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ABSTRACT

Macroeconomics after the crisis – hedgehog or fox?*

Following the financial crisis of 2008/9, there has been renewed interest in what Greenwald and Stiglitz dubbed 'pecuniary externalities'. Two that affect borrowers and lenders balance sheets in pro-cyclical fashion are described, along with measures that might help curb their destabilising effects. These 'pecuniary externalities' can be thought of as the unintended macroeconomic consequences of market conventions designed to check moral hazard.

The issue of moral hazard is explicitly discussed in the context of a simple model of insurance, where there is no Arrow Debreu equilibrium to allocate risk efficiently; but there is a 'noisy' mixed-strategy Nash equilibrium. Our simple example is designed to reinforce the point made by Greenwald and Stiglitz (1986) – that when externalities are present, leaving things to the market may not be 'constrained Pareto efficient'.

While Central Bank policy may have shifted radically now that stability is an explicit objective of policy, the same cannot be said of the econometric models being used for macroeconomic forecasting – even those in Central Banks!

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"The fox knows many things, but the hedgehog knows one big thing" Archilochus of Paros

Introduction

In his essay *The Hedgehog and the Fox*, the Oxford philosopher Isaiah Berlin drew on an ancient Greek aphorism to classify famous writers. He wanted to distinguish between those who view the world through the lens of a single defining idea, like a hedgehog (whose big idea is to roll up in a ball in the face of any danger); and those more foxy types who draw on a wide variety of experiences in the way they see the world and its problems.

Could this distinction not be applied to famous economists[1]? We would, for example, be inclined to put Leon Walras, Karl Marx, and Milton Friedman in the first category, names indissolubly linked in turn with General Equilibrium, with Capital and with Money. While John Maynard Keynes, Amartya Sen and Joseph Stiglitz would come in the second category.

Views on who goes where will differ. But the thought-experiment may help illuminate different perspectives being taken in the post-crisis debate on the macroeconomics. If, as seems evident from the label, DSGE is a direct descendant of GE, then those in this school would, along with Walras, be put in the first category – seeking to use one modelling framework as the lens with which to view the world; and, thanks to this unifying, microfounded framework, seeing economics as a scientific endeavour. By contrast, critics of DSGE can be regarded as foxes, ready to use whatever approach seems most suitable for the problem at hand, and, given this attitude, viewing economics as a problem-solving discipline rather than a science[2].

Others have used the same metaphor.[3] Thus, in surveying recent developments in DSGE modelling, Jagjit Chadha (2014) writes:

> I sometimes wonder whether Isaiah Berlin's separation of thought into the Hedgehog and the Fox is a suitable classification to think about micro-founded macroeconomics versus the more subtle form of political economy

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[1] Chosen, for example, from twelve listed as the 'most important in history' in Luchinger (2011). In addition to those we refer to, the list also includes Adam Smith, David Ricardo, Freidrich von Hayek, Peter Druckerr John Nash and Hernando de Soto.

[2] This is the view of economics espoused by John Hicks (as discussed in Miller (2011) for example).

[3] As we learned soon after this paper was presented at the ESRC Conference on Diversity in Macroeconomics at Essex University, February 2014.

that many seem to wish we used instead. I would like to think that such
models provide a suitable single lens from which to start.

Note however that, for Chadha, those who criticise modern 'micro-founded' DSGE models
are seen as practitioners of political economy: for us, as the examples we discuss illustrate,
they are typically economists using different micro-foundations (allowing for asymmetric
information, for example, or institutional conventions on balance sheets), which are part and
parcel of mainstream economics!

The DSGE-style econometric models widely adopted by Central Banks in the period of the
Great Moderation focussed on interest rate rules and omitted any consideration of money and
banking[4]. Thanks to the efficient markets assumption, there seemed little to gain by explicit
modelling of such institutional detail. In addition, controlling consumer price inflation
trumped financial stability as a policy concern at that time[5]. So, on the premise that price
stability was a sufficient condition for financial stability, deregulation of financial markets
was combined with ' light touch' regulation in the UK and 'self-regulation' in the US, where
Mr Greenspan's adept handling of monetary affairs seemed to put him beyond reproach[6].

Subsequently, however, Mr Greenspan has acknowledged that his trust in the capacity of
financial markets to self-regulate was misplaced; and, of course, major steps have been taken
to reregulate banking and finance on both sides of the Atlantic. Financial factors have
become the focus of attention for macroeconomists, with DSGE practitioners keen to
incorporate 'financial frictions' within their framework.

Instead of attempting a review of such developments[7], however, what we aim to do in this
paper is to go back to the days of the Great Moderation, when faith in markets was at a peak
among policy-makers and increasingly in macroeconomics, and ask: what was missing? At a
time when the West was celebrating the triumph of the market economy over the challenge of
Communism, what key aspects of markets for credit and for risk were left off the radar
screen?

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[4] Perhaps this was done to indicate a clean break from the monetarist tradition established by Milton Friedman.
Banking does not appear in the index (nor 'money' in the title) of Michael Woodford's monograph on the
foundations of a theory of monetary policy, called simply *Interest and Prices.*
[5] As Olivier Blanchard (2012) was to note later at a meeting convened at the IMF in the wake of the crisis
(where at least two of the team of four organisers would count as foxes).
[6] In 2002 he was, for example, knighted by Queen Elizabeth II for his contribution to global economic stability.
[7] For which the reader might like to consult Chadha (2014), the paper referred to above.

Others may well focus on network theory; or on behavioural factors. Here we focus on two interconnected features of market economies: externalities and moral hazard. As regards the first of these, Greenwald and Stiglitz (1986) had already warned that the institutional arrangements in a market economy could generate what they described as 'pecuniary externalities' where prices affect the behaviour of economic agents not simply via the cost of purchases or the proceeds of sales but also via the pressure coming from constraints on balance sheets.

We start with what Shin (2010, p. 131) refers to as *'demand-side' explanations* of credit fluctuations, where 'the key … is the changing strength of the borrower's balance sheet and the resulting change in the creditworthiness of the borrower'. Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) pinpointed the role of wealth and collateral as drivers of such externalities. Businesses whose balance sheets improve as asset prices rise can borrow more; while borrowers who sell assets widely used as collateral in a 'firesale' may force other borrowers to do the same.

In his own writings, however, Shin has focussed on balance sheet pressures that affect the supply of credit, what he refers to as *'supply-side' mechanisms.* The mechanism he proposes to understand the subprime crisis, for example, is that 'the greater risk-taking capacity of the shadow-banking system [led] to an increased demand for new assets to fill the expanding balance sheets, and an increase in leverage.' Shin (2010, p.131)

After a review of these two approaches — and policies that might check the externalities involved — in section 1, we look at issues of asymmetric information. As Rothschild and Stiglitz (1976) pointed out, that there are broad range of conditions under which no competitive equilibrium exists in an insurance market with asymmetric information about types, due to problems of *adverse selection*[8]. Contracts that avoid falling afoul of adverse selection involve 'deductibles': quantity restrictions designed to exclude more risky types from accessing insurance at favourable rates. Competitive equilibrium may be restored thereby, but the presence of risky agents nevertheless imposes an externality on those who are less risky – by denying them full insurance.

In section 2 of the paper we look at the same issue when agents can choose the level of risk, reducing it by costly effort: so the problem is one of *moral hazard.* This 'insurance game' is intended to highlight the problems of relying on markets to allocate risk, where the amount of

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[8] Likewise in the market for 'lemons', adverse selection destroys competitive equilibrium (Akerlof, 1970).

risk is endogenous. In recent papers, Magill, Quinzi and Rochet (2012) have warned that when state probabilities are endogenous, Arrow-Debreu (AD) equilibria may fail to exist: and our simple game is, we believe, a case in point.

The strategy used is to treat trading as a game, where the pure strategy Nash equilibria (NE) correspond to AD competitive outcomes. While risk would be efficiently allocated if it could be conditioned on effort, with asymmetric information there is no AD equilibrium. This exercise opens up another possibility, namely a mixed strategy equilibrium; and we discuss the notion that, without measures to address the problem of moral hazard, market outcomes might exhibit the volatility characteristic of such equilibria. Alternatively, as with adverse selection, measures to check the incidence of moral hazard involve limitations of coverage, giving agents private incentives to limit risk and/or mechanisms to induce revelation.

In the context of credit markets subject to powerful externalities and risk markets where moral hazard is a serious issue, regulatory mechanisms need to be designed carefully to avoid misallocation: indeed the amplification effects we describe can be thought of as the unintended macroeconomic consequences of market conventions to check individual moral hazard.

The wary approach that emerges provides a marked contrast to the simple faith in the operation of market forces that some, including Mr Greenspan himself, expressed before the crisis.

1. Pecuniary Externalities

The problem facing regulators was characterised more than two centuries ago by the philosopher Immanuel Kant as follows[9]:

> The problem is: given a multitude of rational beings requiring universal laws for their preservation, but each of whom is secretly inclined to exempt himself from them, to establish a constitution in such a way that, although their private intentions conflict, they check each other, with the result that their public conduct is the same as if they had no such intentions.
> Kant (1963, p. 112)

This indeed was the perspective of the Basel Committee which assumed that if each financial institution behaved safely system itself would be secure – and came up with Basel II balance sheet requirements to check excess risk taking. But Danielsson et al. (2001), in what was

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[9] Thanks are due to Herakles Polemarchakis for bringing this to our attention.

called 'an academic response to Basel II', pointed out that such *micro*-prudential regulations were not enough, because the balance sheet rules designed to check moral hazard may themselves act as channels that amplify aggregate shocks. So *macro*-prudential rules will be needed to handle the pecuniary externalities involved.

In the examples of 'financial acceleration' reviewed in this section, the externalities operate directly through balance sheet pressures on borrowers or lenders. Later, in discussing non-existence of equilibrium, we turn to the insurance industry example given in Greenwald and Stiglitz.

1.1 Demand side pro-cyclicality with financial accelerator

Even without financial intermediaries, a credit-constrained market economy – where collateral is used to handle repudiation risk – can exhibit credit cycles and collapsing asset prices. Consider the externalities that affect the demand for credit via the price of collateral. In the model of Kiyotaki and Moore (1997), for example, productive Small Business entrepreneurs wish to raise outside finance to acquire the fixed capital assets but face an agency problem because the 'human capital' used in the business is 'inalienable'. Recourse is had to the issuance of debt backed by physical collateral, priced to reflect its productivity outside the entrepreneurial sector (i.e. in the hands of the 'deep pocket' lenders). In the face of uncorrelated, idiosyncratic productivity shocks, agents adversely affected can sell capital and pay down debt without affecting asset prices. But in the face of an adverse *macroeconomic* shock to entrepreneurial productivity, the borrowing constraint can lead to 'fire-sales' which affect the price of the collateral trigger yet further sales, i.e., there is a pecuniary externality.

This is in sharp contrast with the 'first best' economy where all agents are unconstrained in the credit market, and prices and production are unaffected by net worth. How this externality can impact on allocation in the model of Kiyotaki and Moore (1997) can be seen schematically in Figure 1.1.
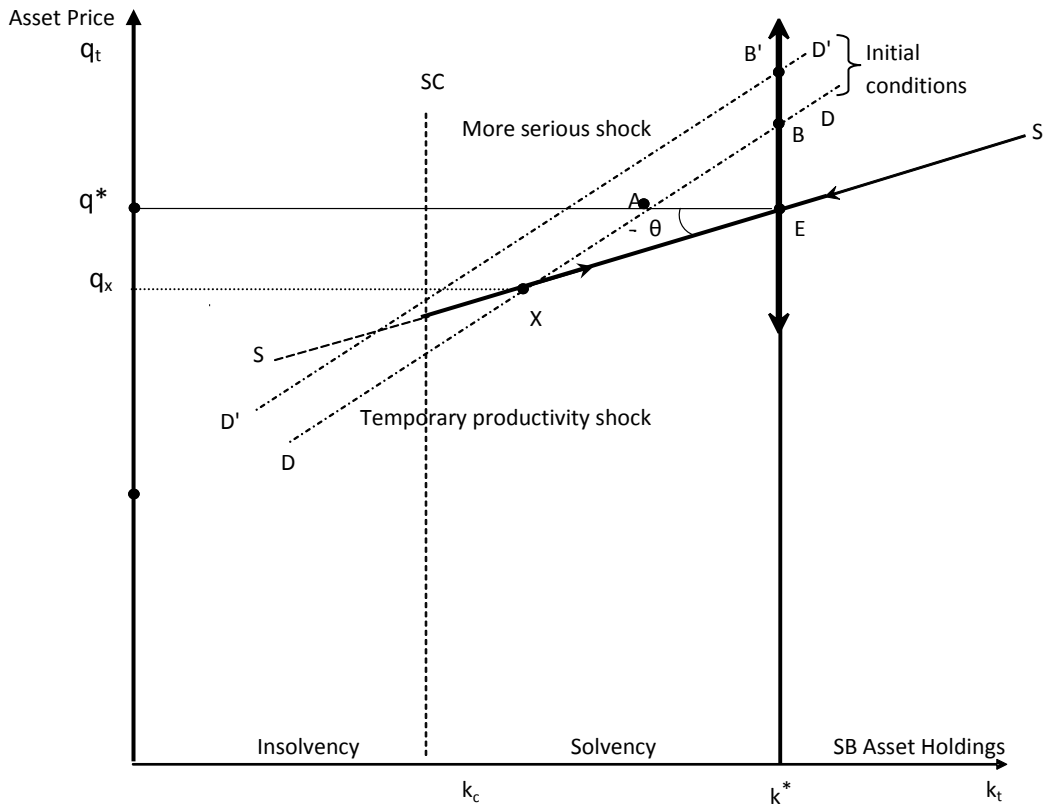
Figure 1. The financial accelerator as pecuniary externality (Miller and Stiglitz, 2010)

From equilibrium at E, where debt-financed Small Businesses entrepreneurs hold a stock k*
of fixed assets at price q*, the immediate impact of an adverse productivity shock is indicated
by the 'initial condition' labelled DD -- a schedule for their disposal of fixed assets , k, as
needed to match the fall in net worth due to a one-period drop in productivity. This schedule
can be interpreted as an unexpected need for liquidity on their part. From this perspective, asset
prices have to fall until, at point X, the balance-sheet-driven 'demand for liquidity' by Small
Businesses (measured to the left from k* to DD) is matched by the 'supply of liquidity' by the
residual buyers who have no balance sheet problems (the agents with 'deep pockets') whose
take-up of assets is measured from k* to SS.

As the figure suggests, the impact on asset holding has two components. The distance EA
indicates how far Small Businesses need to contract their holdings at a constant price, q*, as
they dispose of assets to reduce their borrowing in line with the fall in net worth; the second
component, AX, indicates the need for further disposals due to the adverse net worth effects
of asset prices falling in the face of concerted selling by small businesses to residual buyers
with declining marginal productivity -- net worth effects that are exacerbated by expected

persistence. In the absence of fresh shocks, the system will gradually return to equilibrium along the stable path[10] SS. Thus the pecuniary externality acts as a *'financial accelerator'* that takes short-run equilibrium from A to point X on SS.

Korinek (2011) modifies this framework so that the borrowing is done by financial intermediaries, risk-neutral bankers who raise finance from households and invest in risky projects; and he shows how the externality involved can be thought in terms of their undervaluation of liquidity. Banks who think that in adverse conditions they can sell assets fail to realise that with correlated shocks these sales will help push prices down. A social planner would anticipate the fall and take on less risk.

Two Prescriptions

For social efficiency, Korinek (2011) proposes a state-contingent, proportional tax on risk-taking that brings the private cost in line with the social cost. This is a metaphor for macro-prudential regulation because "it closely captures what BIS defines as the macro-prudential approach to regulation: it is designed to limit system-wide financial distress that stems from the correlated exposure of financial institutions and to avoid the resulting real losses in the economy" (p.26). He also proposes taxation on complex securities such as a CDS swap "which is likely to require large payouts precisely in times of financial turmoil" (p. 27).

1.2 Supply Side pro-cyclicality: financial intermediation and endogenous risk premia

We turn now to pro-cyclicality coming from balance sheet pressures operating on the 'supply-side'. In a paper written before the financial crisis erupted[11], Adrian and Shin (2007) warned of the pro-cyclical behaviour of financial intermediaries who actively manage their balance sheets subject to a Value-at-Risk constraint. The argument is essentially that a change in the market value of assets already held alters the Value-at-Risk risk constraint, allowing the leveraged sector to change its supply of loans by a multiple of the initial shock to its balance sheet.

A positive shock to asset values, for example, will raise the equity proportion of the intermediary's balance sheet and reduce the leverage. To restore the profit-maximising debt/ equity ratio, the intermediary can take on additional debt and make additional loans. As a

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[10] Kiyotaki and Moore (1997) assume that the 'overshooting' will not be severe enough to render the illiquid agents insolvent. Where 'firesales' do threaten insolvency, however, recourse to Chapter 11-style procedures may be necessary (Miller and Stiglitz, 2010).
[11] Published later as "Liquidity and Leverage" Adrian and Shin (2008).

consequence, they argue, financial intermediaries which amplify real shocks in this fashion can lead to a boom bust cycle.

To show this, Adrian et al. (2010) indicate how active balance sheet management can lead to a compression of the risk premium after a positive shock. The figure they use, reproduced here as Figure 2, shows how the price of risky assets is determined before the shock. On the horizontal axis is the amount of the risky asset, with valuations plotted on the vertical axis, q is the expected pay-off, while p is the market price.
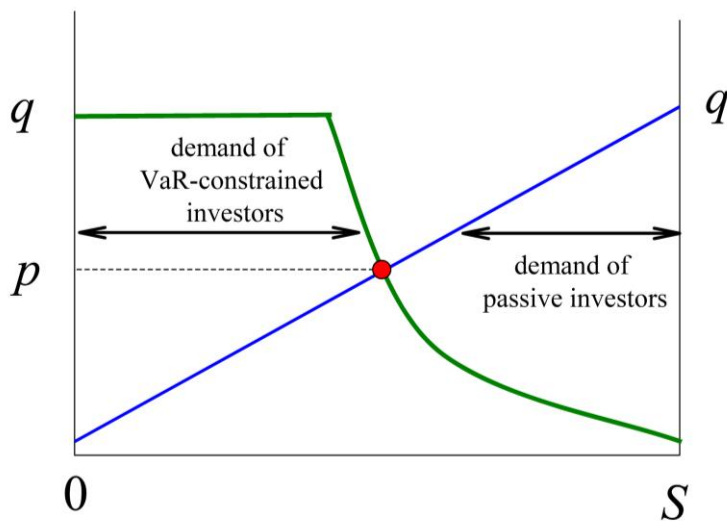

Figure 2. Determination of risk premium

The demand by unleveraged investors is shown measured from the right hand side of the diagram, while demand by VaR-constrained investors is measured from the left; and the equilibrium price is shown as $p < q$. In a one period setting, the expected yield from the risky security is given by $r = (q/p) - 1$, which they refer to as the risk premium.
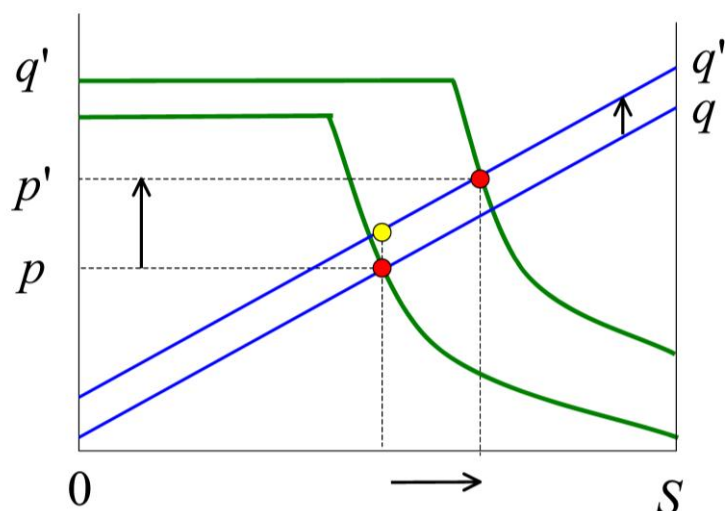
Figure 3. Compression of risk premium from increase in intermediary balance sheets

How this risk spread (or risk premium) falls in response to a positive shock is illustrated in Figure 3 where a positive shock to the fundamental of the risky security raises demand from both sectors, but:

> … there is an amplified response from the leveraged institutions as a result of marked-to-market gains on their balance sheets and (crucially) the balance sheet quantity adjustments entailed by it.
> [As they go on to note] the amplifying mechanism works exactly in reverse on the way down. A negative shock to the fundamentals of the risky security drives down its price, which erodes the marked-to-market capital of the leveraged sector. The erosion of capital induces the sector to shed assets so as to reduce leverage down to a level that is consistent with the VaR constraint. Consequently, the risk premium increases when the leveraged sector suffers losses, since $r = (q/p) - 1$ increases. (Adrian et al., 2010).

This perspective they argue is different from that of Curdia and Woodford (2009): they also introduce a credit spread

> but the intermediaries remain passive entities that provide a risk sharing service to households with differing shocks to wealth. (Adrian et al., 2010, p. 6)

Accordingly, they suggest how the standard New Keynesian model of Woodford (2003) should be modified to incorporate this endogenous risk premium: two new equations are required to determine the risk premium and the 'risk appetite' of intermediaries, which varies in response to shocks as discussed above.

Three Policy Prescriptions

Shin (2010, pp. 171-2) summarises the LSE critique of Basel II, Danielsson et al. (2001), as follows:

> The flaw with Basel II lay … in its twin assumptions – that the purpose of regulation is to ensure the soundness of individual institutions against the risk of loss on their assets, and that ensuring the soundness of each individual institution ensures the soundness of the system as a whole.

What types of macro-prudential policy can check such system-wide externalities? In his discussion of how to moderate the boom/bust cycle Shin (2010, pp. 161 ff.) considers three "prescriptions": regulatory interventions, forward-looking provisioning, and the reform of financial intermediary institutions to shorten the credit chain.

By way of regulatory intervention what is proposed are "leverage caps or countercyclical capital targets aimed at restraining the growth of leverage in boom times so that the corresponding bust phase of the financial cycle is less damaging, or can be avoided altogether" (Shin, 2010, p. 162). Forward looking provisioning is recommended as a way of acting directly on the equity of financial intermediaries and the provisioning scheme of Spain is cited as a good example. The third proposal is for institutional reform aided perhaps by the issuance of covered bonds – bonds issued on a bank's balance sheet, with recourse against the issuing bank itself.

In discussing the run on Northern Rock, he suggests that a liquidity requirement be added to a leverage ratio to mitigate system-wide externalities, noting that:

> Financial regulation … has the role of imposing the appropriate Pigovian taxes that that internalize the externalities as much as possible. The Pigovian tax perspective is likely to yields better insights into system stability than the traditional risk-based capital requirements under the Basel process. Shinn (2010, p. 151)

2. An insurance game with endogenous risk and a mixed-strategy equilibrium

An example of a pecuniary externality given in the original 1986 paper by Greenwald and Stiglitz 'Externalities in economies with imperfect information and incomplete markets' comes from the insurance industry. Assuming insurance companies are unable to monitor the effort in accident prevention being made by individual households, they price to cover their costs. Hence the price an individual pays for insurance will depend on the average level of accident avoidance of those who purchase insurance; but this is an externality to an individual purchaser, so there will on average be a socially inefficient level of effort to avoid accidents. Pigovian taxes or subsidies are need for

social efficiency. Thus, as they go on to note, the government, by subsidizing complements of accident avoidance activities (like fire extinguishers) can encourage accident avoidance, reduce the externality, and improve welfare; so the market equilibrium is not 'constrained Pareto efficient'.

Magill et al. (2012, p. 14) have argued recently that, even if markets based on states of nature exist, the economy may not have an Arrow-Debreu (AD) equilibrium if state probabilities are endogenous. Could this apply in a market for insurance with non-contractible effort? We treat the search for AD prices as the search for Nash Equilibrium in a simple insurance game; and find that, while there may be no Nash Equilibrium in pure strategies, there appears to be a 'noisy' mixed strategy equilibrium.

In what follows we assume that all agents take prices as given (and we introduce an auctioneer as a device to avoid strategic price-setting). In section 2.2 buyers can still act strategically, however, by choosing the level of effort – high or zero. This presents no problem if effort is contractible: but if not, as in section 2.3, we have a game involving the representative buyer of insurance, and the auctioneer who sets prices, a game with no equibrium in pure strategies. [In what follows, we have assumed the auctioneer acts to eliminate excess demand or supply: but maybe following Greenwald and Stiglitz (1986) we could have the auctioneer just set prices to cover costs. Would this be better?]

Note that the key assumption in our example is the non-convexity in production – effort is either zero or high with nothing in between. This can be criticised as rather special, but we believe it is a simple way of making the point of Magill et al. (2012): that market arrangements may not work where state prices are endogenous.

2.1 Set up of simple insurance game

Consider an exchange economy with two types of traders, each type is of measure 1. A 'representative' of the first type is risk-averse buyer facing endowment risk who seeks to share this with a 'representative' of the second type (called seller) who faces no such risk, where the risk involved is *common knowledge* between buyer and seller. Assume specifically that the 'good' and 'bad' endowment levels for the buyer are $(1, 1 - \Delta)$, with state probabilities of $\pi, 1 - \pi$ respectively, taken to be exogenous. For the seller, endowment

levels are (1,1) for sure. To see how risk will be allocated efficiently in an Arrow-Debreu (AD) equilibrium, we focus on the highly tractable case where the seller is risk neutral[12].

Using the consumption in the 'good' state as numeraire, let q denote the Arrow price for 'bad' state consumption measured in these terms.

Maximisation of expected utility by the seller involves:

$$\max_{c_i}[\pi c_G + (1 - \pi)c_B] \tag{1}$$

subject to

$$c_G + q c_B = 1 + q, \tag{2}$$

$$c_i \geq 0 \tag{3}$$

where $i = G, B$ representing either "good" or "bad" state.

The maximisation problem for the agent buying insurance is formally like that for the seller, with its objective function replaced by

$$\max_{c_i}[\pi u(c_G) + (1 - \pi)u(c_B)] \tag{4}$$

and the budget constraint replaced by

$$c_G + q c_B = 1 + q(1 - \Delta) \equiv W_B, \tag{5}$$

where Δ represents the adverse shock to endowment, and solvency requires

$$1 + q(1 - \Delta) > 0. \tag{6}$$

This has the following first order condition

$$\pi u'(c_G) = (1 - \pi)u'(c_B)/q \tag{7}$$

As the seller is risk neutral, he/she is willing to absorb all the risks. The resulting Arrow price when the market is competitive is given by

$$q = \frac{1-\pi}{\pi} \tag{8}$$

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[12] One way to justify this choice of asymmetric preferences is that the sellers may have access to other buyers who have independent endowment risks. So seller can effectively pool these endowment risks to provide insurance. This corresponds to the case where buyer's endowment risks are idiosyncratic.

so the insurance is actuarially fair and matches the state probabilities.

Given (8) and risk averse utility function of the buyer, it is immediate that (7) implies that buyer's state consumption must be the same:

$$c_G = c_B \qquad (9)$$

At the price given by (8), one can check that markets for state consumption clear, namely,

$$c_G(B) + c_G(S) = 2 \qquad (10)$$

$$c_B(B) + c_B(S) = 2 - \Delta \qquad (11)$$

The two budget constraints (2), (5) and (8)-(11) determine the competitive equilibrium. Solving them yields buyer's state consumption of

$$c_G(B) = c_B(B) = \frac{W_B}{1+q} = 1 - (1 - \pi)\Delta \qquad (12)$$

and the state consumption for the seller of

$$c_G(S) = 1 + (1 - \pi)\Delta \qquad (13)$$

$$c_B(S) = 1 - \pi\Delta \qquad (14)$$

where the Arrow price q is given by (8). It is clear from (12) that the amount of insurance purchased is $\pi\Delta$.

This AD equilibrium can be illustrated graphically using a state-space Edgeworth box diagram as in Mas-Colell et al. (1995, p.692). The axes in Figure 1 are global endowments in the good state (horizontal) and bad (vertical). Endowments of agents are located at point E, with the buyer's endowment point, measured from the lower left corner of the box, lying below the 45 degree line because of risk. As the seller faces no endowment risk, however, E lies on the 45% line from the top right corner (not shown until later, see Figure 5).
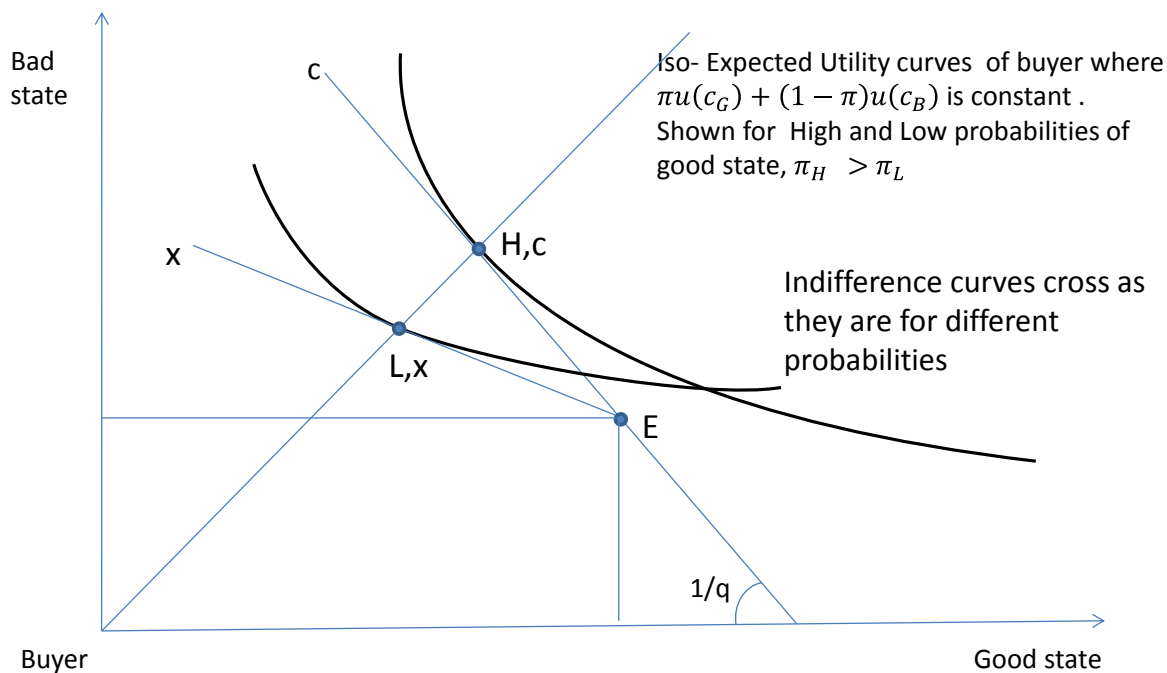
The figure shows axes labelled "Bad state" (vertical) and "Good state" (horizontal), with "Buyer" at the origin. Curves and points are labelled c, x, H,c, L,x, E, and 1/q. Text annotations read:

Iso- Expected Utility curves of buyer where $\pi u(c_G) + (1-\pi)u(c_B)$ is constant. Shown for High and Low probabilities of good state, $\pi_H > \pi_L$

Indifference curves cross as they are for different probabilities

Figure 4. AD equilibria with full insurance

The expected utility curves for buyer are shown for different assumptions about state probabilities. If the state probability π is high, Arrow price q is low, generating a steeper budget line $E(H,c)$. The equilibrium allocation is given by point (H,c) where the buyer's iso-expected-utility is tangent to the budget line. As the buyer obtains full insurance, (H,c) also lies on the 45-degree line. This scenario is referred to as the (high effort, low insurance) outcome in what follows.

What happens for a lower probability of the good state is indicated by a flatter iso-expected-utility in Figure 4. The budget line $E(L,x)$ is also 'flattened' reflecting a decrease in probabilities. The equilibrium is represented by the point labelled (L,x) where the new iso-expected-utility is tangent to the budget line $E(L,x)$. Note that the flattening of the budget line is the consequence of increased Arrow price q indicating that the price of insurance will accordingly be more 'expensive'.

2.2 Pareto efficient AD equilibrium with contractible effort

So far, state probabilities have been treated as exogenous: what if they depend on the effort of the buyer? So long as the effort levels are contractible, the same equilibria can emerge, with the seller offering a 'menu' of prices conditional on the observable effort of the buyer, where the subscript H and L would now refer to High and Low levels of effort by the buyer as attached to prices on the menu.

Which of the equilibria will emerge depends on the cost of effort to the buyer: in the example below, we find that, were it fully contractible, the buyer would choose High effort, with (H, c) as the AD equilibrium.

For analytical tractability we assume that effort level by the buyer is discrete, either zero or 1, with zero effort having no utility cost and the effort level of 1 having a utility cost of e. The effort level of 1 generates a probability of good state to be π_1 and the effort level of zero generates π_0 where $\pi_1 > \pi_0$.

Proposition 1. If effort is fully contractible and $u(c^{H,c}) - e > u(c^{L,x})$, the equilibrium is (high effort, cheap insurance).

Proof: When effort is fully contractible, the only possible outcome would be either (H, c) or (L, x) in Figure 1. Since $u(c^{H,c}) - e > u(c^{L,x})$, buyer will choose high effort given the menu and the seller is indifferent.

It is clear that this equilibrium is Pareto efficient.

2.3 Non-existence of AD equilibrium with non-contractible effort

In what follows, we assume that effort has a significant effect in raising the value of 'self-insurance'. Technically, the expected utility of consumption with expensive insurance and high effort is assumed to exceed the utility of full insurance at this price by the cost of the effort involved. Formally:

$$0 \leq e < \hat{e} \equiv E^H u\big(c_i^{H,x}\big) - u(c^{L,x})$$

where E^H represents expectations conditional on high effort and $c_i^{H,x}$ represents state consumption of the buyer given high effort and expensive insurance.

The game is illustrated in the Table below where the Row player, (the representing buyer of insurance) chooses the level of effort (High or Low) so as to maximise expected utility, and the Column Player (the auctioneer) sets prices of insurance[13] (Cheap or Expensive) so as to cover expected costs.

	Cheap insurance	Expensive insurance

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[13] In fact, we assume the prices set by the auctioneer are those identified in the previous section. So the Arrow price consistent with high effort level represents the equilibrium at (H,c) "cheap" insurance; and that consistent with Low effort represents the equilibrium at (L,x), where insurance is more "expensive".

	Cheap insurance		Expensive insurance
High effort	H,c	↓	← H,x
Low effort	L,c	→	↑ L,x

(a) Actions

	Cheap insurance		Expensive insurance
High effort	$(u(c^{H,c}) - e, u(E))$	↓	← $(u(c^{H,x}) - e, u(E''))$
Low effort	$(u(c^{L,c}), u(E'))$	→	↑ $(u(c^{L,x}), u(E))$

(b) Payoffs

Table1. A simple insurance game

The sequence of events is as follows:

(i)   auctioneer sets price;

(ii)   buyer chooses effort;

(iii) buyer chooses quantity.

The actions taken, and implicitly the associated payoffs, can be seen from the Figure 5 below, which includes the 'offer curves' of the buyer. The points of potential AD equilibrium, lying on the contract curves where the representative buyer's supply of effort matches what sellers expect are, as before, shown as (H, c) and (L, x). The question is whether these will emerge as equilibria in a setting where the sellers cannot observe the effort of the buyer[14].
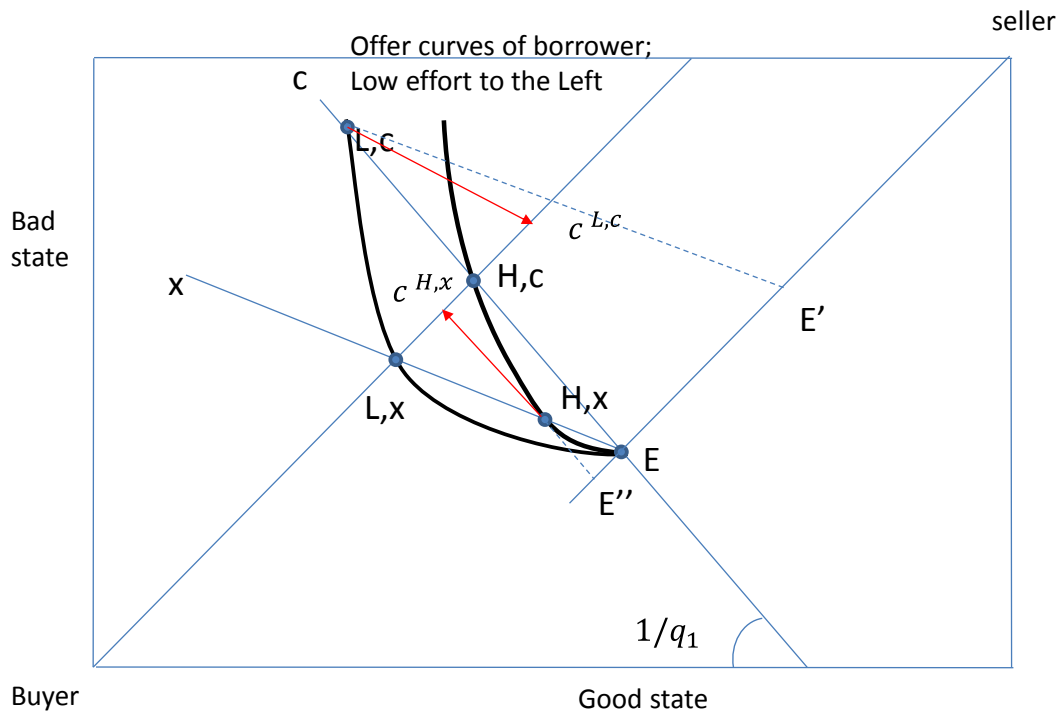

Figure 5. Non-existence of AD equilibrium

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[14] For simplicity, however, we have not ruled out 'over-insurance', as do Rothschild and Stiglitz (1976).

To answer this, we look for Nash equilibria in this simple game of insurance. As the arrows in the table indicate, however, there may be no equilibrium in pure strategies. Consider, for example, the AD allocation (H, c), where the buyer puts in effort at the low price of insurance: could this emerge as a market equiliobrium? No, because, given low price of insurance, the buyer has an incentive to defect, increasing the expected payoff by reducing effort and buying more cheap insurance. This temptation is indicated by the intersection between the low effort offer curve and the low price budget line, at point L,c. As the certainty equivalent of the buyer's expected consumption, labelled $c^{L,c}$, lies above H,c, (as indicated by the red arrow in the figure), the buyer is better off by deviating. This is represented by the arrow from H,c to L,c in Table 1.

Given the lack of effort by the buyer, sellers of insurance will face expected losses. So, as indicated by the arrow from L,c to L,x. in the Table, the price of insurance must be raised to cover costs.

Could Low effort and expensive insurance be an equilibrium? Not if the high effort offer curve intersects the budget line with a high price of insurance at H,x , with certainty equivalence given by $c^{H,x}$; and this, net of cost of effort, lies above L,x, (which is what we have assumed). The incentive by the buyer to deviate by putting in effort is indicated by the arrow from L,x to H,x in Table 1.

The positive profits that this implies mean prices can be reduced, moving from H,x to H,c in Table 1.

The non-existence of Arrow Debreu equilibria: a simple example with log utility

An alternative illustration of how moral hazard can lead to market failure – and the role played by pecuniary externalities – is to use a demand and supply diagram, with the demand for insurance, $c_B - \bar{c}_B$, shown as a function of the price q and the level of effort, see Figure 6. It is assumed for convenience that the representative purchaser of insurance has log utility; takes the price of insurance as given; and decides on the effort level before choosing the quantity purchased.

Formally, we write the demand for insurance as:

$D \equiv c_B - \bar{c}_B$, where $\bar{c}_B = 1 - \Delta$

For log utility, the buyer's demand for state consumption (given q and π) is

$c_G = \pi w_B \equiv \pi\{1 + q(1 - \Delta)\}$, where w_B measures the value of buyer's endowment,

$c_B = \frac{1-\pi}{q} w_B = D + \bar{c}_B$.

From the latter, one obtains the demand for insurance

$$D = \frac{1 - \pi}{q} w_B - \bar{c}_B = \frac{1 - \pi}{q} - \pi(1 - \Delta)$$

Two levels of demand are shown in the figure, D_H and D_L depending on the probability of the good state (which in turn depends on the input of effort). The prices labelled q_c and q_x are the Arrow prices for 'full insurance', $\pi\Delta$ and $\pi'\Delta$ respectively, where $q_c = \frac{1-\pi}{\pi}$ and $q_x = \frac{1-\pi'}{\pi'}$ and $\pi > \pi'$ thanks to the input of effort.
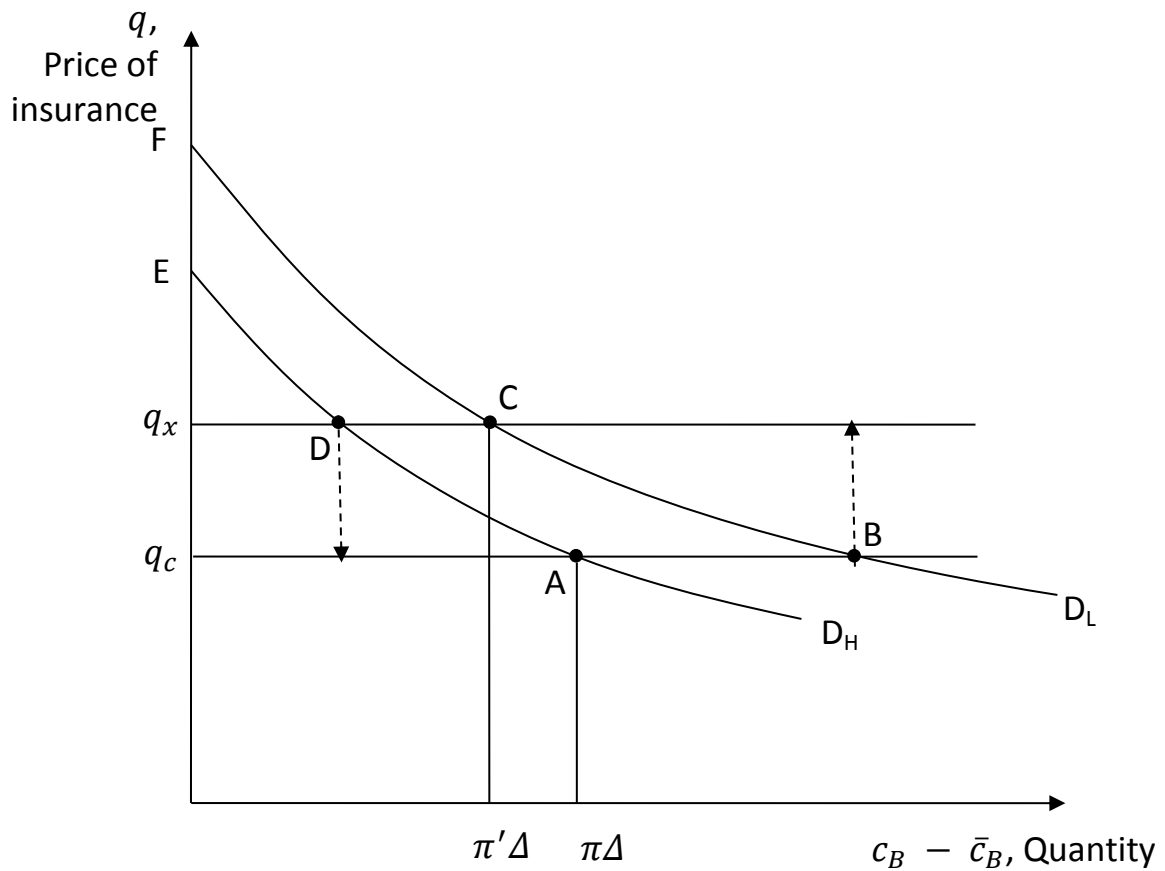

Figure 6. Demand and Supply of Insurance, when effort is non-contractible.

The demand for insurance falls as the price goes up, as indicated by the Arrow Debreu 'full insurance' equilibria at points A and C. But consider how consumers will behave given the price q_c. Where effort is non-contractible, it seems clear that buyers of insurance will supply no effort and demand the quantity shown at point B. That this offers a welfare gain over consumption at the Arrow Debreu equilibrium C, is not only because it saves the cost of effort, but also because of the increase in consumer's surplus – shown in the diagram as increasing from q_c A E to q_c B F. (Note, however, that reduced effort will have an adverse effect of the outside option of 'self-insurance' as the probability of the $\bar{c}_B$ increases.) As supplying insurance is no longer profitable with reduced effort, prices must increase as shown by the vertical arrow in the figure. As Greenwald and Stiglitz (1986) pointed out, there is a 'pecuniary externality' in that the cost of insurance is treated as given while it is in fact endogenous.

Now consider how consumers will behave given the higher price q_x. In the Cobb-Douglas example we are using, customers may choose to put in effort, essentially because of its effect in raising the value of 'self-insurance'. Despite the cost of effort and the smaller size of the consumers surplus triangle (q_x D E compared to q_x C F), this will be worthwhile if (as assumed) the effect on the outside option is strong enough. With effort, however, excess profits will be made in supplying insurance, so prices will be adjusted downwards. This time the externality acts to *reduce* the cost of insurance.

This sequence illustrates why equilibrium will not be attained at points A and C, i.e. why the Arrow-Debreu equilibria do not exist.

2.4 Mixed strategy NE

Given the payoffs outlined in Table 1, we can construct a mixed strategy equilibrium in which each player chooses the probability of his strategy in such a way that the other player is indifferent in selecting her strategies.

Let the seller choose probability of p_c of issuing cheap insurance (and so $1 - p_c$ of using expensive insurance), the expected payoff to the buyer by choosing high effort then becomes

$$[u(c^{H,c}) - e]p_c + [u(c^{H,x}) - e](1 - p_c) = u(c^{H,c})p_c + u(c^{H,x})(1 - p_c) - e$$

while the expected payoff to the buyer by not exerting effort becomes

$$u(c^{L,c})p_c + u(c^{L,x})(1 - p_c)$$

To ensure that the buyer is indifferent between putting in or not putting in effort, we equalize the above two expected payoffs resulting

$$p_c = \frac{e - [u(c^{H,x}) - u(c^{L,x})]}{u(c^{H,c}) - u(c^{H,x}) - [u(c^{L,c}) - u(c^{L,x})]},$$ (15)

Given p_c, it is straightforward to check that the buyer is better off than autarky. So the buyer is willing to participate.

Similarly, let the buyer choose probability of p_d of putting in effort (and so $1 - p_d$ of not putting in effort), the expected payoff to the seller of issuing cheap insurance then becomes

$$u(E)p_d + u(E')(1 - p_d)$$

while the expected payoff to the seller of issuing expensive insurance becomes

$$u(E'')p_d + u(E)(1 - p_d)$$

To ensure that the seller is indifferent between issuing cheap or expensive insurance, we equalize the above two expected payoffs resulting

$$p_d = \frac{u(E') - u(E)}{u(E'') - 2u(E) + u(E')},$$ (16)

Note that $u(E') - u(E) < 0$, for $p_d > 0$ then $u(E'') - 2u(E) + u(E') < 0$.

For the p_d obtained above, the expected utility of the seller is

$$u(E'')p_d + u(E)(1 - p_d) = \frac{u^2(E) - u(E')u(E'')}{u(E'') - 2u(E) + u(E')}$$

So the participation of the seller occurs if $u^2(E) - u(E')u(E'') \leq 0$.

In what follows, we compute the mixed strategy Nash equilibrium when buyer's utility takes the log form.

Proposition 2. With log utility on the part of the buyer, the probabilities of the mixed strategy are given by

$$p_c = \frac{\log(\lambda') - e}{\log(\lambda') + \log(\lambda)}$$

and

$$p_d = \frac{c^{L,x} - \mu c^{H,c}}{(1 - \mu)c^{H,c} + (1 - \mu')c^{L,x}}$$

where

$$c^{H,c} \equiv 1 - (1 - \pi_1)\Delta$$

$$c^{L,x} \equiv 1 - (1 - \pi_0)\Delta$$

and

$$\lambda = \left(\frac{\pi_0}{\pi_1}\right)^{\pi_0} \left(\frac{1 - \pi_0}{1 - \pi_1}\right)^{1 - \pi_0} > 1$$

$$\mu = \frac{(\pi_0)^2}{\pi_1} + \frac{(1 - \pi_0)^2}{1 - \pi_1} > 1$$

$$\lambda' = \left(\frac{\pi_1}{\pi_0}\right)^{\pi_1} \left(\frac{1 - \pi_1}{1 - \pi_0}\right)^{1 - \pi_1} > 1$$

$$\mu' = \frac{(\pi_1)^2}{\pi_0} + \frac{(1 - \pi_1)^2}{1 - \pi_0}$$

The expected utility of the buyer is

$$U(B) = [(\log \lambda' - e) \log(\lambda c^{H,c}) + (\log \lambda + e) \log c^{L,x}]/\log(\lambda' \lambda)$$

And the expected utility of the seller is

$$U(S) = 1 + \frac{(c^{H,c} - \mu' c^{L,x})(c^{L,x} - \mu c^{H,c})}{(1 - \mu)c^{H,c} + (1 - \mu')c^{L,x}}$$

Proof: See Appendix A

Mixed strategy NE as polymorphic equilibrium

It could be objected that the randomization involved is not commonly observed at the level of individual behaviour. Binmore et al. (2007, pp. 30-31) acknowledge that "real people are notoriously bad natural randomizers"; but go on to argue that it is a mistake to demand that the players actively randomize in order judge the relevance of such NE.

Modern eductive accounts of Nash equilibria in mixed strategies therefore stress their interpretation as equilibria in *beliefs* rather than *actions*. One way of realizing an equilibrium in beliefs arises when the players are drawn at random from a population whose characteristics are commonly known… [In which case] we may observe what biologists call a polymorphic equilibrium of the grand game played by the population as a whole. In such an equilibrium, each member of the population may plan to use a *pure* strategy if chosen to play, but the frequencies with which they choose different pure strategies coincide with the probabilities assigned to them by a mixed equilibrium. Binmore et al. (2007, p. 31)

Results from an experiment designed to allow polymorphic equilibria to evolve in the laboratory may be relevant here. Zero sum games were played in sessions involving twelve subjects split into six rows players and six column players, who were repeatedly matched in pairs to play the game 150 times.

	1*	2
1*	-2 ←	↑ 3
2	-1 ↓	→ -2

Table 2. Minimax game with no pure strategy Nash equilibrium

One of these games[15] is that shown in Table 2, for example, where the payoffs are for the row player; and as the arrows indicate, there is no equilibrium in pure strategies. In the mixed strategy equilibrium, however, the first row is played with probability 1/6, while the first column is played with probability 5/6. And, as can be seen from Figure 7 below, the fraction of the population choosing these strategies converged fairly quickly to a neighbourhood of the equilibrium. As the authors note, however:

> Since the payoff to making such adjustments declines to zero as the population frequencies approach their minimax values, it would be unreasonable to expect convergence to go all the way. The best that one can expect is that the system will find its way into a neighborhood of the minimax outcome, wherein it will wander as the subjects find it increasingly difficult to decide between strategies among which they would be indifferent in equilibrium.

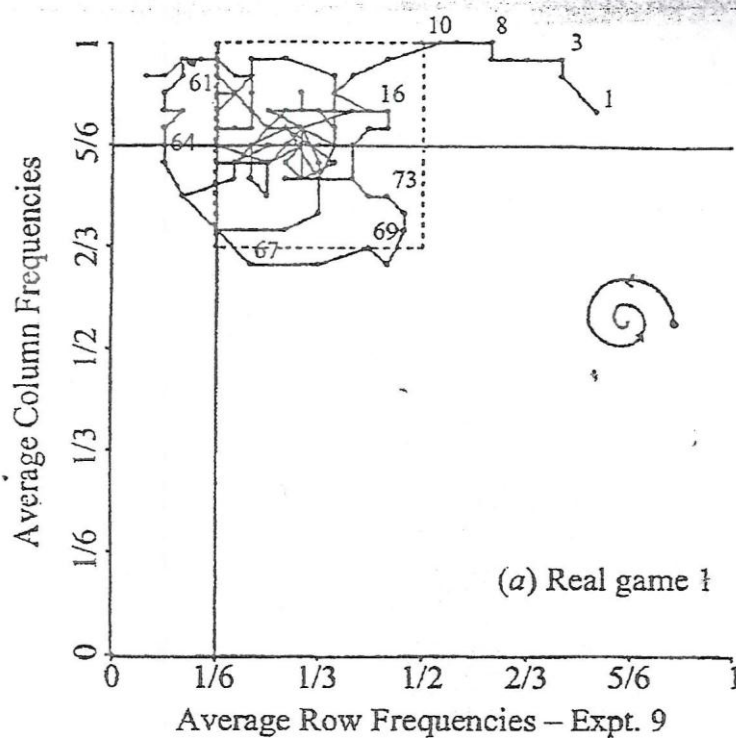[15] Labelled Game I in Binmore et al. (2007, p. 33).

Figure 7. Convergence to a polymorphic equilibrium

The outcomes of this and other similar experiments led the authors to conclude that: "the behaviour of our subjects is close to that predicted by the minimax hypothesis", (Binmore et al., 2007, p. 36).

This experimental evidence suggests that the evolution of the mixed-strategy NE may not be so implausible after all. Could such mixed strategy equilibria arise in practice as the market response to unresolved problems of moral hazard? If so, the dynamics would not be as straightforward as the boom bust cycle discussed in Shin (2010) for example: but, with the switching on and off of effort, and fluctuation in the costs of insurance, there would be plenty of volatility! In order better to assess the efficiency of such stochastic equilibria, we consider the alternative of price-quantity contracts.

2.5 Two Prescriptions

Equilibrium with quantity restriction

As in Rothschild and Stiglitz (1976), one possible equilibrium is where quantity restrictions are imposed on low cost insurance. Assuming the cost of effort is not too high, such

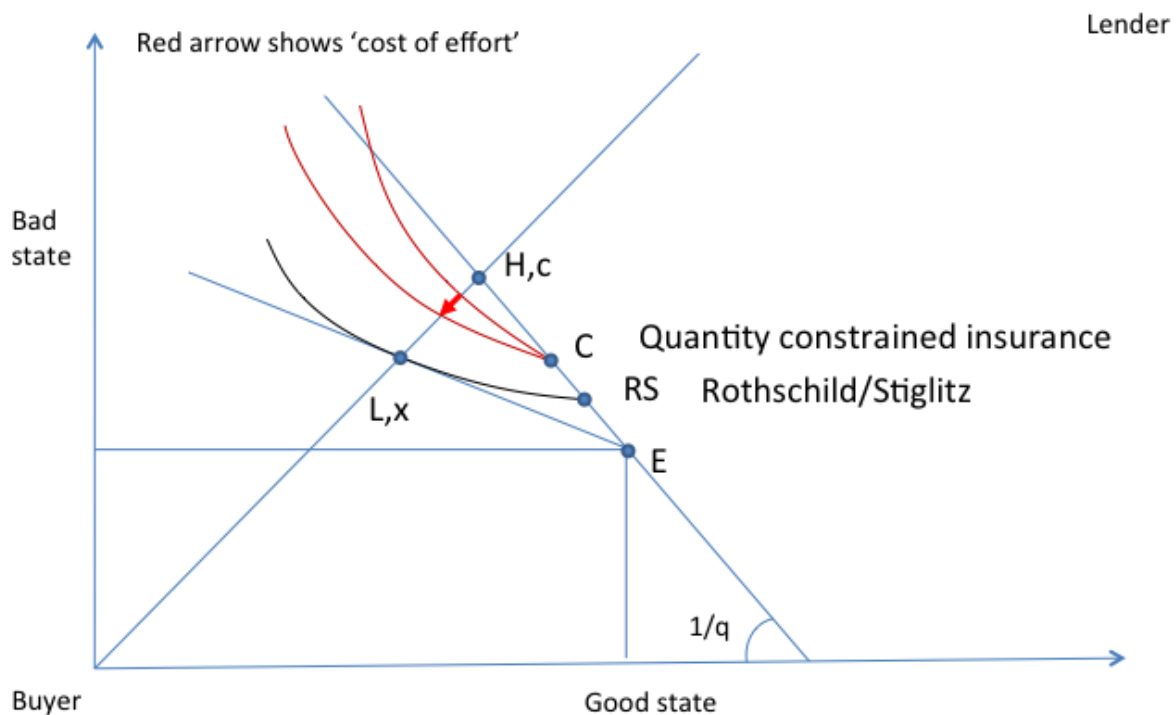deductibility could, in principle, be designed so as to ensure that effort is put in. Figure 8 illustrates.

Figure 8. The 'wishbone' solution

Let the cost of effort for the purchaser of insurance be as indicated by the red arrow in the figure. Then restricting the availability from 'full insurance' to (epsilon below) the amount indicated at the point C will incentivise the agent to put in effort rather than saving on the cost and suffering the higher probability of bad outcomes that follows. The restriction is of course designed to raise risk exposure enough to make prevention worthwhile. (The problem to be faced here is one of mechanism design: the' wishbone' mechanism we describe may succeed in inducing effort, but it fails to achieve full Pareto efficiency.)

It appears, however, that, for some parameter values, the mixed strategy Nash equilibrium described earlier can Pareto-dominate the quantity-price solution just described. An intuition for this result may come from the literature on banking and on sovereign debt, where the stochastic threat of a 'run' can act as a brake on moral hazard, Chatterji and Ghosal (2013), Ghosal and Miller (2003).

Adverse selection a special case

Notice that as the cost of effort increases, the quantity constraint required will approach the point labelled RS, which is what Rothschild and Stiglitz determined as necessary to separate high risk and low risk "types" of buyer. In other words, for this cost of effort (not shown) or higher, the dominant strategy for the buyer will be to choose low effort, i.e., it is effectively a high risk 'type'. So the problem becomes one of the adverse selection, rather than moral hazard.

Rothschild and Stiglitz argue that the contract shown at RS is in fact "the only possible equilibrium for a market with low- and high-risk customers". They go on to show, however, that (depending on the composition of the population), there may be other feasible contracts (labelled γ contracts) which dominate RS, i.e. break even or make profits and are preferred by both types. This leads them to conclude that there may be no competitive equilibrium in the insurance market.

An interesting question is whether the mixed strategy Nash equilibrium in our insurance game with moral hazard might be the equivalent of the γ contracts discussed by Rothschild and Stiglitz for the analogous case of adverse selection.

Market Discipline

What has been discussed may remind one of the imposition of regulatory capital requirements on risk-taking financial institutions – getting them to put 'skin in the game' so as to reduce risk taking[16]. Capital Adequacy is only one of the Three Pillars of Basel II, however, the other two being Supervisory Review and Market Discipline[17]. As Decamps et al. (2008, pp. 281) point out, for banks Market Discipline involves encouraging the monitoring by professional investors and financial analysts[18]; and may involve requiring the bank to issue a security (say subordinated debt) whose payoff would indirectly reveal the risk being taken. In the context of insurance, market discipline would presumably include the use of No Claim Discounts -- an important feature of the market which has been ignored in our simple model.

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[16] Bank regulation poses interesting problems of mechanism design; and in the Vickers Report (ICB, 2011), 'ring-fencing' is used as one way to separate high risk from low risk enterprises.

[17] See Decamps et al. (2008) for a dynamic analysis of how these interact.

[18] For a recent discussion of how more disclosure may promote financial stability see Sowerbutts et al. (2013).

3. Conclusion

From this brief review of pecuniary externalities, such as financial accelerators and procyclical changes to risk premia, and of issues involving moral hazard, it is perhaps not surprising to read that "There has been a revival of interest in the work of Hyman Minsky, who developed the position that a monetary economy tends to be very unstable, prone to bubbles and crashes and in need of active public policy to stabilize it." Driffill (2011, p. 2).

For Central Bankers, recognition that price stability is not sufficient for financial stability has clearly involved a substantial change of focus. In the UK, for example, supervisory functions have been returned to the Central Bank, new regulatory tools are being developed and, symbolically enough, the MPC is now accompanied by a Financial Policy Committee.[19]

What about macroeconomic modelling? Here the story is rather different. Adrian Pagan, who has been studying how econometric models have evolved over the last seventy five years, argues that four generations of models can be identified in the years leading up to the financial crisis, Fukacs and Pagan (2010); and, in recent survey paper by Hall, Jacobs and Pagan (2013), these are very broadly categorised as follows.

Vintage	Approximate dates	Comment
First Generation Models (1G)	1936-1960's	Tinbergen pre-WWII and Klein post-WWII
Second Generation Models (2G)	"emerging in the early 70's and staying for around ten or twenty years"	Include ECM and RE, plus equations for financial system based on flow funds
Third Generation Models (3G)	(late 80's to end of the century)	Have steady state model at the core
Fourth Generation Models (4G)	"have arisen in the 2000's"	Counterpart of DSGE

Table 3. Generations of macro econometric models

In answer to the question "Is there a fifth generation of models?" the authors observe:

> In the aftermath of the Global Financial Crisis there has been a lot of criticism of 4G models under the more general heading of DSGE models. Some of it involves a coherent critique of this class of models with a variety of suggestions being made

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[19] 'Criticising the BoE's failure under former governor Lord King to focus on financial stability when it had inflation under control, [Mark Carney] said: "It doesn't take a genius to see that similar risks exist today". With the BoE pledged to keep interest rates low for a long time, he added that there was now "a tremendous burden on both micro-prudential supervision and macro-prudential management" to preserve financial stability.' Giles and Fleming (2014).

about how these should be modified in response to the GFC. We describe some of these proposals and then ask how many have found their way into the models used in central banks and finance ministries. As we will see few have become incorporated into 4G models… [Leading to the conclusion that] there is little evidence that central banks have given up their 4G model structures, despite all the criticism of them. Analyses of trends around the worlds suggest that any new models are DSGE oriented. Hall et al. (2013, pp. 17, 29)

As Sherlock Holmes might have said: "The puzzle, my dear Watson, is why the hedgehog failed to hear the barking of the fox?"

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