated by integrating (14) over signal realizations s. After some tedious substitutions and integrations or, equivalently, after exploiting results on the moment generating function of a χ^2-distribution, we find:

$$\mathrm{E}[U_\mathrm{f}] = -\frac{1}{\phi}\frac{1}{\sqrt{1+\sigma_r^2/\sigma_\mathrm{f}^2}}\exp\left(-\phi K_{0\mathrm{f}}(1+\bar{r}) - \frac{1}{2\sigma_\mathrm{f}^2}(\mu_\mathrm{f}-\bar{r})^2 + \frac{((1/2\sigma_\mathrm{f}^2)(\mu_\mathrm{f}-\bar{r}) - \phi K_{0\mathrm{f}})^2}{2(\frac{1}{\sigma_r^2}+\frac{1}{\sigma_\mathrm{f}^2})}\right),$$

$$\mathrm{E}[U_\mathrm{h}] = -\frac{1}{\phi}\frac{1}{\sqrt{1+\frac{(\sigma_r-\sigma_\mu)^2}{\sigma_\mathrm{h}^2}}}\exp\left(-\phi K_{0\mathrm{h}}(1+\bar{r}) - \frac{1}{2\sigma_\mathrm{h}^2}(\bar{\mu}_\mathrm{h}-\bar{r})^2 + \frac{((\bar{\mu}_\mathrm{h}-\bar{r})\frac{(\sigma_r-\sigma_\mu)}{\sigma_\mathrm{h}^2} + \sigma_r\phi K_{0\mathrm{h}})^2}{2(1+\frac{(\sigma_r-\sigma_\mu)^2}{\sigma_\mathrm{h}^2})}\right), \tag{15}$$

where $\sigma_r^2 \doteq \mathrm{var}[r(s)]$ and $\sigma_\mu^2 = \mathrm{var}[\mu_\mathrm{h}(s)]$ are given by (11) and (12), respectively, and the mean interest rate, $\bar{r} \doteq E[r(s)]$, is easily calculated using (10):

$$\bar{r} = \frac{\sigma_\mathrm{f}^2\bar{\mu}_\mathrm{h} + \sigma_\mathrm{h}^2\mu_\mathrm{f}}{\sigma_\mathrm{f}^2+\sigma_\mathrm{h}^2} - \phi(K_{0\mathrm{h}}+K_{0\mathrm{f}})\frac{\sigma_\mathrm{h}^2\sigma_\mathrm{f}^2}{\sigma_\mathrm{h}^2+\sigma_\mathrm{f}^2}. \tag{16}$$

A welfare analysis can be conducted by using either ex ante expected utility (averaging over s and z_i) or interim expected utility (averaging only over z_i) or ex post utility (no averaging) to evaluate the well-being of each country's residents. Clearly, only ex ante welfare depends on the interest volatility. Given that the main objective of this paper is to show that more information might decrease welfare due to its effect on interest rate volatility, the subsequent analysis confines attention to ex ante expected utility.[12] Let $W_{\rm h}(\sigma_{\rm h}^2) = {\rm E}U_{\rm h}(\bar{r}(\sigma_{\rm h}^2), \sigma_{\rm r}^2(\sigma_{\rm h}^2), \sigma_{\rm h}^2)$ and $W_{\rm f}(\sigma_{\rm h}^2) = {\rm E}U_{\rm f}(\bar{r}(\sigma_{\rm h}^2), \sigma_{\rm r}^2(\sigma_{\rm h}^2))$ be the ex ante welfare of each country in equilibrium as a function of the forecast error $\sigma_{\rm h}^2$ as given in (15) We have

$$\frac{{\rm d}W_{\rm f}}{{\rm d}\sigma_{\rm h}^2} = \frac{\partial {\rm E}U_{\rm f}}{\partial \bar{r}}\,\frac{{\rm d}\bar{r}}{{\rm d}\sigma_{\rm h}^2} + \frac{\partial {\rm E}U_{\rm f}}{\partial \sigma_r^2}\,\frac{{\rm d}\sigma_r^2}{{\rm d}\sigma_{\rm h}^2},$$

$$\frac{{\rm d}W_{\rm h}}{{\rm d}\sigma_{\rm h}^2} = \frac{\partial {\rm E}U_{\rm h}}{\partial \bar{r}}\,\frac{{\rm d}\bar{r}}{{\rm d}\sigma_{\rm h}^2} + \frac{\partial {\rm E}U_{\rm h}}{\partial \sigma_r^2}\,\frac{{\rm d}\sigma_r^2}{{\rm d}\sigma_{\rm h}^2} + \frac{\partial {\rm E}U_{\rm h}}{\partial \sigma_{\rm h}^2}. \tag{17}$$

An increase in information has a direct effect and an indirect (general equilibrium) effect on welfare. In our mean-variance framework, the indirect effect can be expressed as changes in the mean and the variance of the interest rate. Differentiation of the expression for Home's ex ante welfare shows that the direct effect is always positive. The two indirect effects cannot be unambiguously signed: Any change in $\bar{r}$ potentially hurts one country (the net-capital importer if $\bar{r}$ increases) and benefits the other country. Moreover, the welfare effect of the increase in σ_r^2 can also be ambiguous: An increase in σ_r^2 increases interest rate risk, but also increases profit opportunities since investment decisions are made after the interest rate is known. However, in the appendix we prove that there are cases in which the volatility effect is negative and strong enough to result in a net-reduction of welfare for both countries. In accordance with economic intuition, such scenarios occur if the risk-aversion parameter ϕ is large enough. Furthermore, this result is robust in the sense that it holds for an open set of economies (parameter values).

Proposition 2. *An increase in information quality always increases interest rate (bond-price) and capital flow volatility. If the degree of absolute risk aversion, ϕ, is low, then better information increases the ex ante welfare of at least one country. If the degree of absolute risk aversion is high enough, then there are robust examples of world economies for which better information reduces the ex ante welfare of both countries.*

We conclude this section with several comments on the robustness of the results stated in Proposition 2 with respect to changes in the modeling assumptions. First, we have assumed that investors only receive information about Home's future productivity. However, this assumption is not essential, and has only been made to streamline the analysis. To see this, consider the general case in which investors observe a signal variable $S_{\rm h}$ that is correlated with $Z_{\rm h}$ and a signal variable $S_{\rm f}$ that is correlated

[12] Clearly, the equilibrium allocation is ex post efficient. The equilibrium allocation is also interim efficient, which is implied by the fact that for a given signal realization, there is only one budget constraint. Hence, an increase in information can never decrease the ex post or interim welfare of all countries.

with Z_{f}.[13] A straightforward extension of the previous argument shows that the equilibrium interest rate is

$$r(s) = \frac{\sigma_{\mathrm{f}}^2 \mu_{\mathrm{h}}(s_{\mathrm{h}}) + \sigma_{\mathrm{h}}^2 \mu_{\mathrm{f}}(s_{\mathrm{f}})}{\sigma_{\mathrm{f}}^2 + \sigma_{\mathrm{h}}^2} - \phi(K_{0\mathrm{h}} + K_{0\mathrm{f}}) \frac{\sigma_{\mathrm{h}}^2 \sigma_{\mathrm{f}}^2}{\sigma_{\mathrm{h}}^2 + \sigma_{\mathrm{f}}^2}. \tag{18}$$

Assuming that S_{h} and S_{f} are uncorrelated, expression (18) implies

$$\sigma_r^2 = \frac{\sigma_{\mathrm{f}}^4}{(\sigma_{\mathrm{h}}^2 + \sigma_{\mathrm{f}}^2)^2} \sigma_{\mu_{\mathrm{h}}}^2 + \frac{\sigma_{\mathrm{h}}^4}{(\sigma_{\mathrm{h}}^2 + \sigma_{\mathrm{f}}^2)^2} \sigma_{\mu_{\mathrm{f}}}^2, \tag{19}$$

where $\sigma_{\mu_{\mathrm{h}}}^2 = \sigma_{\mu_{\mathrm{h}}}^2(\sigma_{\mathrm{h}}^2)$ is given by (12) and $\sigma_{\mu_{\mathrm{f}}}^2 = \sigma_{\mu_{\mathrm{f}}}^2(\sigma_{\mathrm{f}}^2)$ by an analogous expression. Differentiation of (19) shows that an increase in either σ_{h}^2 or σ_{f}^2 will increase σ_r^2. This shows that either type of information leads to an increase in interest rate volatility, and suggests that more information may still reduce world welfare.

For tractability reasons, the analysis had disregarded equity trade, and one might wonder whether the introduction of international stock trading will change the main results. If dividends are perfectly correlated with productivity shocks, then this extension would effectively complete the market structure with respect to fundamental risk. However, information-induced asset price risk is still uninsurable, and the negative welfare effect of information discussed here is therefore still operative. Indeed, there are now two channels through which information might decrease welfare since both bond price risk and stock price risk are likely to increase. Thus, the introduction of international stock trading is unlikely to overturn this paper's main result.

One might also ask whether the results are specific to an international context. The following example suggests that this is not the case. Consider a closed economy with two sectors both of which produce the same homogenous good using production functions that are subject to sector-specific productivity shocks. Suppose further that there are two risk averse households (entrepreneurs) each owning one of the two production functions. Households cannot sell shares of their respective companies, but they may trade a risk-free asset in zero net supply (borrowing and lending at the risk-free rate). Clearly, this model is isomorphic to the two-country model discussed in this paper, and the same results hold.

Finally, how crucial are the parametric assumptions for the results derived in this paper? Clearly, this question can only be answered rigorously by moving beyond the current parametric framework and conducting a non-parametric analysis. Even though such a non-parametric analysis is beyond the scope of the current paper, a few comments might be in order. First, the result that better information increases asset price volatility is likely to hold for a non-negligible class (open set) of economies. Indeed, for complete-market exchange economies Krebs (1999b) shows that information always increases asset price volatility. Second, an increase in asset price volatility has generally the potential to reduce the welfare of all countries. Krebs (1999a)[14] shows

[13] The introduction of two signal variables amounts to the assumption that signals represent information about country-specific shocks.

[14] Some results of Krebs (1999a) are published in Krebs (2001).

that in the case of pure exchange better information reduces social welfare for an open set of economies parameterized by endowment vectors, that is, this result is robust with respect to perturbations of the endowment vector. Extending this non-parametric analysis to the production case is an important topic for future research.

4. Information and insurance

In this section, we discuss different institutional arrangements providing insurance against information-induced bond-price (interest rate) risk and how the existence of such insurance alters our welfare conclusions.

4.1. International agency

We consider first a situation in which an international agency makes transfer payments after the arrival of information. If we denote by $T(s)$ the amount received by the country h if signal s has been received, the new (combined first- and second-period) budget constraints for Home and Foreign read

$$\begin{aligned} C_{\mathrm{h}}(s,z_{\mathrm{h}}) &= (1+z_{\mathrm{h}})(K_{0\mathrm{h}}+T(s)-B_{\mathrm{h}}(s))+(1+r(s))\,B_{\mathrm{h}}(s), \\ C_{\mathrm{f}}(s,z_{\mathrm{f}}) &= (1+z_{\mathrm{f}})(K_{0\mathrm{f}}-T(s)-B_{\mathrm{f}}(s))+(1+r(s))\,B_{\mathrm{f}}(s). \end{aligned} \tag{20}$$

Given a transfer policy, an equilibrium is calculated as in the last section. A glance at Proposition 1 shows that the equilibrium interest rate function, $r=r(s)$, is independent of the wealth distribution. Thus, transfer policies do not change the equilibrium interest rate. From (7) we infer that the equilibrium capital allocation is also unaffected. The equilibrium bond trading plans are given by (7) where $K_{0\mathrm{h}}$ is replaced by $K_{0\mathrm{h}}+T(s)$ and $K_{0\mathrm{f}}$ is replaced by $K_{0\mathrm{f}}-T(s)$.

We assume that the international agency chooses a transfer policy that maximizes ex ante world welfare given by the weighted average of each country's ex ante welfare. That is, we assume that the optimal transfer policy is the solution to the following (constrained) social planner problem (using expression (14) for interim welfare):

$$\begin{aligned} \underset{T(.)}{\mathrm{Max}} \Bigg\{ &-\frac{\gamma_{\mathrm{h}}}{\phi}\int_{-\infty}^{\infty}\exp\left(-\phi(K_{0\mathrm{h}}+T(s))(1+r(s))-\frac{(\mu_{\mathrm{h}}(s)-r(s))^2}{2\sigma_{\mathrm{h}}^2}\right)\pi(s)\,\mathrm{d}s \\ &-\frac{\gamma_{\mathrm{f}}}{\phi}\int_{-\infty}^{\infty}\exp\left(-\phi(K_{0\mathrm{f}}-T(s))(1+r(s))-\frac{(\mu_{\mathrm{f}}-r(s))^2}{2\sigma_{\mathrm{f}}^2}\right)\pi(s)\,\mathrm{d}s\Bigg\}, \end{aligned} \tag{21}$$

where $\gamma_{\mathrm{h}}>0$ and $\gamma_{\mathrm{f}}>0$ are the individual welfare weights and $\pi=\pi(s)$ is the density function of a normal distribution with zero mean and variance equal to $\sigma_s^2=\bar{\sigma}_{\mathrm{h}}^2+\sigma_\varepsilon^2$.

Three comments regarding (21) are in order. First, any solution to (21) implements a constrained Pareto efficient consumption allocation. Furthermore, by varying γ_{h} and γ_{f}

we trace out all constrained Pareto efficient consumption allocations.[15] Notice, however, that there are still consumption allocations which dominate the allocations derived from (21) in ex ante terms if one allows for direct redistribution of consumption after the shocks A_f, A_h are realized, which is the reason why we use the term "constrained".

The second comment relates to the interpretation of the transfer policy derived from (21). A straightforward interpretation of (21) is that countries make transfer payments to each other directly without the help of an intermediary. Alternatively, one can think of an international agency that collects lump-sum contributions from both countries before the signal realization and provides financial aid to one of the two countries after the signal-realization. Some basic algebra shows that the provision of financial aid is equivalent to concessional loans (loans at an interest rate below the market rate). Thus, one can also think of the optimal transfer policy (21) as a lending policy.

Lastly, one might ask why an international agency is required at all. Clearly, within the context of the model laid out so far, there is no difference between countries making direct transfer payments to each other and an international agency acting as a financial intermediary. In practice, however, direct transfer payments without the international agency might not be incentive compatible because countries will have an incentive to renege on their contracts. That is, the international agency acts as an enforcement mechanism.

Since (21) is a one-agent decision problem Blackwell's theorem immediately implies that more information about A_h (a reduction in σ_h^2) increases world welfare. Thus, if a reduction in σ_h^2 is accompanied by optimal transfer payments, then the scenario of Section 3, namely that both countries lose, cannot happen. However, it could still be that one country gains and the other loses. This, however, is not possible in our set up as can be seen by writing down the first-order conditions corresponding to the maximization problem (21):[16]

$$\begin{aligned}\gamma_h \exp\left(-\phi(K_{0h} + T(s))(1 + r(s)) - \frac{(\mu_h(s) - r(s))^2}{2\sigma_h^2}\right) \\ = \gamma_f \exp\left(-\phi(K_{0f} - T(s))(1 + r(s)) - \frac{(\mu_f - r(s))^2}{2\sigma_f^2}\right). \qquad (22)\end{aligned}$$

Dividing (22) by ϕ we have $\gamma_h W_h = \gamma_f W_f$, which implies that both W_h and W_f increase when σ_h^2 decreases. Thus, we conclude that if an international agency uses an optimal transfer policy, that is, a transfer policy solving (21), then an increase in information quality always increases the ex ante welfare of both countries.

[15] Since the social planner is allowed to intervene after the arrival of news, this concept of "constrained efficiency" is weaker than the one traditionally used (Diamond, 1967; Geanakoplos and Polemarchakis, 1986) in the sense that in this paper the social planner has a larger choice set.

[16] The objective function is concave and the choice set convex. Thus, if a solution exists, first-order conditions are necessary and sufficient. The simplest way to ensure that a solution to the maximization problem exists is to confine the search for an optimal policy to the normed vector space of twice-continuously differentiable functions $T(.)$ defined on the interval $[\underline{s}, \bar{s}]$. Integration from $-\infty$ to $+\infty$ in (21) can then be viewed as an approximation to the true optimization problem, where the approximation error can be made arbitrarily small.

We can gain additional insight into the nature of the optimal transfer policy by solving (22):

$$T(s)=\frac{1}{2}(K_{0\mathrm{f}}-K_{0\mathrm{h}})+\frac{1}{2\phi(1+r(s))}$$
$$\times\left(\ln\frac{\gamma_{\mathrm{h}}}{\gamma_{\mathrm{f}}}+\frac{(\mu_{\mathrm{f}}-r(s))^2}{2\sigma_{\mathrm{f}}^2}-\frac{(\mu_{\mathrm{h}}(s)-r(s))^2}{2\sigma_{\mathrm{h}}^2}\right). \tag{23}$$

If we consider the symmetric case $K_{0\mathrm{f}}=K_{0\mathrm{h}}$ and $\gamma_{\mathrm{h}}=\gamma_{\mathrm{f}}$, then we have

$$T(s)>0 \quad \text{iff} \quad K_{\mathrm{h}}(s)<K_{0\mathrm{h}}. \tag{24}$$

In other words, Home receives a payment when the news is bad and capital is flowing out of the country and Home has to make a payment when the news is good and capital is flowing into the country.

The characterization of the optimal transfer policy (24) shows that the country experiencing capital outflows should receive compensation. Thus, there is a one-to-one relationship between capital flows and optimal transfer payments, and the optimal transfer policy can therefore be implemented by conditioning payments on capital flows. Since capital flows are more easily observable than signals, this characterization of the optimal transfer policy facilitates the implementation of such policies in practice. Of course, in general multi-period models with random fundamentals capital flows depend not only on signals, but also on shocks to fundamentals, and a simple one-to-one relationship between optimal transfer payments and capital flows can therefore not be expected. However, conditional on the realization of fundamentals, such a one-to-one relationship might still hold. In other words, the optimal transfer policy requires that payments should be made to countries that experience capital outflows without a change in current economic fundamentals, that is, information-induced capital outflows.

4.2. Derivative markets

We now turn to a discussion of market arrangements providing insurance. One possibility would be to imagine that agents trade at date 0 a complete set of securities paying off signal-contingent amounts of the good at date 1. However, there is a much simpler and more realistic market structure yielding the same outcome.

A glance at the optimal transfer payments (23) for $\gamma_{\mathrm{h}}=\gamma_{\mathrm{f}}$ suggests to allow countries to trade at date 0 three securities with payoffs

$$a_1(s)=1,\quad a_2(s)=\frac{(\mu_{\mathrm{f}}-r(s))^2}{1+r(s)},\quad a_3(s)=\frac{(\mu_{\mathrm{h}}(s)-r(s))^2}{1+r(s)}. \tag{25}$$

Notice that the asset payoffs (25) depend on variables that are observable or can be easily estimated.[17] If we allow for redistribution of income at date 0, the date zero

[17] Clearly, in theory it suffices to let countries trade one security with payoffs that are proportional to the optimal transfer payments (23). However, the optimal transfer policy (23) depends on unobservable variables that are difficult to estimate very precisely.

budget constraints are

$$q_1 x_{1\mathrm{h}} + q_2 x_{2\mathrm{h}} + q_3 x_{3\mathrm{h}} = y,$$
$$q_1 x_{1\mathrm{f}} + q_2 x_{2\mathrm{f}} + q_3 x_{3\mathrm{f}} = -y, \tag{26}$$

where q_j denotes the price of security j and x_{ji} the quantity of security j purchased (sold if negative) by agent i. With this market structure, the following security prices,

$$q_1 = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \pi(s,z_i)\, \mathrm{e}^{-C_i(s,z_i)}\, \mathrm{d}z_i\, \mathrm{d}s,$$
$$q_2 = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \pi(s,z_i)\, \frac{(\mu_\mathrm{f} - r(s))^2}{1+r(s)}\, \mathrm{e}^{-C_i(s,z_i)}\, \mathrm{d}z_i\, \mathrm{d}s,$$
$$q_3 = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \pi(s,z_i)\, \frac{(\mu_\mathrm{h}(s) - r(s))^2}{1+r(s)}\, \mathrm{e}^{-C_i(s,z_i)}\, \mathrm{d}z_i\, \mathrm{d}s, \tag{27}$$

and portfolio holdings,

$$x_{1\mathrm{h}} = \tfrac{1}{2}(K_{0\mathrm{f}} - K_{0\mathrm{h}}), \quad x_{2\mathrm{h}} = \frac{1}{4\phi\,\sigma_\mathrm{f}^2}, \quad x_{3\mathrm{h}} = \frac{1}{4\phi\,\sigma_\mathrm{h}^2},$$
$$x_{j\mathrm{f}} = -x_{j\mathrm{h}}, \quad j = 1,2,3, \tag{28}$$

constitute an equilibrium. In (27) the consumption $C_i(s,z_i)$ is the equilibrium consumption when optimal transfer payments (23) are made for $\gamma_\mathrm{f} = \gamma_\mathrm{h}$ and we can use either $i=\mathrm{h}$ or $i=\mathrm{f}$ because of (22). To see that (27) and (28) constitutes an equilibrium, simply observe that by construction markets clear and agents' first-order conditions for derivative trading are satisfied. Furthermore, the transfer y can be chosen so that the budget constraints are satisfied (one of the two budget constraints (26) is redundant because of Walras' law).

By construction, the above equilibrium consumption allocation implied by (28) is identical to the equilibrium allocation that results when an international agency makes optimal transfer payments (23). Since we have already shown that both countries gain from enhanced transparency when signal-contingent transfer payments are chosen optimally, we conclude that both countries gain from enhanced transparency when countries have access to derivative markets at date 0 (allowing for transfer payment at date 0).

Proposition 3. *If countries have the opportunity to insure against information-induced bond-price risk, then an increase in information quality always increases the ex ante welfare of both countries. The following institutional arrangements can provide such insurance*: (i) *an international agency making transfer payments* (*concessional lending*) *or* (ii) *trading of three derivatives with payoffs depending in a non-linear but differentiable fashion on the interest rate* (*bond price*).

We conclude this section with a comment regarding the generality of the "three-security" result. Clearly, this result crucially depends on the form of the optimal transfer payments (23), which in turn depends on the particular mean – variance framework employed here. An interesting question for future research is to study whether a few securities are still sufficient for a more general class of mean – variance models.

5. Conclusion

This paper used a simple neoclassical model of the world economy to discuss the welfare effect of improving transparency. The analysis showed that an increase in the quality of information can reduce the ex ante welfare of all countries because of an increase in bond price volatility. If, however, there are institutions providing insurance against information-induced bond-price risk, then enhancing transparency always makes all countries better off.

Throughout this paper, the increase in information was interpreted as resulting from improvements in the collection and dissemination of macroeconomic data by governments of individual countries. Clearly, the range of applications of the formal analysis is much broader. On an international level, there are several reasons in addition to enhanced transparency why financial integration might increase the quality of publicly available information about country-specific fundamentals.[18] On a national level, the amount of publicly available information about domestic financial market conditions often changes. The analysis conducted in this paper suggests that there is a general relationship between information and the volatility of asset prices which can be tested using financial market data on the national and international level. In this respect, the present theoretical analysis draws attention to a crucial distinction between conditional and unconditional variance not always sufficiently emphasized by the empirical literature: A decrease in the conditional variance of future discount factors and/or asset payoffs increases the unconditional variance of asset prices.

This paper traced out the welfare consequences of an exogenous increase in the quality of publicly available information. The next step in the analysis is to endogenize the choice of information quality. For example, one could imagine that individual governments choose the quality of information strategically taking into account the general equilibrium effects of their choices, and one could ask how the process of international financial integration affects the equilibrium choice of information by governments.[19]

[18] For example, international financial integration is likely to reduce the cost of direct information acquisition because of enhanced transfer of new information technologies across borders, increased competition among private agencies that provide information services, and economies of scale in information production and direct information dissemination (not using market prices). Moreover, there will be more internationally traded assets and fewer asset market distortions so that the number and quality of price signals can be expected to increase.

[19] For this interpretation to make sense, one must assume that countries (agents of individual countries) act competitively when trading in asset markets, but behave strategically when choosing information quality. This combination of competitive with strategic analysis has a long tradition in international trade, where governments choose trade policies strategically taking into account the effect of their actions on world prices that are determined in competitive goods markets (Dixit and Norman, 1979).

Such an extension is beyond the more narrowly defined scope of this paper, but the analysis carried out here might provide a useful starting point for future work on this issue.

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Appendix A.

A.1. Proof of Proposition 2

We begin with the second, more difficult part of the proof of Proposition 2, namely the existence of an open set of economies for which both countries' ex ante welfare decreases when σ_{h}^2 decreases. It suffices to prove the existence of a parameter vector $x = (\bar{\mu}_{\mathrm{h}}, \mu_{\mathrm{f}}, \bar{\sigma}_{\mathrm{h}}^2, \sigma_{\mathrm{f}}^2, K_{0\mathrm{h}}, K_{0\mathrm{f}}, \phi) \gg 0$ such that $(\mathrm{d}W_{\mathrm{h}}/\mathrm{d}\sigma_{\mathrm{h}}^2) > 0$ and $(\mathrm{d}W_{\mathrm{f}}/\mathrm{d}\sigma_{\mathrm{h}}^2) > 0$ when the derivatives are evaluated at x. Robustness follows then immediately from the fact that the functions $W_{\mathrm{h}} = W_{\mathrm{h}}(\sigma_{\mathrm{h}}^2)$ and $W_{\mathrm{f}} = W_{\mathrm{f}}(\sigma_{\mathrm{h}}^2)$are continuously differentiable. We consider the case $(\mathrm{d}\bar{r}/\mathrm{d}\sigma_{\mathrm{h}}^2) = 0$, which holds if and only if

$$\mu_{\mathrm{f}} = \bar{\mu}_{\mathrm{h}} + \phi\sigma_{\mathrm{f}}^2(K_{0\mathrm{f}} + K_{0\mathrm{h}}). \tag{A.1}$$

In what follows, we choose μ_{f} so that (A.1) holds for any $(\bar{\mu}_{\mathrm{h}}, \bar{\sigma}_{\mathrm{h}}^2, \sigma_{\mathrm{f}}^2, K_{0\mathrm{h}}, K_{0\mathrm{f}}, \phi) \gg 0$ (this defines a 6-dimensional submanifold of the 7-dimensional manifold of parameters). Using (A.1), we have

$$\begin{aligned}\frac{\mathrm{d}W_{\mathrm{f}}}{\mathrm{d}\sigma_{\mathrm{h}}^2} &= \frac{\partial \mathrm{E}U_{\mathrm{f}}}{\partial\sigma_r^2}\,\frac{\mathrm{d}\sigma_r^2}{\mathrm{d}\sigma_{\mathrm{h}}^2} \\ &= \frac{1}{\phi}\,\frac{\mathrm{e}^{-\beta_{\mathrm{f}}}}{2\sqrt{1+\sigma_r^2/\sigma_{\mathrm{f}}^2}}\left(\frac{\sigma_{\mathrm{f}}^2}{(1+\sigma_r^2/\sigma_{\mathrm{f}}^2)} - \frac{(\frac{(\mu_{\mathrm{f}}-\bar{r})}{\sigma_{\mathrm{f}}^2} - \phi K_{0k})^2}{(1/\sigma_r^2 + 1/\sigma_{\mathrm{f}}^2)^2}\right)\frac{\mathrm{d}\sigma_r^2}{\mathrm{d}\sigma_{\mathrm{h}}^2},\end{aligned} \tag{A.2}$$

where β_{f} stands for the argument in the exponential function appearing in the expression for W_{f}. Notice that (A.1) implies $\bar{\mu}_{\mathrm{h}} = \bar{r}$.[20] This and (A.1) show that the second term in brackets in (A.2) reads

$$\frac{(\frac{(\mu_{\mathrm{f}}-\bar{r})}{\sigma_{\mathrm{f}}^2} - \phi K_{0\mathrm{f}})^2}{(1/\sigma_r^2 + 1/\sigma_{\mathrm{f}}^2)^2} = \frac{\phi^2 K_{0\mathrm{h}}^2}{(1/\sigma_r^2 + 1/\sigma_{\mathrm{f}}^2)^2}. \tag{A.3}$$

[20] This implies $\mathrm{E}[K_{\mathrm{h}}] = 0$. Since the welfare function is continuously differentiable, our construction also shows that there is an open set of economies for which information reduces world welfare and $\mathrm{E}[K_{\mathrm{h}}] > 0$. Because of the normal distribution assumption, we can never avoid that $K_{\mathrm{h}}(s) < 0$ for some signals s.

Choose now an arbitrary $(\bar{\mu}_{\rm h}, \bar{\sigma}^2_{\rm h}, \sigma^2_{\rm f}, K_{0\rm h}, K_{0\rm f}) \gg 0$ with $K_{0\rm f}(\sigma^2_{\rm h} - 1) + K_{0\rm h}\sigma^2_{\rm h} \neq 0$. Since the volatility term σ^2_r, and therefore also $\mathrm{d}\sigma^2_r/\mathrm{d}\sigma^2_{\rm h}$, is independent of the risk aversion parameter ϕ, we can always find a ϕ large enough (always adjusting $\mu_{\rm f}$ to satisfy (A.1)) so that the second term in (A.2) dominates, that is, $(\mathrm{d}W_{\rm f}/\mathrm{d}\sigma^2_{\rm h}) > 0$ (recall that $(\mathrm{d}\sigma^2_r/\mathrm{d}\sigma^2_{\rm h}) < 0$).

Still assuming (A.1), we have for home

$$\frac{\mathrm{d}W_{\rm h}}{\mathrm{d}\sigma^2_{\rm h}} = \frac{\partial \mathrm{E}U_{\rm h}}{\partial \sigma_r}\frac{\mathrm{d}\sigma_r}{\mathrm{d}\sigma^2_{\rm h}} + \frac{\partial \mathrm{E}U_{\rm h}}{\partial \sigma^2_{\rm h}}. \tag{A.4}$$

As in the argument made above for $\mathrm{d}W_{\rm f}/\mathrm{d}\sigma^2_{\rm h}$, we are interested in the sign of the derivative $\mathrm{d}W_{\rm h}/\mathrm{d}\sigma^2_{\rm h}$ when ϕ becomes large. Noticing again that (A.1) implies $\bar{\mu}_{\rm h} = \bar{r}$, and neglecting terms which become relatively small when ϕ becomes large, we have

$$\frac{\partial \mathrm{E}U_{\rm h}}{\partial \sigma_r}\frac{\mathrm{d}\sigma_r}{\mathrm{d}\sigma^2_{\rm h}} \approx -\frac{\phi K^2_{0\rm h}\,\mathrm{e}^{-\beta_{\rm h}}(\sigma_r(1 + \frac{(\sigma_\mu-\sigma_r)^2}{\sigma^2_{\rm h}}) + \frac{\sigma^2_r(\sigma_\mu-\sigma_r)}{\sigma^2_{\rm h}})}{(1 + \frac{(\sigma_\mu-\sigma_r)^2}{\sigma^2_{\rm h}})^{5/2}}\left|\frac{\mathrm{d}\sigma_r}{\mathrm{d}\sigma^2_{\rm h}}\right| \tag{A.5}$$

and

$$\frac{\partial \mathrm{E}U_{\rm h}}{\partial \sigma^2_{\rm h}} \approx -\frac{\phi K^2_{0\rm h}\,\mathrm{e}^{-\beta_{\rm h}}(\frac{\sigma^2_r(\sigma_\mu-\sigma_r)}{\sigma^2_{\rm h}}\left|\frac{\mathrm{d}\sigma_\mu}{\mathrm{d}\sigma^2_{\rm h}}\right| + \frac{\sigma^2_r(\sigma_\mu-\sigma_r)^2}{2\sigma^4_{\rm h}})}{(1 + \frac{(\sigma_\mu-\sigma_r)^2}{\sigma^2_{\rm h}})^{5/2}}. \tag{A.6}$$

Thus, we have $(\mathrm{d}W_{\rm h}/\mathrm{d}\sigma^2_{\rm h}) > 0$ for large enough ϕ if and only if

$$\left(\sigma_r\left(1 + \frac{(\sigma_\mu - \sigma_r)^2}{\sigma^2_{\rm h}}\right) + \frac{\sigma^2_r(\sigma_\mu - \sigma_r)^2}{\sigma^2_{\rm h}}\right)\left|\frac{\mathrm{d}\sigma_r}{\mathrm{d}\sigma^2_{\rm h}}\right|$$
$$> \frac{\sigma^2_r(\sigma_\mu - \sigma_r)}{\sigma^2_{\rm h}}\left|\frac{\mathrm{d}\sigma_\mu}{\mathrm{d}\sigma^2_{\rm h}}\right| + \frac{\sigma^2_r(\sigma_\mu - \sigma_r)^2}{2\sigma^4_{\rm h}}. \tag{A.7}$$

Condition (A.7) imposes restrictions on the individual variances. To see that there is a vector $(\bar{\sigma}^2_{\rm h}, \sigma^2_{\rm h}, \sigma^2_{\rm f}) \gg 0$ satisfying (A.7) notice that (A.7) can be rewritten as

$$\left[\sigma_r\left(1 + \frac{\sigma^2_{\rm h}\sigma^2_r}{\sigma^4_{\rm f}}\right) + \frac{\sigma^3_r}{\sigma^2_{\rm f}}\right]\left|\frac{\mathrm{d}\sigma_r}{\mathrm{d}\sigma^2_{\rm h}}\right| > \frac{\sigma^3_r}{\sigma^2_{\rm f}}\left|\frac{\mathrm{d}\sigma_r}{\mathrm{d}\sigma^2_{\rm h}}\right| + \frac{1}{2}\frac{\sigma^2_r}{\sigma^4_{\rm f}}, \tag{A.8}$$

where we used $\sigma_\mu - \sigma_r = (\sigma^2_{\rm h}/\sigma^2_{\rm f})\sigma_r$ (which follows directly from the expression for the equilibrium interest rate). Suppose now that the productivity variance is equal for both countries, $\bar{\sigma}^2_{\rm h} = \sigma^2_{\rm f}$, and that the information structure is such that $\sigma^2_{\rm h} = \bar{\sigma}^2_{\rm h}/2$ (which is achieved for $\sigma^2_\varepsilon = \bar{\sigma}^2_{\rm h}$). In this case we have $\sigma^2_r = \frac{\bar{\sigma}^2_{\rm h}}{8}$ (and $\sigma^2_\mu = \bar{\sigma}^2_{\rm h}$) and straightforward but lengthy calculation shows (A.8) is always satisfied (there is only one free parameter, $\bar{\sigma}^2_{\rm h}$, which drops out).

Let us now turn to the first part of Proposition 2. We need to show that $(\mathrm{d}W_{\rm h}/\mathrm{d}\sigma^2_{\rm h}) < 0$ or $(\mathrm{d}W_{\rm f}/\mathrm{d}\sigma^2_{\rm h}) < 0$ for small enough ϕ, where the derivatives of the ex ante welfare of each country are decomposed as in (17). It suffices to show that for small enough ϕ, the volatility terms in (17) are negative for both countries. This proves the claim because the direct term is always negative and one of the two terms corresponding to the change in $\bar{r}$ is always negative. Straightforward (but lengthy) differentiation shows that $(\partial \mathrm{E}U_{\mathrm{h}}/\partial\sigma_r^2) > 0$ and $(\partial \mathrm{E}U_{\mathrm{h}}/\partial\sigma_r^2) > 0$ for small enough ϕ (regardless of the other parameter values). This concludes the proof. □

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