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DIVERSIFICATION AND COMPETITION:
FINANCIAL INTERMEDIATION IN A
LARGE COURNOT-WALRAS ECONOMY

by

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ABSTRACT

Consider an economy under uncertainty where risk sharing is achieved through purchase of securities from partially diversified financial intermediaries who behave as Cournot competitors. When the economy is appropriately replicated, the Cournot-Walras equilibrium converges to the (Malinvaud) perfectly competitive equilibrium with no uncertainty. The price of securities in an r-replicated Cournot-Walras economy converges to the price in the no uncertainty, perfectly competitive economy at the rate $\frac{1}{r}$, as in a benchmark partial equilibrium Cournot market with no uncertainty. However, the rate of convergence of individual welfare is typically slower than in the benchmark market (i.e. slower than $\frac{1}{r^2}$), and so is the rate of convergence of traded quantities. The cause of the slow convergence is the presence of uncertainty, not the general equilibrium nature of the model. An implication of the analysis is that in a sufficiently large economy, risk sharing through (imperfectly competitive) financial intermediaries is an almost perfect substitute for other forms of risk sharing. However, the slow rate of convergence of the welfare level suggests that the qualification "sufficiently large" cannot be taken lightly.

1 Introduction

In a seminal paper, Malinvaud (1972) has shown that in a large economy with idiosyncratic risk and no markets for state contingent claims, a full system of insurance operating as a risk-neutral redistribution scheme, where individual risks are pooled and the insurance institutions operate with a very small margin above expected value, the full insurance equilibrium is closely approximated. Malinvaud acknowledges that the assumed existence of such a perfect insurance system does not claim to be realistic, and should be regarded as an ideal situation towards which it might be interesting to move.[1]

This paper studies a more realistic insurance system, consisting of imperfectly competitive financial intermediaries. The analysis is performed in the framework of a two-period general equilibrium economy, with a single good and no storage, where consumers save by purchasing securities from financial intermediaries who invest the funds in risky technologies. The intermediaries compete à la Cournot. Each intermediary has access to a subset of the risky technologies in the economy. Consumers are also the owners of the intermediaries, and receive the profits in the form of dividends. For simplicity, the following assumptions are made: (a) All consumers are identical; (b) there is no stock market; (c) consumers can buy securities from at most one intermediary; (d) the risky technologies exhibit constant returns to scale; and (e) the outputs of the risky technologies are independently and identically distributed random variables. These assumptions can be relaxed somewhat without affecting the nature of the analysis.[2]

It is shown that when such a Cournot-Walras economy is appropriately replicated, the equilibrium allocation, prices, and welfare level converge to their counterparts in the com-

[1]See page 323 in Malinvaud (1972).

[2]For example, the assumption that outputs are i.i.d. is not essential; incorporating a stock market where some but not all the securities are traded, is also possible, although it requires more notation and additional assumptions.

petitive equilibrium of an economy with no uncertainty. Replication of the economy takes care of both distortions: In the limit, it eliminates the monopoly power of intermediaries and removes idiosyncratic risk. By the term "appropriately replicated" I mean the following. If economy E_r is an r-replica of economy E, then in E_r there are r times as many savers, intermediaries, and i.i.d. risky technologies as in economy E, and every intermediary has access to r times as many risky technologies. That is, as the economy becomes bigger, intermediaries become more numerous and better diversified.

An important question is how fast convergence to the ideal Malinvaud economy occurs. In order to motivate the analysis, let me quote L. Shapley (1975, p.345): "In considering the asymptotic properties of [large] economies and their solutions, it is important not to lose sight of the manner in which the limits are approached. The idealized, limiting solution of a large economic model will not have much relevance to economics—either practical or theoretical—unless there is good reason to believe that corresponding situations in the real world exist, or could exist, that are sufficiently large for the limiting results to apply. The study of "error terms" and rates of convergence is therefore crucial to the question of model validation in this area."

It is shown that the price of securities in an r-replicated Cournot-Walras economy converges to the price in the no uncertainty, perfectly competitive economy at the rate $\frac{1}{r}$, as in a simple partial equilibrium Cournot market with no uncertainty. However, the rate of convergence of traded quantities and of individual welfare is typically slower. In the partial equilibrium, no uncertainty benchmark convergence of the welfare level occurs at the (very fast) rate $\frac{1}{r^2}$. Consider a monopolistic market, and suppose we want to reduce the dead-weight loss to 1% of its current level. It would suffice to replicate the economy ten times. In the model presented here convergence of the welfare level is much slower. A quadratic utility example is provided where convergence of price, quantities, and individual welfare takes place at the rate $\frac{1}{r}$. In order to reduce the dead-weight loss to 1% of its level under monopoly, we would have to replicate the economy one hundred times. Therefore, although convergence of the Cournot-Walras equilibrium to the perfectly competitive equilibrium with no uncertainty suggests that Malinvaud's analysis "in the limit" is sensible, we cannot afford to ignore the behavior of the economy "away from the limit," especially when studying small economies.

Since the model departs from the partial equilibrium, no uncertainty benchmark in two respects—it is a general equilibrium model, and there is uncertainty—it is natural to ask what causes the slow convergence of the welfare level. It is shown that the cause is the presence of uncertainty, not the general equilibrium nature of the model. In the concluding section I discuss possible implications of these results for the study of the structure and organization of financial markets in growing economies.

The appropriate manner for replicating an economy with financial intermediaries and i.i.d. risks is not obvious. A natural possibility is the one described above. There are (at least) two other equally natural manners of doing so. We can think of the number of intermediaries as increasing at the same rate as the rest of the economy, but with each intermediary having access to a constant number of i.i.d. risks. Alternatively, we can think of the number of intermediaries as constant, with each intermediary having access to an increasing number of i.i.d. risks.[3] In section 4 I explicitly consider these alternative ways of generating replica economies, showing that they fail to yield, in the limit, the perfectly competitive equilibrium with no uncertainty.

Before turning to the model, I would like to offer a second (complementary) line of motivation for the analysis. It is well recognized that an important role of financial intermediaries is to provide risk sharing. Implicit in this assertion is the assumption that insurance markets are not complete. If markets were complete the risk sharing services of

[3]We may also want to question the assumption that in replica economies all the risks keep remaining i.i.d. Although this is a perfectly legitimate question, I shall not deal with it here.

financial intermediaries would be redundant. A second implicit assumption in the assertion that intermediaries provide risk sharing is that intermediaries can sell securities whose return structure cannot be mimicked by a portfolio of publicly traded securities. The securities of some firms are not traded on stock markets (e.g. the stock of young companies in new industries), and some firms are engaged in more than one risky activity. In the latter case, even if the shares of all firms were traded on the stock market, some state contingent consumption plans could not be spanned by portfolios of the firms' shares.[4] For these reasons financial intermediaries can improve risk sharing in the economy.

Stock markets in the real world are indeed imperfect substitutes for a complete set of state contingent claims. In some countries there is no stock market; in others, stock markets are "thin."[5] Even when there are developed stock markets in operation, many risks are not traded on these markets . Thus, financial intermediaries can contribute to risk sharing in the economy by selling securities, and investing (some of) the funds in assets which are not publicly traded on stock markets.

In order for risk sharing through financial intermediaries to be effective, the intermediaries need to be big. Otherwise, each intermediary would be able to invest only in a small number of risky assets, and would itself be poorly diversified. The securities sold by intermediaries would be perceived by investors as very risky. Investors would then have to diversify by purchasing securities from several intermediaries. Such diversification is costly; for households it may be prohibitively costly. However, big intermediaries may behave as imperfect competitors, selling securities to the public at a price which exceeds marginal cost. In a small economy there is an obvious tension between the desire for big, well diversified intermediaries, and the desire for a competitive financial sector. The convergence result

[4]See, for example, the stock market economies with incomplete markets in Diamond (1967), Grossman and Hart (1979), and Hart (1979).

[5]Pagano (1993) provides interesting evidence in this regard.

obtained here establishes that this tension vanishes as the economy becomes large. That is, in a sufficiently large economy risk sharing through (imperfectly competitive) financial intermediaries is an almost perfect substitute for other forms of risk sharing. However, the slow rate of convergence of the welfare level suggests that the qualification "sufficiently large" cannot be taken lightly.

The paper is closely related to the literature on economies in general equilibrium with imperfect competition. In most of that literature firms are imperfect competitors, whereas consumers are price takers. Alternatively, in an exchange economy some consumers are price setters while others are price takers. See Gabszewicz and Vial (1972), Laffont and Laroque (1976), J. Roberts and Postlewaite (1976), Novshek and Sonnenschein (1978), Hart (1979, 1985), K. Roberts (1980), Mas-Colell (1982), Guesnerie and Hart (1985), Bonanno (1990), d'Aspremont, Dos Santos Ferreira, and Gérard-Varet (1992), and Codognato and Gabszewicz (1993). This paper departs from the literature by extending the analysis to an environment with uncertainty, focusing on the role of imperfectly competitive financial intermediaries as providers of risk sharing.

A related paper is Machnes Caspi (1975), who considers independent replicae of a complete markets Arrow-Debreu economy. In a replicated economy, agents of the same type have the same ex-ante random endowment, but the actual realizations of endowments across agents may differ. Machnes Caspi shows that the sequence of equilibria of the replicated economies approaches an equilibrium of the perfectly competitive economy with no uncertainty.

Several other papers bear relation to the present one. Matutes and Vives (1991) argue that there are diversification economies in banking, namely that larger banks are better diversified and hence have a lower probability of failure. They focus on the interaction between competition for deposits and the probability of failure. Krasa and Villamil (1992a, 1992b) study the tradeoff between the gains from having more diversified banks, and the increased cost of monitoring banks which are more diversified. Winton (1993) and Paroush (1994) have pointed out that large banks are better diversified on the one hand, but are more prone to collusion on the other.[6] Weinstein and Yafeh (1993) provide evidence indicating that powerful Main Banks in Japan extract rents from client firms. In these papers the analysis is carried out in a partial equilibrium setting. Finally, the paper is related to work on the rate of convergence of non-Walrasian allocations to Walrasian outcomes (e.g. Debreu 1975) and of non-cooperative equilibria under asymmetric information to rational expectations equilibrium (e.g. Vives 1993).

The model is presented in section 2. Proposition 1 establishes the existence of a sequence of Cournot-Walras equilibria for a sufficiently large economy, and the convergence of this sequence to the perfectly competitive equilibrium with no uncertainty. Proposition 2 establishes, under an additional (minor) assumption, that every sequence of Cournot-Walras equilibria converges to the perfectly competitive equilibrium with no uncertainty. Section 3 (proposition 3) is devoted to the rate of convergence. In section 4 alternative manners of replicating the economy are studied. Section 5 concludes.

2 The Model

Consider a two period economy with a single non-storable good. There are I identical, risk-averse consumers with VNM utility function $u(\cdot)$, and first and second period endowments ω_1 and ω_2.

A1 The function $u(\cdot)$ is three times differentiable, and satisfies for $0 < y < \infty$: (a) $0 < u'(y) < \infty$; (b) $-\infty < u''(y) < 0$; and (c) $|u'''(y)| < \infty$.

A2 ω_1 and ω_2 are finite and strictly positive.

[6]This was also pointed out in Winton's doctoral dissertation (Penn., 1990) and my own (Harvard, 1992).

There are K technologies in the economy, $k = 1 \ldots K$, exhibiting constant returns to scale.

A3 Technology k takes the form $(-c, x_k)$ where the x_k's are i.i.d. random variables, with support $[\underline{x}, \bar{x}]$, where $0 \leq \underline{x} < \bar{x} < \infty$.

That is, for every c units of input of the single good in period 1, technology k yields the random amount x_k of the single good in period 2.

Remark. The model can be modified to handle less extreme assumptions regarding the distribution of the x_k's. The i.i.d. assumption can be relaxed, as long as some form of the Law of Large Numbers holds. Compactness of the support of x_k is imposed for the following reason. We shall be interested in the limits of (real valued) sequences of the form $\{Eh[\frac{1}{j}(y_1 + \ldots + y_j)]\}_{j=1}^{\infty}$, where $y_1, \ldots, y_j$ are i.i.d. random variables with mean μ, and where $E(\cdot)$ is the expectation operator, and $h(\cdot)$ is a real valued function. The compactness of the support of the random variables is a sufficient condition (although by no means necessary) for $\lim_{j \to \infty} Eh[\frac{1}{j}(y_1 + \ldots + y_j)] = h(\mu)$, a property which will turn out to be useful in the analysis. The assumption that consumers are identical can also be relaxed, although this would entail significantly more notation as well as assumptions regarding properties of the aggregate demand function for securities.

In period 1 consumers can buy securities from financial intermediaries. There are G intermediaries indexed $g = 1, \ldots, G$.

A4 In period 1 every intermediary can invest the funds received from consumers in $N \leq K$ risky technologies.

We can think of the intermediaries as financing projects in different geographical regions, or in different sectors of the economy such as real estate, agriculture, or energy, or a combination of both (e.g. real estate in a particular geographical region). The assumption

$N \leq K$ means that a single intermediary may not be able to invest in all sectors and in all regions of the economy. Although it is not necessary for the analysis, it makes sense to assume that $N \ll K$. There is no stock market in the economy. As a consequence, consumers cannot diversify their savings portfolios by purchasing shares of firms or of intermediaries. The absence of a stock market also limits the ability of intermediaries to diversify their investments.

I normalize units so that one security sold by an intermediary represents a claim on the period 2 output generated by an expenditure of c units of output in period 1. Each intermediary divides its investment equally between the N technologies to which it has access, pooling the outputs in period 2. Every security sold by intermediary g yields, therefore, the random amount $\xi = \frac{1}{N}\sum_{k\in\mathcal{N}^g} x_k$, where $\mathcal{N}^g$ is the set of technologies (of cardinality N) to which intermediary g has access. ξ is the intermediary's average output per c units invested in period 1. By our normalization, this is the amount of output on which the holder of one security sold by the intermediary has claim in period 2. Note that ξ depends only on N, which is the same for all intermediaries. As a result of the constant returns to scale assumption, ξ does not depend on the number of consumers buying securities from the intermediary. Finally, it is evident that every x_k is a mean preserving spread of ξ. This is the sense in which financial intermediaries contribute to risk sharing.[7]

As the securities sold by the G intermediaries are ex-ante identical, they will sell at a single market clearing price. Let p be the price of a security, an endogenous variable to be determined in equilibrium.

The following assumption is made regarding the objective of financial intermediaries:

[7] It should also be evident that it is in fact optimal for an intermediary to divide its investments equally between the N technologies to which it has access. Failing to do so would result in a security with dominated return (same mean, higher variance) as compared to securities sold by other intermediaries.

A5 Intermediaries want to maximize first period profits.

Recall that each security represents a claim on the period 2 output generated by an expenditure of c units of output in period 1. Therefore, for each security sold by an intermediary, the intermediary will invest c units of output in the risky technologies to which it has access, and will distribute, in period 1, the (per security) profits $p - c$ as dividends. Note that, as the intermediary cares only about profits in the first period, in equilibrium (to be rigorously defined below) we must have $p \geq c$, otherwise by not issuing securities the intermediary can make itself better off.[8] In period 2 the realized output of the risky technologies is distributed to the individuals who purchased the securities in period 1.

The following claim is a consequence of A5:

Claim 1 *Securities will not be sold short.*

Proof of claim 1. A short sale of securities means that the intermediary pays the consumer in period 1 in exchange for a (possibly random) payment by the consumer in period 2. In light of A5, even if intermediaries had resources of their own, and could afford to engage in such short sales, they would prefer not to do so. ||

Consumers are also the shareholders of the intermediaries. They own equal shares of all the intermediaries in the economy. In period 1, every consumer-saver receives a dividend d which is the average per capita profit of all the intermediaries in the economy. As p is an endogenous variable, so are profits, and so must be d. When making the saving decision, consumers regard both p and d as exogenously given. We shall, of course, require that in equilibrium, consumers take as given the true values of p and d.

A6 Every consumer can buy securities from exactly one intermediary.

[8]As first period profits are not random, it would change nothing if intermediaries maximized a strictly concave function of first period profits. This assertion relies on the assumption that intermediaries do not take into account the preferences of their shareholders. See Grossman and Hart (1979) and Hart (1979).

This assumption, and the assumptions "no storage" and no "stock market," capture the inability of consumers-savers to fully diversify their portfolios (for example, due to time and information constraints, and to transaction fees).[9]

Summarizing, in period 1 consumers buy securities at a price p per security, and consume the remainder of their endowment and dividend income. For each security sold, intermediaries invest c in the risky technologies to which they have access, and distribute (in period 1) $p - c$ as dividends. In period 2 intermediaries distribute the realized returns of their investments to the holders of the securities, and consumption occurs.

The individual demand for securities. Each consumer solves the problem

$$\max_{\alpha} u(\omega_1 + d - p\alpha) + Eu(\omega_2 + \alpha\xi). \tag{1}$$

The following assumptions ensure an interior solution:

A7 $-cu'(\omega_1 - c\alpha)_{|\alpha=0} + Eu'(\omega_2 + \alpha\xi)_{|\alpha=0}\xi > 0$, or equivalently $\frac{u'(\omega_2)}{u'(\omega_1)} > \frac{c}{Ex_k}$, i.e. when price equals marginal cost—and hence profits of the intermediaries and dividends are zero—there is a strictly positive demand for securities.

A8 For any $p \geq c$ and $d \geq 0$, $-pu'(0) + Eu'(\omega_2 + \frac{\omega_1+d}{p}\xi)\xi < 0$, i.e. $u'(0)$ is sufficiently big (or alternatively, ω_2 is sufficiently big) so that a consumer-saver will never find it optimal to invest all the period 1 wealth $\omega_1 + d$ in risky securities, consuming nothing in period 1.

The necessary conditions for an interior solution of (1) are

$$-pu'(\omega_1 + d - p\alpha) + Eu'(\omega_2 + \alpha\xi)\xi = 0. \tag{2}$$

[9]The assumptions are extreme, as they imply that *no* diversification of savings is possible. The analysis and the results would remain unchanged if storage—possibly subject to depreciation—were allowed, and if a consumer were able to purchase securities from some, but not all, intermediaries.

Strict concavity of $u(\cdot)$ ensures that second order conditions are satisfied. Let $\alpha(p,d,\xi)$ denote the individual demand function for securities.[10] Recall that consumers are identical and that all the securities are ex-ante identical. Therefore, all consumers form the same demand for securities.

The inverse aggregate demand for securities. Totally differentiating (2) with respect to p yields

$$\alpha_p(p,d,\xi) = \frac{u'(\cdot) - p\alpha(p,d,\xi)u''(\cdot)}{p^2u''(\cdot) + E[u''(\omega_2 + \alpha(p,d,\xi)\xi)(\xi)^2]}, \tag{3}$$

where $(\cdot)$ stands for $\omega_1 + d - p\alpha(p,d,\xi)$. The following claim establishes that the individual demand function for securities is strictly decreasing in price. This will enable us to invert the aggregate demand function for securities. I shall be somewhat pedantic in the statement and proof of this simple fact, as the invertibility of demand is a well known source of trouble in models of imperfect competition in general equilibrium.[11]

Claim 2 $-\infty < \alpha_p(p,d,\xi) < 0$ *for all* $0 < p < \infty$ *and* $0 \leq d < \infty$ *such that* $0 < \alpha(p,d,\xi) < \infty$.

Proof of claim 2. By A7, $\omega_1 + d - p\alpha(p,d,\xi) > 0$. Hence, by A1, $u'(\cdot)$ and $u''(\cdot)$ are non-zero and finite. As $\alpha(p,d,\xi)$ is finite by assumption, and since ξ has bounded support, $u''(\omega_2 + \alpha(p,d,\xi)\xi)\xi^2$ is finite for any ξ, and so is the expectation in the denominator of the right hand side of (3). By A1 this expectation is strictly negative. Therefore, the right hand side of (3) is strictly negative and finite. ||

In what follows we shall make use of the elasticity with respect to quantity of the individual

[10] The demand for securities is, of course, not a random variable.

[11] See, for example, K. Roberts (1980), Mas-Colell (1982), and Bonanno (1990).

inverse demand function for securities. This elasticity is given by

$$\begin{aligned}\epsilon(p,d,\xi) &= \frac{1}{\alpha_p(p,d,\xi)}\frac{\alpha(p,d,\xi)}{p} \\ &= \frac{\alpha(p,d,\xi)\{p^2u''(\cdot)+E[u''(\omega_2+\alpha(p,d,\xi)\xi)\xi^2]\}}{p[u'(\cdot)-p\alpha(p,d,\xi)u''(\cdot)]}.\end{aligned} \tag{4}$$

Let $Q(p,d,\xi) = I\alpha(p,d,\xi)$ be the aggregate demand for securities, with $Q_p(p,d,\xi) = I\alpha_p(p,d,\xi) < 0$ (claim 2). Therefore $Q(p,d,\xi)$ can be inverted, yielding the aggregate inverse demand function for securities $P(Q,d,\xi)$, satisfying

$$P_Q(Q,d,\xi) = \frac{1}{I\alpha_p[P(Q,d,\xi),d,\xi]} < 0. \tag{5}$$

The supply of securities. The financial intermediaries compete à la Cournot, using as the strategic variable the quantity of securities to be issued. The intermediaries do not take into account the effect of their action on d, i.e. each group perceives the inverse aggregate demand function $P(Q,d,\xi)$ as exogenously given, regarding d as a parameter. We shall require that in equilibrium, the perceived demand function be the true demand function. Intermediary g chooses q_g, the number of securities to issue, by solving the problem

$$\max_{q_g}\left[P\left(q_g+\sum_{j\neq g}q_j\ ,d\ ,\ \xi\right)-c\right]q_g, \quad g=1,\ldots,G, \tag{6}$$

where $q_g + \sum_{j\neq g} q_j = Q$. By assumption A7, the demand for securities is strictly positive when $p = c$ and $d = 0$. Therefore, in a solution to problem (6) it is not possible that $q_g = 0$ for all $g = 1,\ldots,G$. If this were the case, an intermediary could make strictly positive profits by deviating and selling some securities for a price slightly exceeding marginal cost c. As attention is restricted to a symmetric Cournot equilibrium, the solution to problem

(6), for all intermediaries, must be interior. The necessary conditions are

$$P\left(q_g + \sum_{j\neq g} q_j \ , d \ , \ \xi\right) + q_g P_Q\left(q_g + \sum_{j\neq g} q_j \ , d \ , \ \xi\right) - c = 0, \qquad g = 1, \ldots, G. \tag{7}$$

In a symmetric Cournot equilibrium, letting $q_g = q$ for all $g = 1, \ldots, G$, (7) becomes

$$P(Gq, d, \xi) + qP_Q(Gq, d, \xi) - c = 0. \tag{8}$$

The second order condition is $2P_Q + qP_{QQ} < 0$. P_{QQ} is obtained by differentiating (5). Substituting for P_{QQ} yields $P_Q\left[2 - q\frac{\alpha_{pp}}{I\alpha_p^2}\right] < 0$. For this condition to hold, it would be, for example, sufficient that $\alpha_{pp} < 0$ (as $P_Q < 0$). The general equilibrium nature of the model does not allow us to make such an assumption regarding the individual demand function for securities. Later, in the proof of existence of equilibrium (for a sufficiently large economy) it will be verified that the second order condition is indeed fulfilled in equilibrium.

A benchmark: The perfectly competitive economy with no uncertainty. In this benchmark economy intermediaries are perfect competitors, each having access to a technology which yields Ex_k with certainty. Denote this economy by E^*. Perfect competition entails $p^* = c$ and $d^* = 0$. The securities sold by the intermediaries promise Ex_k with certainty. The individual demand for securities, α^*, is the solution to $\max_\alpha u(\omega_1 - c\alpha) + u(\omega_2 + \alpha Ex_k)$, and the elasticity with respect to quantity of the individual inverse demand function for securities is $\epsilon^* = \epsilon(c, 0, Ex_k) = \frac{1}{\alpha_p(c,0,Ex_k)}\frac{\alpha(c,0,Ex_k)}{c}$. The utility achieved in equilibrium is $U^* = u(\omega_1 - c\alpha^*) + u(\omega_2 + \alpha^* Ex_k)$. The number of securities sold in equilibrium by every intermediary is indeterminate. I shall assume symmetry. Thus, the number of securities sold by every intermediary is $q^* = \frac{I\alpha^*}{G}$.

I make the following assumption regarding the equilibrium of E^*:

A9 $0 < c\alpha^* < \omega_1$.

An implication of A9 is that in the benchmark economy, a symmetric, perfectly competitive equilibrium (with no uncertainty) exists, is unique, and is interior. Assumption A9 also entails, using A1, that $\infty < \epsilon^* < 0$. We return to the Cournot-Walras economy.

Definition of a Cournot-Walras equilibrium. The economy is said to be in Cournot-Walras equilibrium if p, α, q, and d satisfy the following conditions:

(A) Consumers form demand optimally: α satisfies (2), given p and d.

(B) Intermediaries are in a symmetric Cournot equilibrium: q satisfies (8), given d, and the second order conditions for problem (6) are satisfied.

(C) The market for securities clears: $I\alpha = Gq$.

(D) Dividends are perceived correctly by consumers: $d = \frac{Gq}{I}(p - c)$.

(E) The aggregate inverse demand function $P(\cdot, d, \xi)$ is perceived correctly by intermediaries (i.e. it is derived from (2)), and $p = P(Gq, d, \xi)$.

Replicating the economy. Denote by E the above economy, with I consumers, K technologies, G intermediaries, where every intermediary has access to N risky technologies. Consider the r-replica economy E_r, where there are $I_r = rI$ consumers, $K_r = rK$ risky technologies, $G_r = rG$ intermediaries, and where every intermediary has access to $N_r = rN$ risky technologies. For this economy, the following notation is used: p_r, α_r, q_r, d_r and ϵ_r. Each intermediary, say g, sells securities which yield $\xi_r = \frac{1}{N_r}\sum_{k \in \mathcal{N}_r^g} x_k$, where $\mathcal{N}_r^g$ is the set of technologies (of cardinality N_r) to which intermediary g has access. The utility level achieved by a consumer-saver is $U_r = u(\omega_1 + d_r - p_r\alpha_r) + Eu(\omega_2 + \alpha_r\xi_r)$. The sequence of r-replicated economies $E, E_2, E_3, \ldots$ is denoted $\{E_r\}$. Along the sequence, the support of ξ_r is $[\underline{x}, \bar{x}]$ for all r.

Replicating the economy in this manner can be interpreted as follows. Suppose that there are three intermediaries—1, 2, and 3—each investing in a different sector of the economy—A, B, and C respectively, with N risky technologies in each sector. In the twice-replicated economy there are six intermediaries, where, intermediaries 1 and 4 operate in sector A, each having access to $2N$ risky technologies, and so forth for the other sectors.

This is a quite realistic scenario of development for an economy. Consider, for example, the manufacturing sector. As the economy develops, more firms appear, producing a variety of new products, enabling each intermediary to better diversify its investments. The increased number of firms entails entry of new intermediaries who specialize in loans to manufacturers. Thus, intermediaries who operate in this sector become more numerous and better diversified. A similar logic holds if the word "region" is substituted for the word "sector."

In the above scenario the sectors form a partition of the set of risky technologies. This need not be the case—the model allows for overlaps between the technologies to which the intermediaries have access. Also, as pointed out earlier, the assumption that the outputs of all the risky technologies in the economy are i.i.d. random variables can be relaxed. In practice, one would expect to find some correlation between the outputs of technologies in the same sector (or region). Such correlation can be incorporated, as long as some version of the Law of Large Numbers holds.

Finally, there may be alternative ways of replicating the economy, corresponding to other plausible scenarios of development. In particular, when the economy doubles in size, we may want the number of sectors (or regions) to increase as well. Also, it is not evident that the number of intermediaries must increase as the economy becomes larger. I shall return to this issue in more detail in section 4.

Existence of equilibrium and convergence. The following proposition establishes the existence of a sequence of Cournot-Walras equilibria for a sufficiently large economy, and the convergence of this sequence to the equilibrium of the (benchmark) perfectly competitive economy with no uncertainty.

Proposition 1 *There exists a sequence of r-replica economies* $\{E_r\}$ *and* $\hat{r}$*, such that for all* $r \geq \hat{r}$*,* E_r *has a Cournot-Walras equilibrium. Along the sequence, for* $r \geq \hat{r}$*,* $\alpha_r > 0$*,* $p_r > c$*, and* $0 < p_r\alpha_r < \omega_1$*. Moreover, the equilibrium sequences* $\{p_r\}$*,* $\{\alpha_r\}$*,* $\{q_r\}$*,* $\{d_r\}$*, and* $\{U_r\}$ *converge to their counterparts in the equilibrium of* E^**, the perfectly competitive economy with no uncertainty.*

[12] Mas-Colell (1982, p.185) has observed that it would be fully justified to call Walrasian theory the limit (as the economy grows large) of Cournotian theory if the following three desiderata are satisfied. As the economy becomes large: I. There are "no escapes to infinity" (of prices, of per firm production levels, and of per capita consumption levels); II. the limit of a converging sequence of Cournot-Walras equilibria is Walrasian; and III. for any Walrasian equilibrium of the limit economy, there is a sequence of Cournot-Walras equilibria which converges to it. Proposition 1 establishes requirement III, namely that there is a sequence of Cournot-Walras equilibria converging to the unique (symmetric) Walrasian equilibrium of the limit economy.

In order to establish requirements I and II, we need an additional assumption:

A10 Along any sequence of Cournot-Walras equilibria $\lim_{r\to\infty} \alpha_p(p_r, d_r, \xi_r) < 0$.

The significance of the assumption is that as the economy becomes large, the individual demand for securities does not become almost perfectly inelastic. This is not very restrictive. For example, a brief inspection of (10) reveals that if $u'(\cdot)$ is bounded away from zero and $u''(\cdot)$ is bounded away from negative infinity, A10 is satisfied. The intuition behind the need for A10 is as follows. As the economy is replicated, two effects are at work, both tending to increase competition: (a) There are more intermediaries; and (b) there are more

[12]The proof is provided below.

consumers, meaning that, other things equal, the aggregate demand for securities tends to be more elastic. It may happen, though, that as the economy is replicated, the individual demand for securities becomes more and more inelastic. This effect works against increased competition. Assumption A10 ensures that even if this effect is present, effects (a) and (b) have the upper hand.

Proposition 2 *Any sequence $\{E_r\}$ of replica economies in Cournot-Walras equilibrium converges to E^*. That is, the equilibrium sequences $\{p_r\}$, $\{\alpha_r\}$, $\{q_r\}$, $\{d_r\}$, and $\{U_r\}$ converge to their counterparts in the equilibrium of E^*.*

We turn to the proofs of the propositions. The strategy of the proof of proposition 1 consists of constructing a sequence of (sufficiently large) economies $\{E_r\}$ (i.e. sequences $\{p_r\}$, $\{\alpha_r\}$, $\{q_r\}$, and $\{d_r\}$) such that, along the sequence, requirements (A) through (E) in the definition of Cournot-Walras equilibrium are satisfied, including the second order conditions for the Cournot profit maximization problem. By a series of substitutions the problem is reduced to finding—for each economy E_r—a fixed point $\hat{p}_r$ of a function parametrized by ξ_r. The sequence $\{\hat{p}_r\}$ is shown to converge to c.

Before turning to the proof of the proposition we need to introduce some notation, and to establish a technical result. The new notation is introduced in order to eliminate the variable d_r from the calculations. Consider a sequence of economies $\{E_r\}$. For economy E_r let $I_r\alpha_r = G_r q_r$ and $d_r = \alpha_r(p_r - c)$. Thus, $\omega_1 + d_r - p_r\alpha_r = \omega_1 - c\alpha_r$, and (2) becomes

$$-p_r u'(\omega_1 - c\alpha_r) + Eu'(\omega_2 + \alpha_r\xi_r)\xi_r = 0. \tag{9}$$

Equation (9) can be solved uniquely for $\tilde{\alpha}(p_r, \xi_r)$. As $d_r = \alpha_r(p_r - c)$, the value of α which solves (2) must be equal to the value of α which solves (9). Hence, $\tilde{\alpha}(p_r, \xi_r) = \alpha(p_r, d_r, \xi_r)$.

Then (3) and (4) become

$$\tilde{\alpha}_p(p_r,\xi_r) = \frac{u'(\cdot) - p_r\tilde{\alpha}(p_r,\xi_r)u''(\cdot)}{p_r^2u''(\cdot) + E[u''(\omega_2 + \tilde{\alpha}(p_r,\xi_r)\xi_r)(\xi_r)^2]}, \tag{10}$$

and

$$\tilde{\epsilon}(p_r,\xi_r) = \frac{\tilde{\alpha}(p_r,\xi_r)\{p_r^2u''(\cdot) + E[u''(\omega_2 + \tilde{\alpha}(p_r,\xi_r)\xi_r)\xi_r^2]\}}{p_r[u'(\cdot) - p_r\tilde{\alpha}(p_r,\xi_r)u''(\cdot)]}, \tag{11}$$

where $(\cdot)$ stands for $\omega_1 - c\tilde{\alpha}(p_r,\xi_r)$. The aggregate demand can then be written as $\tilde{Q}(p_r,\xi_r) = I_r\tilde{\alpha}_r(p_r,\xi_r)$, with inverse $\tilde{P}(\tilde{Q}_r,\xi_r)$, satisfying

$$\tilde{P}_Q(\tilde{Q}_r,\xi_r) = \frac{1}{I_r\tilde{\alpha}_p(p_r,\xi_r)}. \tag{12}$$

Note that $\tilde{\alpha}(p_r,\xi_r)$, $\tilde{\alpha_p}(p_r,\xi_r)$, $\tilde{\epsilon}(p_r,\xi_r)$, and $\tilde{Q}(p_r,\xi_r)$ are not random variables. The explicit inclusion of ξ_r in the arguments is made in order to underline the fact that $\tilde{\alpha}(\cdot,\xi_r)$ is the demand function for securities when securities yield ξ_r, and similarly for the other functions.

The following result is of a technical nature and will be used in the proof of proposition 1.

Claim 3 *Let $\delta > 0$. There is r' such that for all $r \geq r'$ and all $p \in [c, c+\delta]$,* $\frac{|\tilde{\epsilon}(p,\xi_r)|}{rG} \leq \frac{\delta}{c+\delta}$.

Proof of claim 3. Consider some $p \in [c, c+\delta]$. Throughout the proof p and δ will remain fixed. Let $\tilde{\alpha}(p, Ex_k)$ be the unique solution of $-pu'(\omega_1 - c\alpha) + u'(\omega_2 + \alpha Ex_k)Ex_k = 0$. Let $\tilde{\alpha}(p,\xi_r)$ be the unique solution of $-pu'(\omega_1 - c\alpha) + Eu'(\omega_2 + \alpha\xi_r)\xi_r = 0$. Consider $u'(\omega_2 + \alpha\xi_r)\xi_r$. As ξ_r is bounded, $u'(\omega_2 + \alpha\xi_r)\xi_r$ is a bounded (and by assumption A1, continuous) function of ξ_r. We can invoke a standard result in probability theory (Feller 1966, lemma 1, p.218) to obtain $\lim_{r\to\infty} Eu'(\omega_2 + \alpha\xi_r)\xi_r = u'(\omega_2 + \alpha Ex_k)Ex_k$. Thus, $\lim_{r\to\infty}\tilde{\alpha}(p,\xi_r) = \tilde{\alpha}(p, Ex_k)$, which by A7 and A8 is strictly positive and finite. Note that the limit is taken on a sequence of non-stochastic real numbers.

Consider $u''(\omega_2 + \tilde{\alpha}(p, Ex_k)\xi_r)\xi_r^2$. By analogous arguments, $u''(\omega_2 + \tilde{\alpha}(p, Ex_k)\xi_r)\xi_r^2$ is bounded, and is continuous in ξ_r, and hence $\lim_{r\to\infty} Eu''(\omega_2 + \tilde{\alpha}(p, Ex_k)\xi_r)\xi_r^2 = u''(\omega_2 + \tilde{\alpha}(p, Ex_k)Ex_k)(Ex_k)^2$. Thus (by the continuity of $u''(\omega_2 + \alpha\xi_r)\xi_r^2$ in α), $\lim_{r\to\infty} Eu''(\omega_2 + \tilde{\alpha}(p, \xi_r)\xi_r)\xi_r^2 = u''(\omega_2 + \tilde{\alpha}(p, Ex_k)Ex_k)(Ex_k)^2$.

Using once more the continuity of u' and u'', we have

$$\begin{aligned} \lim_{r\to\infty} \tilde{\epsilon}(p, \xi_r) &= \lim_{r\to\infty} \frac{\tilde{\alpha}(p,\xi_r)\{p^2u''(\cdot)+E[u''(\omega_2+\tilde{\alpha}(p,\xi_r)\xi_r)\xi_r^2]\}}{p[u'(\cdot)-p\tilde{\alpha}(p,\xi_r)u''(\cdot)]} \\ &= \frac{\tilde{\alpha}(p,Ex_k)\{p^2u''(\cdot\cdot)+[u''(\omega_2+\tilde{\alpha}(p,Ex_k)Ex_k)Ex_k^2]\}}{p[u'(\cdot\cdot)-p\tilde{\alpha}(p,Ex_k)u''(\cdot\cdot)]}, \end{aligned} \tag{13}$$

where $(\cdot)$ stands for $\omega_1 - c\tilde{\alpha}(p_r, \xi_r)$, and $(\cdot\cdot)$ stands for $\omega_1 - c\tilde{\alpha}(p, Ex_k)$. By A1, A7, and A8 this limit is finite. It follows that $\lim_{r\to\infty} \frac{|\tilde{\epsilon}(p,\xi_r)|}{rG} = 0$, and hence there is r' such that for all $r \geq r'$, $\frac{|\tilde{\epsilon}(p,\xi_r)|}{rG} \leq \frac{\delta}{c+\delta}$. ||

Proof of proposition 1.

Step 1. With the new notation introduced in this sub-section, and suppressing the index of p_r, equation (8) becomes $\tilde{P}(\tilde{Q}(p, \xi_r), \xi_r) + \frac{I_r\tilde{\alpha}(p,\xi_r)}{G_r}\tilde{P}_Q(\tilde{Q}(p, \xi_r), \xi_r) - c = 0$. Using $\tilde{P}(\tilde{Q}(p, \xi_r), \xi_r) = p$, $I_r = rI$, $G_r = rG$, and (12), it can be rearranged to yield

$$\frac{c}{1 - \frac{|\tilde{\epsilon}(p,\xi_r)|}{rG}} = p. \tag{14}$$

By claim 3 we know that there is $\delta > 0$ and r' such that for all $r \geq r'$ and all $p \in [c, c+\delta]$, $\frac{|\tilde{\epsilon}(p,\xi_r)|}{rG} \leq \frac{\delta}{c+\delta}$, or equivalently $\frac{c}{1-\frac{|\tilde{\epsilon}(p,\xi_r)|}{rG}} \leq c + \delta$. Consider some $r \geq r'$. As the left hand side of (14) is greater than c, equation (14) defines a continuous function of p from $[c, c+\delta]$ to itself, and hence must have at least one fixed point, $\hat{p}_r$.

Step 2. Let $\hat{\alpha}_r = \tilde{\alpha}(\hat{p}_r, \xi_r)$, $\hat{q}_r = \frac{I_r\hat{\alpha}_r}{G_r} = \frac{I\hat{\alpha}_r}{G}$, and $\hat{d}_r = \hat{\alpha}_r(\hat{p}_r - c)$. These values constitute a Cournot-Walras equilibrium provided that the second order conditions for problem (6) are satisfied. Before the second order conditions can be verified, more results need to be established.

Step 3. Claim 3 states that for a fixed $p \in [c, c+\delta]$, $\lim_{r\to\infty} \frac{|\bar{\epsilon}(p,\xi_r)|}{rG} = 0$. It follows that for a sequence of equilibrium prices $\{\hat{p}_r\}$, such that $\hat{p}_r \in [c, c+\delta]$, $\lim_{r\to\infty} \frac{|\bar{\epsilon}(\hat{p}_r,\xi_r)|}{rG} = 0$. From (14) it then follows that $\lim_{r\to\infty} \hat{p}_r = c$. As in the proof of claim 3, continuity and the Feller lemma invoked above imply that $\lim_{r\to\infty} \tilde{\alpha}(\hat{p}_r, \xi_r) = \tilde{\alpha}(c, Ex_k) = \alpha^*$, and hence $\lim_{r\to\infty} \hat{q}_r = q^*$ and $\lim_{r\to\infty} \hat{d}_r = 0$.

We turn to the sequence $\{U_r\}$. Using the Feller lemma invoked above, and continuity of $u(\omega_1 + d - p\alpha) + u(\omega_2 + \alpha\xi)$ in d, p, α, and ξ (in all directions), we have $\lim_{r\to\infty} u(\omega_1 + \hat{d}_r - \hat{p}_r\hat{\alpha}_r) + Eu(\omega_2 + \hat{\alpha}_r\xi_r) = u(\omega_1 - c\alpha^*) + u(\omega_2 + \alpha^* Ex_k) = U^*$.

Step 4. The results of this step are for later use. The Feller lemma used in the proof of claim 3 is used here several times. From (10) we get $\lim_{r\to\infty} \tilde{\alpha}_p(\hat{p}_r, \xi_r) = \frac{u'(\omega_1 - c\alpha^*) - c\alpha^* u''(\omega_1 - c\alpha^*)}{c^2 u''(\omega_1 - c\alpha^*) + u''(\omega_2 + \alpha^* Ex_k)(Ex_k)^2}$ α_p^*, which by A1 and A9 is strictly negative and finite.

By totally differentiating (3) with respect to p we get an expression for $\alpha_{pp}(p, d, \xi)$. Setting $p = \hat{p}_r$ and $\xi = \xi_r$, eliminating $\hat{d}_r$ using $\hat{d}_r = \hat{\alpha}_r(\hat{p}_r - c)$, we obtain $\alpha_{pp}(p, d, \xi) = \tilde{\alpha}_{pp}(\hat{p}_r, \xi_r)$. Taking the limit, we have $\lim_{r\to\infty} \tilde{\alpha}_{pp}(\hat{p}_r, \xi_r) = \frac{X-Y}{Z}$, where $X = (c\alpha_p^* + \alpha^*)[c\alpha^* u'''(\omega_1 - c\alpha^*) - 2u''(\omega_1 - c\alpha^*)]$, $Y = \alpha_p^*[2cu''(\omega_1 - c\alpha^*) + u'''(\omega_2 + \alpha^* Ex_k)(Ex_k)^3 \alpha_p^* - (c\alpha_p^* + \alpha^*)c^2 u'''(\omega_1 - c\alpha^*)]$, and $Z = c^2 u''(\omega_1 - c\alpha^*) + u''(\omega_2 + \alpha^* Ex_k)(Ex_k)^2$. By A1 and A9, $\frac{X-Y}{Z}$ is finite.

We turn to the second order conditions.

Step 5. Consider the left hand side of (7) (which is the first derivative of the objective function of financial intermediary g), as it would apply to economy E_r, i.e. with the subscript r wherever appropriate. Differentiating it once more with respect to q_g, letting $q_g = \hat{q}_r$ for all g, substituting for P_Q and P_{QQ} using (5) (P_{QQ} is obtained by differentiating (5)), recalling that $\hat{q}_r = \frac{I_r \hat{\alpha}_r}{G_r}$, $G_r = rG$, $I_r = rI$, and $\alpha(\hat{p}_r, \hat{d}_r, \xi_r) = \tilde{\alpha}(\hat{p}_r, \xi_r)$, yields the expression

$$\frac{1}{rI\tilde{\alpha}_p(\hat{p}_r, \xi_r)} \left[2 - \frac{\tilde{\alpha}(\hat{p}_r, \xi_r)\tilde{\alpha}_{pp}(\hat{p}_r, \xi_r)}{rG\tilde{\alpha}_p^2(\hat{p}_r, \xi_r)}\right]. \tag{15}$$

The term outside the square brackets is strictly negative. Consider the fraction inside the square brackets. By steps 3 and 4, $\tilde{\alpha}(\hat{p}_r, \xi_r)$ and its derivatives converge to finite limits. Therefore, the fraction converges to zero, and hence, for sufficiently large r, the term in square brackets is strictly positive. It follows that there is r'' such that for all $r \geq r''$ the expression in (15) is strictly negative, and hence the second order conditions for problem (6) are satisfied.

Step 6. Let $\hat{r} = \max(r', r'')$, where r' is as defined in claim 3 and in step 1 above, and r'' is as defined in step 5 above. Then for $r \geq \hat{r}$, requirements (A) through (E) in the definition of Cournot-Walras equilibrium, including the second order conditions for the Cournot profit maximization problem, are satisfied by $\hat{p}_r$, $\hat{\alpha}_r$, $\hat{q}_r$, and $\hat{d}_r$. We have constructed a sequence of economies in Cournot-Walras equilibrium, which converges (step 3) to the equilibrium of E^*. From (14) it follows that along the sequence $\hat{p}_r > c$. By assumptions A7 and A8, along the sequence $\hat{\alpha}_r > 0$ and $0 < \hat{p}_r\hat{\alpha}_r < \omega_1$. ‖

We turn to the proof of proposition 2, for which we need assumption A10 above. The assumption should not be confused with the result in step 4 in the proof of proposition 1. There, we knew that along a particular sequence of Cournot-Walras equilibria $\lim_{r\to\infty} p_r = c$, and we used this fact to show that $\lim_{r\to\infty} \tilde{\alpha}_p(p_r, \xi_r)$ is negative and finite. In proposition 2 we want to show that along any sequence of Cournot-Walras equilibria $\lim_{r\to\infty} p_r = c$, and we need to assume that $\tilde{\alpha}_p(p_r, \xi_r)$ does not converge to 0.

Proof of proposition 2. It is sufficient to show that along a sequence $\{E_r\}$ of economies in Cournot-Walras equilibrium it must be the case that $\lim_{r\to\infty} p_r = c$. Along the sequence

$p_r \geq c$, otherwise intermediaries would be better off not selling securities. Using (5) and $q_r = \frac{I_r \alpha_r}{G_r}$, we can write (8) as

$$p_r + \frac{\tilde{\alpha}(p_r, \xi_r)}{rG\tilde{\alpha}_p(p_r, \xi_r)} - c = 0. \tag{16}$$

Noting that $\lim_{r\to\infty} \tilde{\alpha}(p_r, \xi_r) < \infty$ (otherwise, far enough along the sequence $p_r\tilde{\alpha}(p_r, \xi_r) > \omega_1$), and using A10, we have $\lim_{r\to\infty} \frac{\tilde{\alpha}(p_r,\xi_r)}{rG\tilde{\alpha}_p(p_r,\xi_r)} = 0$, implying $\lim_{r\to\infty} p_r = c$. ‖

3 The Rate of Convergence

A useful benchmark for the rate of convergence is the following partial equilibrium model. Let $P = A - \frac{b}{r}Q$ represent the aggregate inverse demand in economy E_r, where there are r identical consumers and r identical Cournot producers, with linear cost functions (i.e. constant marginal cost) and no fixed costs. There is no free entry. Straightforward computations reveal that in this market, as r becomes large, the rate of convergence of price to marginal cost, of quantity to the perfectly competitive quantity, and of profits to zero, is $\frac{1}{r}$, whereas the rate of convergence of individual welfare to the first best (perfectly competitive) level is $\frac{1}{r^2}$.

Previous literature has focused on the rate of convergence of individual welfare to the first best level in the presence of increasing returns to scale. Guesnerie and Hart (1985) find that when average cost is U-shaped convergence of individual welfare takes place at the rate $\frac{1}{r}$, whereas when average cost is decreasing, convergence takes place at the rate $\frac{1}{\sqrt{r}}$. The latter result has been obtained by Dasgupta and Ushio (1981) in a setting similar to the one described in the previous paragraph. Thus, increasing returns slow down the rate of convergence of individual welfare. Here—a general equilibrium model under uncertainty—the rate of convergence of individual welfare is also slowed down with respect to the partial equilibrium, no uncertainty benchmark. For example, when utility is quadratic it is slowed down to $\frac{1}{r}$. The reason for the slower rate of convergence is the uncertainty, not the general equilibrium nature of the model. Finally, the rate of convergence of price to marginal cost is not slowed down with respect to the partial equilibrium benchmark with no uncertainty. These results are summarized in

Proposition 3 *Let $\{E_r\}$ be a sequence of economies in Cournot-Walras equilibrium. Then: (a) $p_r - c$ is $O(\frac{1}{r})$; (b) $\alpha_r - \alpha^*$ and $U_r - U^*$ are $o\left(\frac{1}{r^{\frac{1}{2}-\theta}}\right)$ for $0 < \theta < \frac{1}{2}$; (c) if there is no uncertainty (x_k equals Ex_k with probability 1, for all k) then $p_r - c$ and $\alpha_r - \alpha^*$ are $O(\frac{1}{r})$, whereas $U_r - U^*$ is $O(\frac{1}{r^2})$.*

Proof of proposition 3.

(a) Rearranging (16) and taking a limit we get $\lim_{r\to\infty} r(p_r - c) = -\lim_{r\to\infty} \frac{\tilde{\alpha}(p_r,\xi_r)}{G\tilde{\alpha}_p(p_r,\xi_r)} = \frac{\alpha^*}{G\alpha_p^*}$, which is non-zero and finite.

(b) Consider the expression $-p_r u'(\omega_1 - c\alpha_r) + u'(\omega_2 + \alpha_r\xi_r')\xi_r'$, which is a function of (p_r, α_r, ξ_r'), where p_r and α_r are the equilibrium price and quantity, and ξ_r' is a particular realization of ξ_r. Using Taylor's formula, we can expand the expression around (c, α^*, Ex_k):

$$\begin{aligned}
& -p_r u'(\omega_1 - c\alpha_r) + u'(\omega_2 + \alpha_r\xi_r')\xi_r' \\
= \; & -cu'(\omega_1 - c\alpha^*) + u'(\omega_2 + \alpha^* Ex_k)Ex_k \\
- \; & (p_r - c)u'(\omega_1 - c\alpha_r^\circ) \\
+ \; & (\alpha_r - \alpha^*)[cp_r^\circ u''(\omega_1 - c\alpha_r^\circ) + u''(\omega_2 + \alpha_r^\circ\xi_r^\circ)(\xi_r^\circ)^2] \\
+ \; & (\xi_r' - Ex_k)[u'(\omega_2 + \alpha_r^\circ\xi_r^\circ) + u''(\omega_2 + \alpha_r^\circ\xi_r^\circ)\xi_r^\circ\alpha_r^\circ],
\end{aligned} \tag{17}$$

where p_r° is in the segment joining p_r and c, α_r° is in the segment joining α_r and α^*, and ξ_r° is in the segment joining ξ_r' and Ex_k.

Note that for every realization ξ_r' of ξ_r there are (possibly) different values of p_r°, α_r°, and ξ_r° which satisfy the equality. Hence p_r°, α_r°, and ξ_r° are random variables with probability distributions induced by that of ξ_r. Recalling that $-cu'(\omega_1 - c\alpha^*) + u'(\omega_2 + \alpha^* Ex_k)Ex_k = 0$

(see the definition of equilibrium for economy E^*), taking an expectation on both sides of (17), using (9), suppressing the superscript on ξ_r', and rearranging, we obtain

$$\begin{aligned}(p_r - c)Eu'(\omega_1 - c\alpha_r^\circ) &= (\alpha_r - \alpha^*)E[cp_r^\circ u''(\omega_1 - c\alpha_r^\circ) + u''(\omega_2 + \alpha_r^\circ\xi_r^\circ)(\xi_r^\circ)^2] \\ &\quad + E(\xi_r - Ex_k)[u'(\omega_2 + \alpha_r^\circ\xi_r^\circ) + u''(\omega_2 + \alpha_r^\circ\xi_r^\circ)\xi_r^\circ\alpha_r^\circ].\end{aligned} \tag{18}$$

Let $0 < \theta < \frac{1}{2}$. First, I show that the second term on the right hand side of (18) is $o\left(\frac{1}{r^{\frac{1}{2}-\theta}}\right)$. Let $m = \max|[u'(\omega_2 + \alpha_r^\circ\xi_r^\circ) + u''(\omega_2 + \alpha_r^\circ\xi_r^\circ)\xi_r^\circ\alpha_r^\circ]|$ over $(\alpha_r^\circ, \xi_r^\circ) \in [0, \frac{\omega_1}{c}] \times [\underline{x}, \bar{x}]$. Then $\lim_{r\to\infty} r^{\frac{1}{2}-\theta}E(\xi_r - Ex_k)[u'(\omega_2 + \alpha_r^\circ\xi_r^\circ) + u''(\omega_2 + \alpha_r^\circ\xi_r^\circ)\xi_r^\circ\alpha_r^\circ] \le m \lim_{r\to\infty} r^{\frac{1}{2}-\theta}E|\xi_r - Ex_k| = 0$, because, recalling that the support of ξ_r is uniformly bounded, $r^{\frac{1}{2}-\theta}|\xi_r - Ex_k|$ converges to 0 with probability 1 (Fabian and Hannan, 1985, Corollary 4, p.78).

Next, recall that for every realization ξ_r, p_r° is sandwiched between p_r and its limit c, α_r° is sandwiched between α_r and its limit α^*, and ξ_r° is sandwiched between ξ_r and Ex_k. Regarding p_r°, α_r°, and ξ_r° as functions of ξ_r, we have, using the Feller lemma invoked in the proof of claim 3, $\lim_{r\to\infty} Eu'(\omega_1 - c\alpha_r^\circ) = u'(\omega_1 - c\alpha^*)$ and $\lim_{r\to\infty} E[cp_r^\circ u''(\omega_1 - c\alpha_r^\circ) + u''(\omega_2 + \alpha_r^\circ\xi_r^\circ)(\xi_r^\circ)^2] = c^2u''(\omega_1 - c\alpha^*) + u''(\omega_2 + \alpha^*Ex_k)(Ex_k)^2$ which by A1 and A9 are finite. Thus, if we multiply both sides of (18) by $r^{\frac{1}{2}-\theta}$ and take limits, we find that the left hand side vanishes, and so does the second term on the right hand side, implying $\lim_{r\to\infty} r^{\frac{1}{2}-\theta}(\alpha_r - \alpha^*) = 0$.

We turn to the rate of convergence of U_r, and expand the expression $u(\omega_1 - c\alpha_r) +$

$u(\omega_2 + \alpha_r \xi'_r)$ around (c, α^*, Ex_k):

$$
\begin{aligned}
& u(\omega_1 - c\alpha_r) + u(\omega_2 + \alpha_r \xi'_r) \\
= \; & u(\omega_1 - c\alpha^*) + u(\omega_2 + \alpha^* Ex_k) \\
+ \; & (\alpha_r - \alpha^*)[u'(\omega_1 - c\alpha_r)(-c) + u'(\omega_2 + \alpha_r \xi'_r)\xi'_r] \\
+ \; & (\xi'_r - Ex_k)u'(\omega_2 + \alpha_r \xi'_r)\alpha_r \\
+ \; & \tfrac{1}{2}(\alpha_r - \alpha^*)^2[c^2 u''(\omega_1 - c\alpha_r^\circ) + u''(\omega_2 + \alpha_r^\circ \xi_r^\circ)(\xi_r^\circ)^2] \\
+ \; & (\alpha_r - \alpha^*)(\xi'_r - Ex_k)[u'(\omega_2 + \alpha_r^\circ \xi_r^\circ) + u''(\omega_2 + \alpha_r^\circ \xi_r^\circ)\xi_r^\circ \alpha_r^\circ] \\
+ \; & \tfrac{1}{2}(\xi'_r - Ex_k)^2 u''(\omega_2 + \alpha_r^\circ \xi_r^\circ)(\alpha_r^\circ)^2.
\end{aligned}
\tag{19}
$$

Recalling that $U^* = u(\omega_1 - c\alpha^*) + u(\omega_2 + \alpha^* Ex_k)$ (see the definition of equilibrium for economy E^*), taking an expectation on both sides of (19), using (9), and suppressing the superscript on ξ'_r, we obtain

$$
\begin{aligned}
U_r - U^* = \; & \alpha_r E(\xi'_r - Ex_k)u'(\omega_2 + \alpha_r \xi'_r) \\
& + \tfrac{1}{2}(\alpha_r - \alpha^*)^2 E[c^2 u''(\omega_1 - c\alpha_r^\circ) + u''(\omega_2 + \alpha_r^\circ \xi_r^\circ)(\xi_r^\circ)^2] \\
& + (\alpha_r - \alpha^*)E(\xi_r - Ex_k)[u'(\omega_2 + \alpha_r^\circ \xi_r^\circ) + u''(\omega_2 + \alpha_r^\circ \xi_r^\circ)\xi_r^\circ \alpha_r^\circ] \\
& + \tfrac{1}{2}E(\xi_r - Ex_k)^2 u''(\omega_2 + \alpha_r^\circ \xi_r^\circ)(\alpha_r^\circ)^2.
\end{aligned}
\tag{20}
$$

Multiply both sides of (20) by $r^{\frac{1}{2}-\theta}$ and take limits. By arguments analogous to the ones used in the proof of the rate of convergence of α_r, and using that result, we find that the right hand side of (20) vanishes, establishing the desired result.

(c) If there had been no uncertainty (x_k equals Ex_k with probability 1, for all k) then only the second term on the right hand side of (20) and the first term on the right hand side of (18) would survive (before taking any limits). In that case we would have α_r converging to α^* at the rate $\frac{1}{r}$, and therefore U_r converging to U^* at the rate $\frac{1}{r^2}$, as in the partial equilibrium, no uncertainty case. ||

Remark. If $\tilde{\alpha}_p(p_r, \xi_r)$ is bounded away from zero we have the following, stronger convergence result: There is a constant $K > 0$ such that $p_r - c \leq \frac{K}{r}$ for all $r \geq 1$. Assumption A6 has been strengthened—we must require that the individual demand for securities is not very inelastic anywhere along the sequence of economies, whereas A6 imposes this restriction only in the limit. The proof is as follows. As $\tilde{\alpha}_p(p_r, \xi_r)$ is bounded away from zero, there is a constant $K' > 0$ such that $|\tilde{\alpha}_p(p_r, \xi_r)| \geq K' > 0$ for all $r \geq 1$. Using (16) we have $(p_r - c) = \frac{\tilde{\alpha}(p_r,\xi_r)}{G|\tilde{\alpha}_p(p_r,\xi_r)|}\frac{1}{r} \leq \frac{1}{G}\frac{\omega_1}{c}\frac{1}{K'}\frac{1}{r}$.

An example of slow convergence. Let the utility function of consumers-savers be quadratic. Then the rate of convergence of price, quantities, and individual welfare to their counterparts in the competitive equilibrium with no uncertainty is $\frac{1}{r}$. The proof is relegated to the Appendix. The main effect at work here is that the first term on the right hand side of (20) behaves as the variance of ξ_r (as $u'(\cdot)$ is linear), and hence converges to zero at the rate $\frac{1}{r}$. The other terms converge to zero even faster.

4 Other Ways of Replicating the Economy

In the above analysis the economy was replicated so that in an r-replica the number of consumers, risky technologies, and intermediaries is r times bigger than in the base economy. Furthermore, each intermediary had access to r times as many risky technologies. I shall call this manner of replicating the economy *balanced replication*. It was argued that balanced replication corresponds to a scenario where, as the economy grows and develops, more firms appear, producing a variety of new products. This allows intermediaries to better diversify their loan portfolios. At the same time, the increased number of firms entails entry of more intermediaries, increasing the degree of competition among intermediaries.

As pointed out in the introduction, there may be other, equally reasonable manners of replicating the economy. For example, we may think of the number of intermediaries as increasing at the same rate as consumers and technologies, but with each intermediary having access to a fixed number of technologies. Such a scenario is plausible if we believe that it is very costly for intermediaries to increase the number of borrowing firms, especially if these borrowers are not identical.[13] Thus, as the economy is replicated, competition between intermediaries increases, but the degree of diversification (the extent to which the portfolio of a single intermediary is diversified) does not. I shall call this *competition oriented replication.*

It is not implausible to assume that although the number of consumers and technologies increases, the number of intermediaries remains constant, with each intermediary gaining access to an increasing number of risky technologies. This approach reflects the view that the capacity of an intermediary is neither limited nor very costly. Intermediaries need to be put in place (possibly at a fixed cost) once and for all. They will supply all the intermediation needs of the economy along the path of development. As the economy is replicated the degree of competition between intermediaries remains unchanged, whereas the degree of diversification increases. I shall call this *diversification oriented replication.*

Clearly, competition oriented and diversification oriented replication do not yield, in the limit, the Malinvaud outcome. In the former, the price of securities p_r approaches marginal cost c (at the rate $\frac{1}{r}$). Yet, for any r, the return of the securities sold by the intermediaries is the random variable ξ^N, which does not depend on r. The superscript N denotes the (fixed) number of risky technologies to which each intermediary has access. Denoting the limit of α_r by α^N, we have $\lim_{r\to\infty} u(\omega_1 - c\alpha_r) + Eu(\omega_2 + \alpha_r\xi^N) = u(\omega_1 - c\alpha^N) + Eu(\omega_2 + \alpha^N\xi^N) < U^*$.

Similarly, when replication is diversification oriented, the return of the securities sold by the intermediaries ξ_r along the sequence converges (in probability) to Ex_k. The price of

[13] The i.i.d. assumption is of course only a modeling simplification. In reality, intermediaries tend to establish personal relationships with the borrowers, and usually engage in monitoring. This puts a bound on the number of borrowers a single intermediary can handle.

securities p_r approaches $p^G > c$, which is the price when an oligopoly of G intermediaries operates in an economy with no uncertainty. Denoting the limit of α_r by α^G, we have $\lim_{r\to\infty} u(\omega_1 - c\alpha_r) + Eu(\omega_2 + \alpha_r\xi_r) = u(\omega_1 - c\alpha^G) + u(\omega_2 + \alpha^G Ex_k) < U^*$.

The formal analysis and the proofs are very similar to those in the previous section (in fact, for the competition oriented case they are almost identical). They are thus omitted.

5 Concluding Remark

The analysis points to an important aspect of development economics which, to the best of my knowledge, has not been studied in detail. In a developing economy centralized securities markets are not well developed, so financial intermediaries are key to risk sharing. Further, in a developing economy there is a viability problem for a large number of financial institutions. Therefore we should expect to find an oligopolistic market structure in the financial sector of such economies. Finally, it is not easy for financial intermediaries in a developing country to diversify their assets portfolio.

Thus, a developing country suffers heavily from two distortions: There is monopoly power in the intermediation sector, and each intermediary is poorly diversified. The analysis in this paper suggests that as the economy grows, the number of financial intermediaries should be allowed to increase (in order to increase competition), and intermediaries should be encouraged to become larger and more diversified. The analysis also suggests that perfect competition (price equals marginal cost) is achieved relatively fast, whereas the degree of diversification may improve at a slower rate. Thus, in the later stages of development, it may become desirable to gradually shift the focus of government regulation from competition enhancing measures to the encouragement of diversification.

Appendix: Quadratic utility

Let $u(y) = -\frac{1}{2}y^2 + \gamma y$, with γ big enough so that marginal utility is strictly positive for the relevant range of y. Rearranging (18), and using the fact that utility is quadratic, yields

$$\alpha_r - \alpha^* = -\frac{(p_r - c)(\gamma - \omega_1 + cE\alpha_r^\circ) + 2E(\xi_r - Ex_k)\alpha_r^\circ \xi_r^\circ}{E(\xi_r^\circ)^2 + cEp_r^\circ}. \tag{21}$$

In the remainder of the proof, proposition 3 and the Feller lemma invoked in the proof of claim 3 will be used several times. We multiply both sides of (21) by r and take limits. First, note that $\lim_{r\to\infty}[E(\xi_r^\circ)^2 + E\xi_r^\circ] = (Ex_k)^2 + c^2$, which is finite and non-zero. Second, $\lim_{r\to\infty} r(p_r - c)(\gamma - \omega_1 + cE\alpha_r^\circ) = (\gamma - \omega_1 + c\alpha^*)\lim_{r\to\infty} r(p_r - c)$, which is also finite and non-zero. In order to establish the desired result, we have to show that $\lim_{r\to\infty} r2E(\xi_r - Ex_k)\alpha_r^\circ \xi_r^\circ$ is finite. Note first that $E(\xi_r - Ex_k)\xi_r^\circ \leq E(\xi_r - Ex_k)\xi_r$ (since ξ_r° is sandwiched between ξ_r and Ex_k, and $\xi_r \geq 0$ by assumption, we have $0 \leq (\xi_r - Ex_k)\xi_r^\circ \leq (\xi_r - Ex_k)\xi_r$ for $\xi_r \geq Ex_k$, and $(\xi_r - Ex_k)\xi_r^\circ \leq (\xi_r - Ex_k)\xi_r \leq 0$ for $\xi_r \leq Ex_k$). Thus, $\lim_{r\to\infty} r2E(\xi_r - Ex_k)\alpha_r^\circ \xi_r^\circ \leq 2\frac{\omega_1}{c}\lim_{r\to\infty} rE(\xi_r - Ex_k)\xi_r$, which is non-zero and finite (as $E(\xi_r - Ex_k)\xi_r$ is simply the variance of ξ_r, that is the variance of x_k divided by r).

We turn to the rate of convergence of U_r. When utility is quadratic, equation (20) becomes

$$\begin{aligned} U_r - U^* &= (\alpha_r)^2 E(\xi_r' - Ex_k)\xi_r' \\ &\quad -\tfrac{1}{2}(\alpha_r - \alpha^*)^2[c^2 + E(\xi_r^\circ)^2] \\ &\quad -(\alpha_r - \alpha^*)2E(\xi_r - Ex_k)\alpha_r^\circ \xi_r^\circ \\ &\quad -\tfrac{1}{2}E(\xi_r - Ex_k)^2(\alpha_r^\circ)^2. \end{aligned} \tag{22}$$

We multiply both sides by r and take limits. First, note that $\lim_{r\to\infty} r(\alpha_r)^2 E(\xi_r' - Ex_k)\xi_r'$ is finite and non-zero as α_r approaches α^* and $E(\xi_r' - Ex_k)\xi_r'$ is the variance of x_k. Second, $\lim_{r\to\infty} r\frac{1}{2}(\alpha_r - \alpha^*)^2[c^2 + E(\xi_r^\circ)^2] = 0$ as $c^2 + E(\xi_r^\circ)^2$ approaches a constant, and $(\alpha_r - \alpha^*)^2$ approaches zero at the rate $\frac{1}{r^2}$. Third, noting that $E(\xi_r - Ex_k)\alpha_r^\circ$ approaches zero and

$r(\alpha_r - \alpha^*)$ approaches a finite constant, we have that the third term vanishes. Finally, the fourth term is bounded above and below—far enough along the sequence—by an expression which is $O(\frac{1}{r})$. This is seen as follows: $E(\xi_r - Ex_k)^2(\alpha_r^\circ)^2 \leq \left(\frac{\omega_1}{c}\right)^2 E(\xi_r - Ex_k)^2$; also, as α_r converges to $\alpha^* > 0$, there is $\bar{\alpha} > 0$ and r' large enough such that for all $r \geq r'$, $E(\xi_r - Ex_k)^2(\alpha_r^\circ)^2 \geq (\bar{\alpha})^2 E(\xi_r - Ex_k)^2$. ||

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