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Risk spillovers and hedging: why do firms invest too much in systemic risk?
by

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Energy, Transport and Environment

Center for Economic Studies
Discussions Paper Series (DPS) 11.17
http://www.econ.kuleuven.be/ces/discussionpapers/default.htm

May 2011

DISCUSSION
PAPER

Risk Spillovers and Hedging: Why Do Firms Invest Too Much in Systemic Risk?

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May 13th 2011

Abstract

In this paper we show that free entry decisions may be socially inefficient, even in a perfectly competitive homogeneous goods market with non-lumpy investments. In our model, inefficient entry decisions are the result of risk-aversion of incumbent producers and consumers, combined with incomplete financial markets which limit risk-sharing between market actors. Investments in productive assets affect the distribution of equilibrium prices and quantities, and create risk spillovers. From a societal perspective, entrants underinvest in technologies that would reduce systemic sector risk, and may overinvest in risk-increasing technologies. The inefficiency is shown to disappear when a complete financial market of tradable risk-sharing instruments is available, although the introduction of any individual tradable instrument may actually decrease efficiency. We therefore believe that sectors without well-developed financial markets will benefit from sector-specific regulation of investment decisions.

1 Introduction

This paper studies whether investments by a small competitive firm are socially efficient, when market outcomes are uncertain and financial markets are incomplete. We show that decisions about real investments, i.e. investments in productive assets,

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may be suboptimal, because the presence of those assets changes the distribution of overall industry risk, which, if financial markets are incomplete, creates a risk externality for the firms already active in the market. In particular, private investment decisions will lead to a market in which the industry as a whole takes too much risk by investing too much in production activities with highly correlated risk profiles. Firms that could reduce the overall risk of the industry by offsetting the aggregate risk, do no enter often enough, and firms that increase the overal industry risk, enter too often. It is important to note that if the entrant only invests in financial products and not in real physical assets, then its investment decisions will be socially optimal, even if the market is incomplete.

The results of our discussion are relevant for specific sectors such as electricity or oil, in which investment costs are significant, financial markets do not cover all potential contingencies[1] and firms can choose between different technologies or locations with different risk profiles. In such situations, the industry as a whole becomes too risky. In those cases sector-specific regulation might be necessary. Sector-specific regulation could take the form of entry-regulation or the creation of additional financial instruments.

The fact that entry decisions might be socially inefficient in an *oligopolistic* market structure is well known. The most obvious case is the case of entry deterrence by oligopolistic incumbents, a topic that has been studied extensively in the industrial organization literature, following the seminal work by Bain (1949), Sylos Labini (1969) and Modigliani (1958). With entry deterrence, there is *too little* entry from a welfare standpoint. For example, Spence (1977) – later extended by Dixit (1980) and Schmalensee (1981) among others – shows that entry deterrence through prior capacity commitments by the incumbent may result in larger costs than are necessary for a given output level, and higher prices. Our paper does not consider the preemptive strategic actions of incumbents and focuses on the potential entrant's investment decision. In such a context, one finds not only cases with too little entry, but also cases with *excessive* entry: von Weizsäcker (1980) shows that there are plausible parameter configurations under which welfare would be improved by limiting entry. Similar to Mankiw and Whinston (1986), we use a two-stage model with capacity investment decisions by entrant(s) in stage one and actual production in stage two. As Mankiw and Whinston (1986) point out, suboptimal entry is due to the fact that the entrant's evaluation of the desirability of his entry is different than the 'social planner's' evaluation – a phenomenon one could call *investment exter-*

[1]Markets might be incomplete because productive assets have a long lifetime, or because some sources of risks are non-tradable. For instance, there might not be financial instruments to hedge regulatory uncertainty.

nalities. In the analysis by Mankiw and Whinston (1986), the externality is due to 'business-stealing' from other players: the entrant will gain some profit by reducing the profit of the existing players. This leads to a redistribution of industry profits, but not necessarily to an increase in the total surplus of the industry. Note that the business stealing effect disappears if the stage-two game is perfectly competitive and the post-entry market price reflects the marginal cost of firms.[2] Our model is quite different from the industrial organization literature because it has a perfectly competitive post-entry market. Furthermore, the models by Spence (1977), Dixit (1980) and Schmalensee (1981) either assume a minimum entry capacity or a fixed set-up cost – independent of entry capacity. In contrast, our model allows for infinitesimal capacity investment by the entrant. Finally, our model incorporates uncertainty, a feature which has also been added to the above-mentioned models, by e.g. Perrakis and Warskett (1983) and Maskin (1999). Most importantly however, we assume *imperfect financial markets*. The investment externality in our model turns out to be a 'risk externality': the real investment changes the risk profile of future shocks.

Investment under uncertainty has been thoroughly studied in the real option framework (Dixit and Pindyck, 1994): firms should take into account the option value of an investment opportunity. By delaying the investment the firm learns more about the likely profitability of the project and might be able to avoid investments that are likely to be loss-making. Recently, Miao and Wang (2007) and Hugonnier and Morellec (2007) have extended the real option framework to the case of incomplete markets, using a utility-based approach. They study how market incompleteness affects the investment decisions of firms. Miao and Wang (2007) for example, find that – unlike in standard real options analysis – an increase in project volatility can accelerate investment if the agent has a sufficiently strong precautionary savings motive. Although we use a similar utility-based model framework, our point of view is complementary in that we do not focus on how the entrant should make investment decisions, but rather study the social welfare implications of those decisions.

This paper is an extension and generalization of Willems and Morbee (2010), in which the effect of increasing market completeness on an entrant's investment decisions was examined numerically for the case of the electricity market. In the current paper we develop a general analytical model. In the next section, we first demonstrate the possibility of suboptimal entry when risk markets are incomplete. We will start from the traditional deterministic model, where entry is optimal, and

[2]Reaching a sufficient number of entrants in order to satisfy this condition typically requires the absence of fixed set-up costs that would create barriers to entry.

subsequently include uncertainty and risk aversion, which may lead to suboptimal entry. Then, in section 3 we study the effect of increasing market completeness, i.e. increasing availability of instruments to trade risk between market participants. Section 4 summarizes our conclusions and briefly provides policy recommendations and areas for future research.

2 Suboptimal entry with incomplete markets

Building on the industrial organization literature, we first describe a deterministic version of our model, in which entry is always socially optimal, as there are no risk spillovers. In a second step, we demonstrate the possibility of suboptimal entry when uncertainty and risk aversion are introduced.

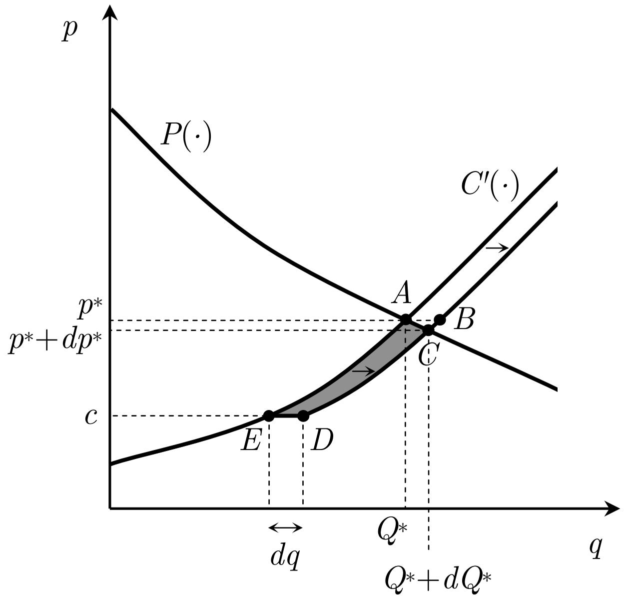
2.1 Traditional deterministic model

Following Mankiw and Whinston (1986), we model entry as a two-stage game. In the first stage, the *investment stage*, the entrant decides whether to enter the industry by investing in capacity. In stage two, the *production stage*, firms produce and sell a homogeneous product in a perfectly competitive market. $P(Q)$ denotes the inverse demand function, where Q is aggregate output, and assume $P'(Q) \leq 0, \forall Q$. Before any entry takes place, the industry marginal cost curve is given by $C'(Q)$, with $C''(Q) \geq 0, \forall Q$. In the absence of entry, the competitive market equilibrium is (p^*, Q^*) with $p^* = P(Q^*) = C'(Q^*)$. We consider an entrant who, in the first stage, has the possibility to invest in an infinitesimal amount of production capacity dq, at an investment cost of $k\,dq$. If the entrant decides to invest, she will have access to a production capacity dq with marginal production cost c in the second stage.[3]

Figure 1 shows how the entry decision in stage one affects the outcome of the production stage, for the case in which $c \leq p^*$. Entry reduces the equilibrium price to $p^* + dp^*$, and increases the equilibrium quantity to $Q^* + dQ^*$. Entry increases stage-two Marshallian aggregate surplus by an amount corresponding to the shaded area $\widehat{ACDE}$. Since the area $\widehat{ABC}$ is only a second-order effect (it is approximately given by $\frac{1}{2}dp^* \cdot dq$), the surface area of $\widehat{ACDE}$ can be approximated by $\widehat{ABDE}$, which

[3]We assume an infinitesimal small entrant as we want to model the behavior of a competitive, price-taking entrant. An infinitesimal investor will affect market outcomes only marginally, which justifies the price-taking assumption. Note that in contrast with many entry models we do not assume that investment decisions are lumpy. Spence (1977), Dixit (1980) and Schmalensee (1981) either assume a minimum entry capacity or a fixed set-up cost – independent of entry capacity. By assuming away lumpiness we eliminate a possible source of inefficiency in the market, and the results of our model become stronger.

Figure 1: Effect of entry on stage-two Marshallian aggregate surplus



corresponds to $(p^* - c)dq$. Taking into account the investment cost $k\, dq$ incurred by the entrant in stage one, the net effect of entry on social welfare W is therefore:

$$dW = (p^* - c)dq - k\, dq \tag{1}$$

This amount dW corresponds exactly to the entrant's profit $d\pi$, hence the entrant's incentives are perfectly aligned with social interest: the entrant invests if and only if it is socially optimal to do so. This is the well-known textbook result about the social efficiency of free entry in a perfectly competitive market.

At this point it is useful to take a closer look at equation (1). In general, the change in social welfare caused by entry is given by:

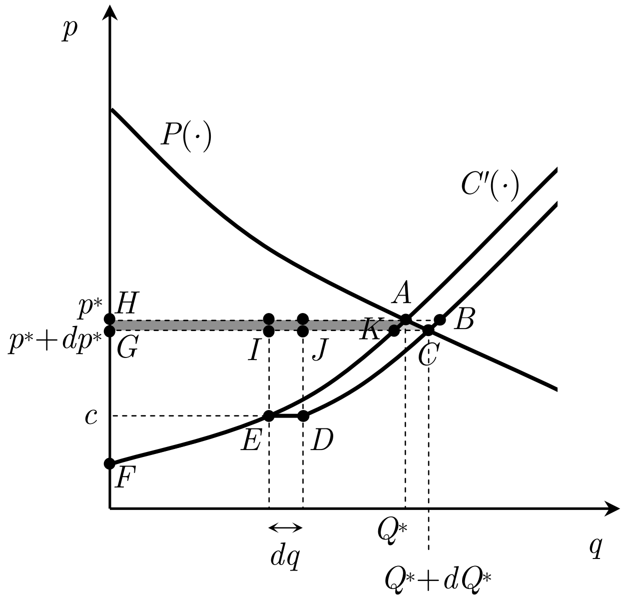
$$dW = d\Pi + dCS + d\pi \tag{2}$$

where Π represents aggregate industry profits (producer surplus) of existing producers, CS represents aggregate consumer surplus and $d\pi$ the profit of the infinitesimal entrant. Since we concluded above that $dW = d\pi$, we must have:

$$d\Pi = -dCS \tag{3}$$

Equation (3) is illustrated in figure 2. The investment in capacity dq causes a (negative) price change $dp^* = \frac{dp^*}{dq}dq$. As a result, CS increases by the area $\widehat{HACG}$, which in first order corresponds to $-Q^*dp^*$. The effect on Π is similar, but slightly

Figure 2: Effect of entry on producer surplus of existing firms and on consumer surplus



more complicated to compute. In the absence of entry, the producer surplus Π of existing firms is given by $\widehat{HAF}$. In the event of entry, the producer surplus of existing firms changes to $\widehat{GIEF} + \widehat{JCD} = \widehat{GKF}$. Hence, $d\Pi = -\widehat{HAKG}$, which in first order corresponds to $Q^* dp^* = -dCS$.[4] Again, this result stems from $\widehat{ACK} = \widehat{ABC} = \frac{1}{2} dp^* \cdot dq$ being a second-order effect, which should be ignored in infinitesimal analysis. The fact that there is no net effect of entry on $\Pi + CS$ is due to the perfectly competitive nature of the production stage. In a non-competitive setting, entry would have an additional negative externality, due to 'business-stealing' from existing inframarginal capacity. In a perfectly competitive setting, existing firms produce up to the point where price equals marginal cost, hence the only existing capacity that is being displaced by business-stealing is the capacity at the margin, which does not have any net social value.

The above reasoning is for the case in which $c \leq p^*$. The alternative case $c > p^*$ is trivial: since neither Π nor CS is affected by the entrant's investment, we obviously have $dW = d\pi$ and $d\Pi = -dCS = 0$ in this case.

[4]Note that $d\Pi = Q^* dp^*$ is in fact nothing but Hotelling's lemma for the case of a one-good economy, while $dCS = -Q^* dp^*$ is Roy's identity for the case of a quasilinear utility function (as is implicitly assumed in our partial equilibrium setting).

2.2 Model including uncertainty and risk aversion

We will extend the deterministic model from section 2.1 to include the effects of uncertainty and risk aversion. Uncertainty is included by making the second stage stochastic: stage two takes place in a random *state-of-the-world* denoted ω, chosen stochastically among a range of possible states Ω. As a result, the variables Π, CS and $d\pi$, as well as all equilibrium prices and quantities, become random variables, which will be denoted using boldface.[5] The randomness may be caused by uncertainty in demand (as in Willems and Morbee, 2010), but may also be due to other factors, such as e.g. uncertainty in the prices of input factors, possible unforeseen outages of some of the production capacity, or regulatory uncertainty. Our reasoning is not limited to any of these sources of uncertainty.

The random nature of stage two requires additional assumptions about the social welfare function. As before we use a utilitarian social welfare function, i.e. the sum of the individual utilities of existing firms, consumers and entrant. As for the individual utility functions, we incorporate *risk aversion*, i.e. a preference for more certain outcomes over more uncertain outcomes for a given expected value of the outcome. For the sake of analytical convenience, we assume that the aggregate utility U_p of the existing producers is given by the well-known *mean-variance utility function:*

$$U_p = \mathrm{E}[\mathbf{\Pi}] - \frac{A_p}{2}\mathrm{Var}[\mathbf{\Pi}] \tag{4}$$

and, likewise, that the aggregate utility U_c of consumers is given by:

$$U_c = \mathrm{E}[\mathbf{CS}] - \frac{A_c}{2}\mathrm{Var}[\mathbf{CS}] \tag{5}$$

with the risk aversion parameters for producers and consumers $A_p, A_c \geq 0$. The expected-value and variance operators $\mathrm{E}[\cdot]$ and $\mathrm{Var}[\cdot]$ in equations (4) and (5) are computed on the sample space Ω. Social welfare is assumed to be given by:

$$W = U_p + U_c + U_e \tag{6}$$

in which U_e represents the utility of the entrant, for which we do not make functional-form assumptions.

Proposition 2.1. *When social welfare is given by equations (4), (5) and (6), the effect of an infinitesimal entrant with capacity dq, on social welfare, is given by:*

$$dW = dU_e + \mathrm{Cov}[A_p\mathbf{\Pi} - A_c\mathbf{CS}, \mathbf{x}]dq \tag{7}$$

[5]Later we will interpret random variables as vectors in $\#\Omega$-dimensional space.

where:

$$\mathbf{x} = -\mathbf{Q}^* \frac{d\mathbf{p}^*}{dq} \tag{8}$$

Proof. If the entrant decides to invest in capacity dq in stage one, this will have an effect on $\mathbf{\Pi}$ and $\mathbf{CS}$ in stage two. The effect may be different in each state-of-the-world ω. However, equation (3) will hold for each ω. Therefore, we can write the effect of entry on $\mathbf{\Pi}$ and $\mathbf{CS}$ as:

$$d\mathbf{\Pi} = -d\mathbf{CS} = -\mathbf{x}dq \tag{9}$$

with $\mathbf{x}$ as in equation (8). The effect on U_p is obtained by differentiation of equation (4):

$$\begin{aligned} dU_p &= d(\mathrm{E}[\mathbf{\Pi}] - \frac{A_p}{2}\mathrm{Var}[\mathbf{\Pi}]) \\ &= \mathrm{E}[d\mathbf{\Pi}] - \frac{A_p}{2}(\mathrm{Var}[\mathbf{\Pi} + d\mathbf{\Pi}] - \mathrm{Var}[\mathbf{\Pi}]) \\ &= \mathrm{E}[-\mathbf{x}dq] - \frac{A_p}{2}(\mathrm{Var}[\mathbf{\Pi} - \mathbf{x}dq] - \mathrm{Var}[\mathbf{\Pi}]) \\ &= -\mathrm{E}[\mathbf{x}]dq + A_p\mathrm{Cov}[\mathbf{\Pi}, \mathbf{x}]dq \end{aligned} \tag{10}$$

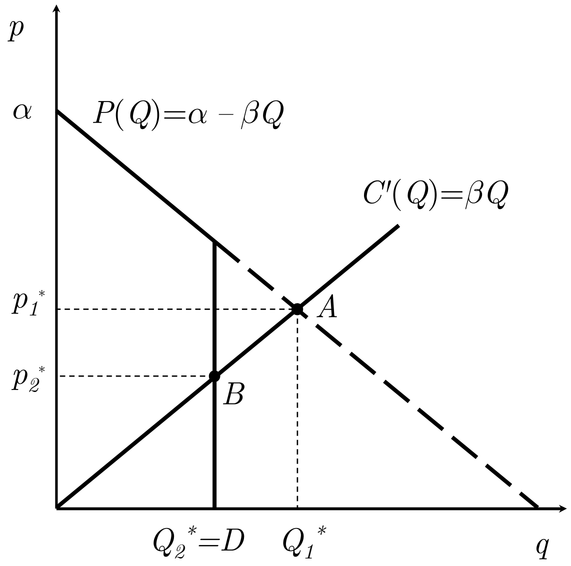
where we have used the fact that $\mathrm{Var}[\mathbf{x}dq] = \mathrm{Var}[\mathbf{x}](dq)^2$ can be ignored as a second-order term. Using an analogous reasoning, we obtain

$$dU_c = \mathrm{E}[\mathbf{x}]dq - A_c\mathrm{Cov}[\mathbf{CS}, \mathbf{x}]dq \tag{11}$$

Putting equations (6), (10) and (11) together, we find equation (7). □

The first term dU_e in equation (7) is the effect of entry on the utility of the entrant himself. The second term in equation (7) is an *externality*: unlike dU_e, this effect of entry on social welfare is not fully internalized by the entrant, and hence is not included in his investment decision. Of particular interest are the cases in which the entrant would like to enter, $dU_e > 0$ but it would not be socially optimal, $dW < 0$, or vice versa. Such cases exist when dU_e and $\mathrm{Cov}[A_p\mathbf{\Pi} - A_c\mathbf{CS}, \mathbf{x}]$ have different signs and A_p and/or A_c are large enough. In such circumstances, a decision to enter (or refrain from entering) may be privately optimal, but socially detrimental. The externality is due to the fact that the investment in new capacity leads to a shift in market outcomes, which affects risk-sharing between existing producers and consumers. Hence, despite the perfectly competitive nature of stage two, the combination of uncertainty and risk-averse agents may lead to suboptimal entry. We will illustrate the potential inefficiency of free entry in the following example.

Figure 3: Graphical illustration of Example 2.2



Example 2.2. Let us consider a sector with linear inverse demand $P(Q) = \alpha - \beta Q$ with $\alpha, \beta > 0$. The industry marginal cost curve is given by $C'(Q) = \bar{c}Q$, with $\bar{c}$ a constant. For analytical convenience we assume $\bar{c} = \beta$. In the absence of any intervention, the competitive equilibrium will be $(p_1^*, Q_1^*) = (\frac{\alpha}{2}, \frac{\alpha}{2\beta})$, shown as point A in Figure 3. We introduce uncertainty into this market by assuming that with probability ψ, government will intervene and forbid the lowest-value applications of the product.[6] The result of this intervention would be that demand becomes flat as soon as it reaches a certain level D. The part of the inverse demand curve to the right of $Q = D$ is clipped and becomes a vertical line at $Q = D$. Hence, with probability ψ the equilibrium is $(p_2^*, Q_2^*) = (\alpha - \beta D, D)$, which is shown as point B in Figure 3. Conversely, with probability $1 - \psi$ there is no government intervention and the equilibrium is at point A. No other source of uncertainty is assumed. Furthermore, we assume that $Q_2^* < Q_1^*$, i.e. $D < \frac{\alpha}{2\beta}$. Social welfare is assumed to be given by equations (4), (5) and (6), with $A_p = 0$ and $A_c > 0$. Hence, producers are risk-neutral while consumers are risk-averse.

Let us now consider an entrant who has access to two technologies: a 'peak' technology with marginal cost c_P such that $p_2^* < c_P < p_1^*$, and a 'base' technology with marginal cost c_B such that $0 < c_B < p_2^*$. The unit investment cost of the two technologies is k_P and k_B, respectively. Hence, the 'peak' technology will be

[6] Environmental concerns would be a typical reason for this kind of interventions. One could think, for example, of a ban on using tap water for filling up swimming pools, or – as it exists in some European countries – a fine for installing electrical heating in new houses.

activated only if there is no government intervention (probability $1 - \psi$), while the 'base' technology will be activated both in the case of government intervention and in the case of no government intervention. Obviously, a necessary condition for the 'peak' technology to be attractive, is that $k_P < k_B$. More than that, we will assume that both technologies yield equal, zero NPV for the investor. Assuming the entrant is risk-neutral like the other producers (in fact, the entrant could be one of the existing producers), we would then have $dU_e = 0$, which would make the entrant indifferent between investing and not investing in either technology. To make matters more interesting, we shall assume that k_B is infinitesimally smaller and k_P is infinitesimally larger, so that the entrant would have a marginal preference for investing in the 'base' technology and not investing in the 'peak' technology.

Since $dU_e = 0$, the social welfare impact of the investment is only the 'investment externality': $dW = dU_p + dU_c$. Using Proposition 2.1, or by directly computing U_p and U_c, one can demonstrate that the social welfare impact of an infinitesimal investment dq_B in the 'base' technology, for the case $\psi = \frac{1}{2}$, is given by:

$$\frac{dW}{dq_B} = -\frac{3A\beta^2}{8}\left(\frac{\alpha}{2\beta} - D\right)\left(D - \frac{\alpha}{6\beta}\right)\left(D - \frac{\alpha}{4\beta}\right) \tag{12}$$

while the welfare impact of an infinitesimal investment dq_P in the 'peak' technology, for the case $\psi = \frac{1}{2}$, is given by:

$$\frac{dW}{dq_P} = \frac{3A\beta^2}{8}\left(\frac{\alpha}{2\beta} - D\right)\left(D - \frac{\alpha}{6\beta}\right)\frac{\alpha}{4\beta} \tag{13}$$

Assuming that $D > \frac{\alpha}{4\beta}$, we find that $dW/dq_B < 0$ while $dW/dq_P > 0$. Hence, from a social welfare point of view, the entrant would overinvest in the 'base' technology, and underinvest in the 'peak' technology. The underlying cause is that the 'peak' technology takes costly risk out of the market, but the entrant is not rewarded for this. In this example, we have assumed that the uncertainty is due to unhedgeable political factors. In the next section, we will examine the case in which risk-sharing instruments are available.

3 Effects of increasing market completeness

As mentioned before, the demonstration of suboptimal entry in section 2.2 is related to imperfect risk-sharing between market participants. Indeed, the setting described above does not offer any instruments that would allow market participants to trade risk between them: markets are *incomplete*. In this section we will examine the case of increasingly complete markets.

3.1 Increasing market completeness without entry

Let us consider a case with n tradable financial instruments, such as forwards and options. Such instruments are fully represented by prices $F_i, i = 1, \ldots, n$ and their pay-offs $\mathbf{T}_i, i = 1, \ldots, n$, the latter being random variables because they depend on the state-of-the-world $\omega \in \Omega$ in stage two. Buying (selling) an instrument i means paying (receiving) a fixed price F_i in stage one, and receiving (paying) an uncertain pay-off $\mathbf{T}_i$ in stage two. Without loss of generality, we can assume that $\mathrm{E}[\mathbf{T}_i] = 0, \forall i$. To study the impact of the availability of these financial instruments on the behavior of producers and consumers, it is convenient to consider random variables as 'vectors'. Indeed, the space of zero-mean random variables (i.e. all functions $\mathbf{X} : \Omega \to \mathbb{R}$ with $\mathrm{E}[\boldsymbol{X}] = 0$) can be augmented with an inner product $\langle \mathbf{X}, \mathbf{Y} \rangle = \mathrm{E}[\mathbf{XY}] = \mathrm{Cov}[\mathbf{X}, \mathbf{Y}]$, to form a Hilbert space. The instrument pay-offs $\mathbf{T}_i, i = 1, \ldots, n$ span a subspace of this Hilbert space. Through orthogonal projection of the two zero-mean random variables $\mathbf{\Pi} - \mathrm{E}[\mathbf{\Pi}]$ and $\mathbf{CS} - \mathrm{E}[\mathbf{CS}]$ onto this subspace, we can uniquely rewrite $\mathbf{\Pi}$ and $\mathbf{CS}$ as:[7]

$$\mathbf{\Pi} \;=\; \mathrm{E}[\mathbf{\Pi}] + \vec{\lambda}_p^T \vec{\mathbf{T}} + \boldsymbol{\varepsilon}_p \tag{14}$$

$$\mathbf{CS} \;=\; \mathrm{E}[\mathbf{CS}] + \vec{\lambda}_c^T \vec{\mathbf{T}} + \boldsymbol{\varepsilon}_c \tag{15}$$

with $\mathrm{E}[\boldsymbol{\varepsilon}_p] = \mathrm{E}[\boldsymbol{\varepsilon}_c] = 0$ and $\mathrm{Cov}[\mathbf{T}_i, \boldsymbol{\varepsilon}_p] = \mathrm{Cov}[\mathbf{T}_i, \boldsymbol{\varepsilon}_c] = 0, \forall i$. The arrow $\vec{\cdot}$ denotes an n-dimensional column matrix, and $\cdot^T$ denotes matrix transposition. Furthermore, we write $\vec{\mathbf{T}} = [\mathbf{T}_1 \ldots \mathbf{T}_n]^T$ and $\vec{F} = [F_1 \ldots F_n]^T$. Finally, note that $\boldsymbol{\varepsilon}_p$ and $\boldsymbol{\varepsilon}_p$ are stochastic, while $\vec{\lambda}_p$ and $\vec{\lambda}_c$ are deterministic.

The trade of financial instruments modifies producers' profits and consumer surplus. The resulting quantities are:

$$\tilde{\mathbf{\Pi}} \;=\; \mathbf{\Pi} + \vec{k}_p^T (\vec{\mathbf{T}} - \vec{F}) \tag{16}$$

$$\tilde{\mathbf{CS}} \;=\; \mathbf{CS} + \vec{k}_c^T (\vec{\mathbf{T}} - \vec{F}) \tag{17}$$

with the column matrices $\vec{k}_p$ and $\vec{k}_c$ denoting the amount of each of the n instruments bought by producers and consumers, respectively. Negative amounts represent 'selling'. The resulting utility levels $\tilde{U}_p$ and $\tilde{U}_c$ are related to $\tilde{\mathbf{\Pi}}$ and $\tilde{\mathbf{CS}}$ in the same way as in equations (4) and (5).

[7]Uniqueness requires that the $\mathbf{T}_i, i = 1, \ldots, n$ not be linearly dependent. We assume here that this condition is fulfilled.

Lemma 3.1. *In the absence of other players on the financial markets, the equilibrium quantities and prices of financial instruments bought and sold by producers and consumers are given by:*

$$\vec{k}_p = -\vec{k}_c = \frac{A_c\vec{\lambda}_c - A_p\vec{\lambda}_p}{A_c + A_p} \tag{18}$$

and

$$\vec{F} = -\frac{A_c A_p}{A_c + A_p}\Sigma(\vec{\lambda}_c + \vec{\lambda}_p) \tag{19}$$

with Σ *the* $n \times n$*-dimensional covariance matrix of* $\vec{\mathbf{T}}$.

Proof. From equations (4), (14) and (16), we find that:

$$\tilde{U}_p = \mathrm{E}[\mathbf{\Pi}] - \vec{k}_p^T\vec{F} - \frac{A_p}{2}((\vec{\lambda}_p + \vec{k}_p)^T\Sigma(\vec{\lambda}_p + \vec{k}_p) + \mathrm{Var}[\boldsymbol{\varepsilon}_p]) \tag{20}$$

using the fact that $\mathrm{Cov}[\mathbf{T}_i, \boldsymbol{\varepsilon}_p] = 0, \forall i$. The gradient in $\vec{k}_p$, assuming price-taking behavior on the financial market, is easily derived as:

$$\vec{\nabla}_{k_p}\tilde{U}_p = -\vec{F} - A_p\Sigma(\vec{\lambda}_p + \vec{k}_p) \tag{21}$$

from which the first-order equilibrium condition for $\vec{k}_p$ can be determined:

$$\vec{k}_p = -\left(\frac{1}{A_p}\Sigma^{-1}\vec{F} + \vec{\lambda}_p\right) \tag{22}$$

A completely analogous condition can be derived for $\vec{k}_c$. In the absence of other players on the financial markets, we must have $\vec{k}_p + \vec{k}_c = \vec{0}$, from which we can derive equation (19). Substituting (19) into (22), we obtain (18). □

Equation (18) represents the optimal risk-sharing between producers and consumers, for the given set of available financial instruments.

Example 3.2. Assume the market is complete ($\boldsymbol{\varepsilon}_p = \boldsymbol{\varepsilon}_c = 0$) and $A_p = A_c = A$. Then $\vec{k}_p = \frac{\vec{\lambda}_p - \vec{\lambda}_c}{2}$, hence $\tilde{\mathbf{\Pi}} = \mathrm{E}[\mathbf{\Pi}] - \vec{k}_p^T\vec{F} + \left(\frac{\vec{\lambda}_p + \vec{\lambda}_c}{2}\right)\vec{\mathbf{T}}$, so that $\tilde{\mathbf{\Pi}}$ becomes identical to $\frac{\mathbf{\Pi}+\mathbf{CS}}{2}$, except for a non-stochastic component. The same holds for $\mathbf{CS}$, hence risk is perfectly distributed between producers and consumers: the only remaining risk is the sector risk $\mathbf{\Pi} + \mathbf{CS}$, which is shared equally between producers and consumers. The transition from an incomplete market (as in Section 2.2) to a complete market as in this example, increases social welfare from $\mathrm{E}[\mathbf{\Pi} + \mathbf{CS}] - \frac{A}{2}(\mathrm{Var}[\mathbf{\Pi}] + \mathrm{Var}[\mathbf{CS}])$ to $\mathrm{E}[\mathbf{\Pi} + \mathbf{CS}] - \frac{A}{4}(\mathrm{Var}[\mathbf{\Pi} + \mathbf{CS}])$.[8]

[8]Note that market completion does not increase social welfare when the stochastic variations

3.2 Production entry in an increasingly complete market

Let us now study the effect of an infinitesimal entrant in the case of an increasingly complete financial market. Analogous to equations (14) and (15), we can write $\mathbf{x}$ (defined as in Section 2.2) as:

$$\mathbf{x} = \mathrm{E}[\mathbf{x}] + \vec{\lambda}_x^T \vec{\mathbf{T}} + \boldsymbol{\varepsilon}_x \tag{23}$$

Lemma 3.3. *In first order, an entrant who only invests in physical capacity and does not enter the financial markets, does not change the prices of tradable financial instruments ($d\vec{F} = 0$), while the quantities of financial instruments traded change by an amount corresponding to the hedgeable part of the impact of the entrant ($d\vec{k}_p = -d\vec{k}_c = \vec{\lambda}_x dq$).*

Proof. From equations (9), (14), (15), (23) and the uniqueness of orthogonal projection, one can infer that the effect on $\vec{\lambda}_p$ and $\vec{\lambda}_c$, of an infinitesimal entrant with capacity dq, is $d\vec{\lambda}_p = -d\vec{\lambda}_c = -\vec{\lambda}_x dq$. Lemma 3.3 then follows directly from Lemma 3.1. □

Proposition 3.4. *Assume the same conditions as in Proposition 2.1. When tradable financial instruments $\vec{\mathbf{T}}$ are available, the effect of an infinitesimal entrant with capacity dq, on social welfare, is given by:*

$$d\tilde{W} = dU_e + \mathrm{Cov}[A_p\boldsymbol{\varepsilon}_p - A_c\boldsymbol{\varepsilon}_c, \boldsymbol{\varepsilon}_x]dq \tag{24}$$

with $\boldsymbol{\varepsilon}_p$, $\boldsymbol{\varepsilon}_c$ and $\boldsymbol{\varepsilon}_x$ defined as in equations (14), (15) and (23).

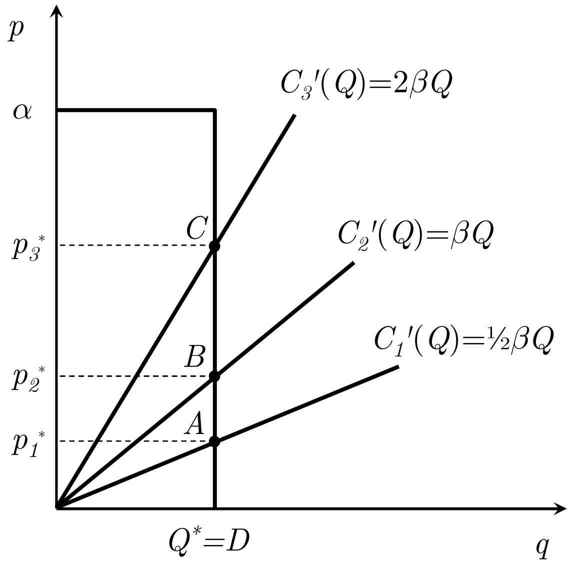
Proof. Using reasoning analogous to the proof of Proposition 2.1, we find

$$\begin{aligned}
d\tilde{U}_p &= d\left(\mathrm{E}[\boldsymbol{\Pi}] - \vec{k}_p^T\vec{F} - \frac{A_p}{2}((\vec{\lambda}_p + \vec{k}_p)^T\Sigma(\vec{\lambda}_p + \vec{k}_p) + \mathrm{Var}[\boldsymbol{\varepsilon}_p])\right) \\
&= \mathrm{E}[d\boldsymbol{\Pi}] - \vec{\lambda}_x^T\vec{F}dq - A_p(\vec{\lambda}_p + \vec{k}_p)^T\Sigma d(\vec{\lambda}_p + \vec{k}_p) \\
&\quad -\frac{A_p}{2}(\mathrm{Var}[\boldsymbol{\varepsilon}_p - \boldsymbol{\varepsilon}_x dq] - \mathrm{Var}[\boldsymbol{\varepsilon}_p]) \\
&= -\mathrm{E}[\mathbf{x}]dq - \vec{\lambda}_x^T\vec{F}dq - A_p(\vec{\lambda}_p + \vec{k}_p)^T\Sigma(-\vec{\lambda}_x dq + \vec{\lambda}_x dq) \\
&\quad -\frac{A_p}{2}(-2\mathrm{Cov}[\boldsymbol{\varepsilon}_p, \boldsymbol{\varepsilon}_x dq]) \\
&= -\mathrm{E}[\mathbf{x}]dq - \vec{\lambda}_x^T\vec{F}dq + A_p\mathrm{Cov}[\boldsymbol{\varepsilon}_p, \boldsymbol{\varepsilon}_x]dq
\end{aligned}$$

and analogous for $d\tilde{U}_c$. Putting both expressions together, we find equation (24). □

in $\boldsymbol{\Pi}$ and $\mathbf{CS}$ are identical. In that case, social welfare remains the same before and after the introduction of a complete market, because there are no gains to be made from trading risk.

Figure 4: Graphical illustration of Example 3.5



As before, the second term in equation (24) is an externality that may lead to over- or underinvestment. Proposition 3.4 clearly demonstrates the impact of increasing market completeness. As markets become more complete, the subspace spanned by the instruments $\vec{\mathbf{T}}$ approaches the complete space of random variables. As a result, $\text{Var}[\boldsymbol{\varepsilon}_p] = \|\boldsymbol{\varepsilon}_p\|^2 \to 0$, and likewise for $\boldsymbol{\varepsilon}_c$, so that, in a complete market, the externality disappears and the entry decision is socially optimal.

Example 3.5. Let us consider a sector in which consumers have fixed inelastic demand D, with reservation price α. We assume that the industry marginal cost curve takes one of the following three forms: $C_1'(Q) = \frac{1}{2}\beta Q$, $C_2'(Q) = \beta Q$, or $C_3'(Q) = 2\beta Q$. In words: costs can take a reference value, or double the reference value, or half the reference value. As an example, the uncertainty in industry costs may be due to uncertainty in prices of input products, such as oil. To focus our thoughts, let us assume indeed that the industry is strongly dependent on oil and that all the above-described uncertainty in production costs is due to uncertainty about the oil price. The choice between the three cost curves is stochastic. We assume that the three states-of-the-world are equally likely. The sector assumptions are illustrated in Figure 4. Note that we assume $\alpha > 2\beta D$. The competitive equilibrium price in the absence of entry is $p_1^* = \frac{1}{2}\beta D$ (point A), $p_2^* = \beta D$ (point B), or $p_3^* = 2\beta D$ (point C), each with probability $\frac{1}{3}$. The top part of Table 1 summarizes the pay-offs $\mathbf{\Pi}$ and $\mathbf{CS}$ in each of the states-of-the-world. Social welfare is assumed to be given by equations (4), (5) and (6), with $A_p = A_c \equiv A$. Hence, consumers and producers are equally risk-averse.

Table 1: Example 3.5: profits of existing producers and consumer surplus in the three states-of-the-world (top part of the table), and impact of the entrant (bottom part of the table)

State-of-the-world $\omega =$	ω_1	ω_2	ω_3
$C'(Q) =$	$\frac{1}{2}\beta Q$	βQ	$2\beta Q$
$\mathbf{\Pi} =$	$\frac{1}{4}\beta D^2$	$\frac{1}{2}\beta D^2$	βD^2
$\mathbf{CS} =$	$(\alpha - \frac{1}{2}\beta D)D$	$(\alpha - \beta D)D$	$(\alpha - 2\beta D)D$
$\frac{d\mathbf{CS}}{dq_B} = -\frac{d\mathbf{\Pi}}{dq_B} = \mathbf{x}_B =$	$\frac{1}{2}\beta D$	βD	$2\beta D$
$\frac{d\mathbf{CS}}{dq_M} = -\frac{d\mathbf{\Pi}}{dq_M} = \mathbf{x}_M =$	0	βD	$2\beta D$
$\frac{d\mathbf{CS}}{dq_P} = -\frac{d\mathbf{\Pi}}{dq_P} = \mathbf{x}_P =$	0	0	$2\beta D$

Let us now consider an entrant who has access to three technologies: a 'peak' technology with marginal cost c_P such that $p_2^* < c_P < p_3^*$, a 'base' technology with marginal cost c_B such that $0 < c_B < p_1^*$, and a 'medium' technology with marginal cost c_M such that $p_1^* < c_M < p_2^*$. We assume that the costs c_P, c_B and c_B do not exhibit any uncertainty. In the story of our example: they are independent of the oil price. The unit investment cost of the three technologies is k_P, k_B and k_M, respectively. The 'peak' technology will be activated only in state ω_3, the 'medium' technology will be activated only in states ω_2 and ω_3, while the 'base' technology will be activated in all three states. As in Example 2.2, we assume that all three technologies yield equal, zero NPV for the investor. Again assuming the entrant is risk-neutral, we would then have $dU_e = 0$ for all technologies, which would make the entrant indifferent between investing and not investing in any of the technologies. We will assume that in this case the entrant does not invest. The bottom part of Table 1 shows the impact (on profits of existing producers and on consumer surplus) of an entrant investing in an infinitesimal amount of 'base' capacity (dq_B), 'medium' capacity (dq_M), or 'peak' capacity (dq_P), respectively. Since $dU_e = 0$, the social welfare impact of the investment is only the 'investment externality': $d\tilde{W} = d\tilde{U}_p + d\tilde{U}_c$. Looking at Table 1 and considering Proposition 2.1, it is easy to see that $d\tilde{W} > 0$ for all three technologies, because they reduce the variability of profits of existing producers and consumer surplus. However, since the entrant does not invest, we have a case of underinvestment (insufficient entry) compared to the social optimum.

Now let us introduce tradable financial instruments. Since there are three states-of-the-world, the Hilbert space of zero-mean random variables is two-dimensional. Hence, two linearly independent instruments $\mathbf{T}_1$ and $\mathbf{T}_2$ are sufficient to make the

Table 2: Example 3.5: pay-offs of the tradable financial instruments

State-of-the-world $\omega =$	ω_1	ω_2	ω_3
$\mathbf{T}_1 =$	-1	0	1
$\mathbf{T}_2 =$	-1	-1	2
$\mathbf{T}_3 =$	4	-5	1

Table 3: Example 3.5: Social welfare impact of the entrant (for each of the three technologies) as a function of the available tradable instruments

	No instruments	Only $\mathbf{T}_1$	Only $\mathbf{T}_2$	Both $\mathbf{T}_1$ and $\mathbf{T}_2$
$\frac{d\tilde{W}}{dq_B} =$	$\frac{7}{12}$	$\frac{1}{48}$	$\frac{1}{16}$	0
$\frac{d\tilde{W}}{dq_M} =$	$\frac{3}{4}$	0	$\frac{1}{8}$	0
$\frac{d\tilde{W}}{dq_P} =$	$\frac{5}{6}$	$\frac{1}{12}$	0	0

Note: all values in this table need to be multiplied by $A\beta^2 D^3$.

market complete. Let us define the pay-offs of $\mathbf{T}_1$ and $\mathbf{T}_2$ as in Table 2. $\mathbf{T}_1$ could be considered as a 'future' contract on the oil price, while $\mathbf{T}_2$ could be considered as a 'call option' contract. The table also mentions $\mathbf{T}_3$, which will be considered later on. The availability of tradable financial instruments alters the risk-sharing between existing producers and consumers. As a result, the risk-reducing external benefits of an investment by the entrant may be less important. Using Proposition 3.4, we can compute the impact of an infinitesimal investment on social welfare, when an increasing number of tradable instruments are available. Table 3 provides an overview of the results, for each of the three technologies. The presence of either $\mathbf{T}_1$ or $\mathbf{T}_2$ reduces the positive externalities of entry. When both instruments are present, the market is complete, hence risk-sharing between producers and consumers is perfect and entry (or, in this example, lack thereof) is socially optimal. Finally, it is interesting to note that the externalities for some types of entry may become 0 even when the market is not yet fully complete. This is the case when an instrument is available with exactly the same risk profile as the impact of the entrant. For example, the presence of only $\mathbf{T}_1$ already makes the externality of the 'medium' technology disappear. The same holds for $\mathbf{T}_2$ and the 'peak' technology.

The observation in Table 3 that the investment externality goes down for each tradable instrument added, is however not general:

Corollary 3.6. *Adding a tradable instrument does not necessarily decrease the investment externality computed in Propositions 2.1 or 3.4.*

To see this, let us consider a market in which the instruments $\mathbf{T}_i, i = 1, \ldots, n$ are available. The investment externality per unit of investment dq according to Proposition 3.4 is given by:

$$\mathrm{Cov}[A_p\boldsymbol{\varepsilon}_p - A_c\boldsymbol{\varepsilon}_c, \boldsymbol{\varepsilon}_x] = \langle \boldsymbol{\varepsilon}_{pc}, \boldsymbol{\varepsilon}_x \rangle \tag{25}$$

with $\boldsymbol{\varepsilon}_{pc} = A_p\boldsymbol{\varepsilon}_p - A_c\boldsymbol{\varepsilon}_c$. Consider the addition of a new instrument $\mathbf{T}_{n+1}$. Let $\mathbf{T}'_{n+1}$ denote the component of $\mathbf{T}_{n+1}$ that is orthogonal to $\mathbf{T}_i, i = 1, \ldots, n$. We can now write $\boldsymbol{\varepsilon}_{pc} = \boldsymbol{\varepsilon}'_{pc} + a_{pc}\mathbf{T}'_{n+1}$ and $\boldsymbol{\varepsilon}_x = \boldsymbol{\varepsilon}'_x + a_x\mathbf{T}'_{n+1}$, with $\left\langle \boldsymbol{\varepsilon}'_{pc}, \mathbf{T}'_{n+1} \right\rangle = \left\langle \boldsymbol{\varepsilon}'_x, \mathbf{T}'_{n+1} \right\rangle = 0$. The new value of the investment externality is now given by $\left\langle \boldsymbol{\varepsilon}'_{pc}, \boldsymbol{\varepsilon}'_x \right\rangle$. We find:

$$\begin{aligned} \langle \boldsymbol{\varepsilon}_{pc}, \boldsymbol{\varepsilon}_x \rangle &= \left\langle \boldsymbol{\varepsilon}'_{pc} + a_{pc}\mathbf{T}'_{n+1}, \boldsymbol{\varepsilon}'_x + a_x\mathbf{T}'_{n+1} \right\rangle & (26) \\ &= \left\langle \boldsymbol{\varepsilon}'_{pc}, \boldsymbol{\varepsilon}'_x \right\rangle + a_x \left\langle \boldsymbol{\varepsilon}'_{pc}, \mathbf{T}'_{n+1} \right\rangle + a_{pc} \left\langle \mathbf{T}'_{n+1}, \boldsymbol{\varepsilon}'_x \right\rangle + & (27) \\ &\quad + a_{pc}a_x \left\langle \mathbf{T}'_{n+1}, \mathbf{T}'_{n+1} \right\rangle & (28) \end{aligned}$$

hence:

$$\left\langle \boldsymbol{\varepsilon}'_{pc}, \boldsymbol{\varepsilon}'_x \right\rangle = \langle \boldsymbol{\varepsilon}_{pc}, \boldsymbol{\varepsilon}_x \rangle - a_{pc}a_x \left\| \mathbf{T}'_{n+1} \right\|^2 \tag{29}$$

Clearly, when $a_{pc}a_x < 0$ (i.e. when $\mathrm{sgn} \left\langle \boldsymbol{\varepsilon}_{pc}, \mathbf{T}'_{n+1} \right\rangle \neq \mathrm{sgn} \left\langle \boldsymbol{\varepsilon}_x, \mathbf{T}'_{n+1} \right\rangle$), the investment externality increases. If in addition, $\langle \boldsymbol{\varepsilon}_{pc}, \boldsymbol{\varepsilon}_x \rangle > 0$, then the investment externality increases also in absolute terms. By analogy, the same holds when no instruments are available yet and the instrument added is the first (i.e. $n = 0$). As mentioned before, however, when sufficiently many instruments are added so that the market becomes complete, the externality always tends to 0.

Example 3.7. *(Continuation of Example 3.5)* Consider the same set-up as in Example 3.5. Suppose that we do not introduce $\mathbf{T}_1$ and $\mathbf{T}_2$, but instead we introduce $\mathbf{T}_3$ (and only $\mathbf{T}_3$), an instrument with pay-offs shown in Table 2. In the story of the example, $\mathbf{T}_3$ can be considered as an asymmetric long straddle option on the oil price. The investment externality after introduction of $\mathbf{T}_3$ is shown in Table 4. The introduction of $\mathbf{T}_3$ increases the investment externality of entry in 'peak' technology. Hence, if only the 'peak' technology is available, the introduction of $\mathbf{T}_3$ increases the inefficiency in entry. To illustrate this point, suppose that instead of $dU_e = 0$, we have $dU_e = -\frac{71}{84}A\beta^2D^3dq_P$. Clearly, the entrant would not invest. When no tradable instruments are available, this would also be the socially optimal behavior, since $dW = (-\frac{71}{84} + \frac{5}{6})A\beta^2D^3dq_P < 0$. Now suppose that the instrument $\mathbf{T}_3$ is available. The entrant obviously still would not invest. But in this case, this would not be socially optimal, since $d\tilde{W} = (-\frac{71}{84} + \frac{6}{7})A\beta^2D^3dq_P > 0$.

Table 4: Example 3.5 – continued: Social welfare impact of the entrant (for each of the three technologies) as a function of the available tradable instruments

		No instruments			Only $\mathbf{T}_3$	
$\frac{d\tilde{W}}{dq_B} =$	$\frac{7}{12}$	$=$	0.583	$\frac{4}{7}$	$=$	0.571
$\frac{d\tilde{W}}{dq_M} =$	$\frac{3}{4}$	$=$	0.750	$\frac{5}{7}$	$=$	0.714
$\frac{d\tilde{W}}{dq_P} =$	$\frac{5}{6}$	$=$	0.833	$\frac{6}{7}$	$=$	0.857

Note: all values in this table need to be multiplied by $A\beta^2 D^3$.

3.3 Entry in financial markets

Until now, we have assumed that the entrant invests only in physical capacity and does not trade on the financial markets. Let us now consider an entrant on the financial markets. As before, the available financial instruments are $\mathbf{T}_i, i = 1, \ldots, n$. The pre-entry equilibrium on the financial markets is described by Lemma 3.1. Entry here means that the entrant invests in an infinitesimal amount of financial instruments $d\vec{k}_e$ in stage one, thereby causing a change $d\vec{F}$ in the prices $\vec{F}$ of financial instruments, and a change $d\vec{k}_p$ and $d\vec{k}_c$, respectively, in the quantities $\vec{k}_p$ and $\vec{k}_c$ of financial instruments bought by existing producers and consumers, respectively. In the absence of other players on the financial markets, we must have $d\vec{k}_e + d\vec{k}_p + d\vec{k}_c = 0$.

Lemma 3.8. *In response to a change $d\vec{F}$ in the price of financial instruments – caused by infinitesimal entry on the financial markets – the existing producers and consumers change their quantities of financial instruments bought, by:*

$$d\vec{k}_j = -\frac{1}{A_j}\Sigma^{-1} d\vec{F} \qquad j = p, c \tag{30}$$

Proof. The proof follows directly from differentiation of equation (22). □

Proposition 3.9. *Entry on the financial markets without production entry, does not have an externality on the existing producers and consumers:*

$$d(\tilde{U}_p + \tilde{U}_c) = 0 \tag{31}$$

Proof. Differentiation of equation (20) yields:

$$d\tilde{U}_p = -d\vec{k}_p{}^T \vec{F} - \vec{k}_p^T d\vec{F} - A_p(\vec{\lambda}_p + \vec{k}_p)^T \Sigma d\vec{k}_p \tag{32}$$

Using Lemma 3.8, we obtain:

$$d\tilde{U}_p = \left(\frac{1}{A_p}\Sigma^{-1}d\vec{F}\right)^T \vec{F} - \vec{k}_p^T d\vec{F} - A_p(\vec{\lambda}_p + \vec{k}_p)^T \Sigma \left(-\frac{1}{A_p}\right)\Sigma^{-1}d\vec{F} \quad (33)$$

$$= \frac{1}{A_p} d\vec{F}^T \Sigma^{-1}\vec{F} + \vec{\lambda}_p^T d\vec{F} \quad (34)$$

and a completely analogous expression for $d\tilde{U}_c$. Putting both together, we find:

$$d(\tilde{U}_p + \tilde{U}_c) = \left(\frac{1}{A_p} + \frac{1}{A_c}\right) d\vec{F}^T \Sigma^{-1}\vec{F} + d\vec{F}^T(\vec{\lambda}_p + \vec{\lambda}_c) \quad (35)$$

Substituting $\vec{F}$ from Lemma 3.1 into the last factor of the first term, we find that the first term and the second term cancel out, hence equation (31). □

Proposition 3.9 is equivalent to saying $d\tilde{W} = d\tilde{U}_e$. The entrant on the financial markets therefore 'sees' the full societal impact of its entry. Entry decisions in the financial market are therefore always optimal from a societal perspective.

4 Conclusions

In this paper we have developed a model of investment in a perfectly competitive industry. We have shown that a combination of risk aversion of existing players and incomplete financial markets, leads to a situation in which entrants' investment decisions in productive assets may be inefficient. In particular, we have demonstrated that there are situations in which new entrants overinvest in one technology and underinvest in another technology, compared to the socially optimal investment decisions. The underlying cause is that presence of the new productive assets changes the distribution of overall industry risk, which, if financial markets are incomplete, creates a risk externality for the firms already active in the market. The availability of an additional tradable financial instrument (without making the market complete) does not necessarily reduce the externality. When financial markets become complete however, the externality disappears. If the entrant invests in the financial market instead of in productive assets, there are no externalities, hence entry decisions in the financial market are always optimal from a societal perspective.

The result of the above is that the industry as a whole takes too much risk by investing too much in production activities with highly correlated risk profiles. Firms that could reduce the overall industry risk, do no enter often enough, while firms that increase overall industry risk, enter too often. Governments could attempt to reduce these inefficiencies by stimulating the creation of financial markets. More than that, in the absence of financial markets, the results could provide a ground for sector-specific regulation of investment decisions. Indeed, one could imagine a regulatory setting in which all project proposals need to be screened in advance by the regulator in order to assess the impact of the proposed investment on systemic risk. Approval would be given when project benefits weigh up against a possible negative risk spillover. Finally, from the perspective of competition policy, the analysis of this paper shows that, in the absence of complete financial markets, an efficiency defense based on optimal risk-sharing may be a valid argument in vertical mergers.

Our model takes the number and types of tradable financial instruments as an exogenous input. Future work could endogenize the degree of market completeness, in order to study e.g. whether incumbent firms might have strategies to create market incompleteness as an entry barrier. Furthermore, the model assumes mean-variance utility, which allows for simple closed-form expressions of welfare impacts of entrants. Using numerical methods, one could study the effect of assuming a different structure for the utility functions. Finally, our model makes no assumptions about the risk behavior of the entrant. By making such assumptions, one could make an integrated study of the effect of market completeness on both the risk externality and the entrant's decision-making under (hedgeable) uncertainty.

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