Financial Macroeconomics

EC882: Topics in Macroeconomics

Course notes for Spring 2018

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Introduction and motivation

Economies "fall to pieces" after financial crises (Hall, 2010). From the perspective of a real business cycle model, this is bizarre. Financial crises don't destroy any physical capital, they don't have any impact on the number of or the skills of workers. Typically, financial crises do reduce asset prices, but this just entails changes in the price today of consumption goods tomorrow. It is not clear why this should cause workers to lose their jobs and machines to fall idle.

Financial market incompleteness causes depressions; it also amplifies business cycles with real causes. Financial macroeconomics, the study of these interactions, has helped us to better understand not only of the depressions of 1929 and 2008 but also of the determinants of business cycle volatility in normal times. Researchers in financial macroeconomics do not *typically* model the financial industry explicitly. Instead, we model the financial contracts that move savings and risk between households and firms. As it turns out, we can learn a lot about financial crises even while largely ignoring the financial industry itself, an industry that produces a similar amount of gross output as the *Agriculture, forestry, fishing, and hunting* industry, the *Mining* industry, or the *Construction* industry.[1]

Study in financial macroeconomics is motivated by the experience of severe recessions that coincided with financial sector disruption. The main theoretical mechanisms in financial macroeconomics trace their pedigree back to Fisher (1933), who, during the Great Depression, explained how the losses from falls in asset prices were largely borne by firms rather than their creditors. These losses lead to reductions in output and investment, further depressing asset prices. Fisher's theory of *debt deflation* is still at the heart of modern financial macroeconomic models.

1 Motivating Facts

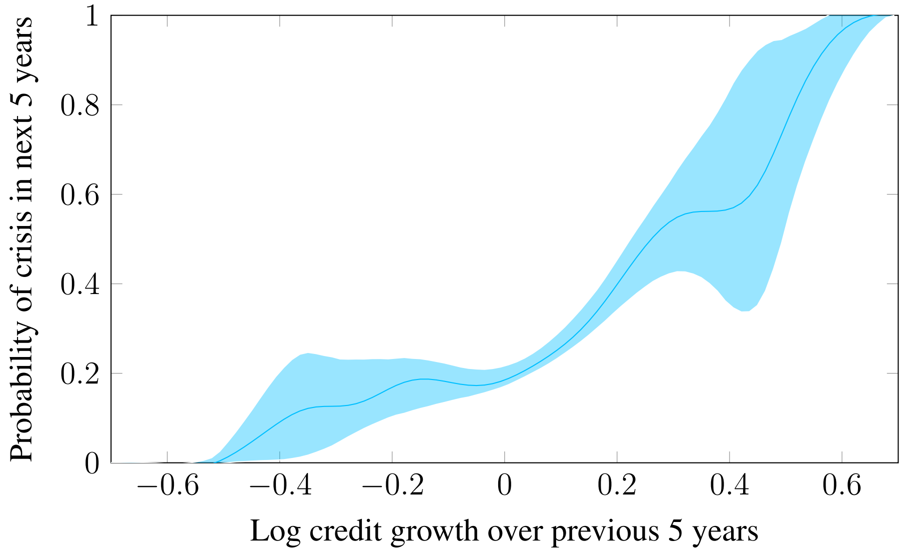
We'll start with two motivating stylised facts to get us started.

Stylised Fact 1 *Credit growth predicts crises (Figures 1 and 4).*

Stylised Fact 2 *When debt levels are high, recessions are deeper and are more persistent (Figures 3 and 4).*

[1]Figures taken for the US in 2016. Source: BEA and author calculations. `https://www.bea.gov/industry/gdpbyind_data.htm` Accessed 17 February 2018.

Figure 1: Crises and credit growth



Source: Duncan and Nolan (2018b), constructed from the Jorda et al. (2017) dataset using their crisis definition.

Figure 2: Log real GDP (blue) and log real credit to non-financial firms (green).

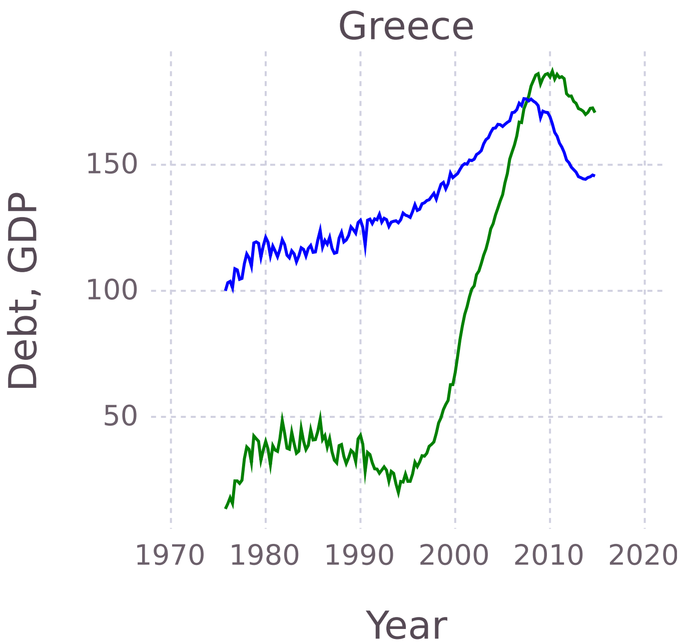
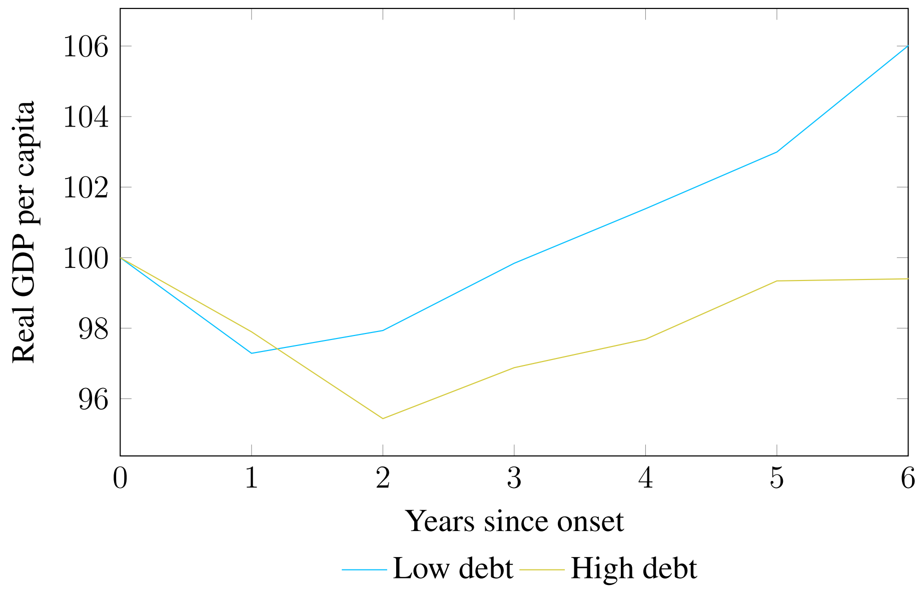
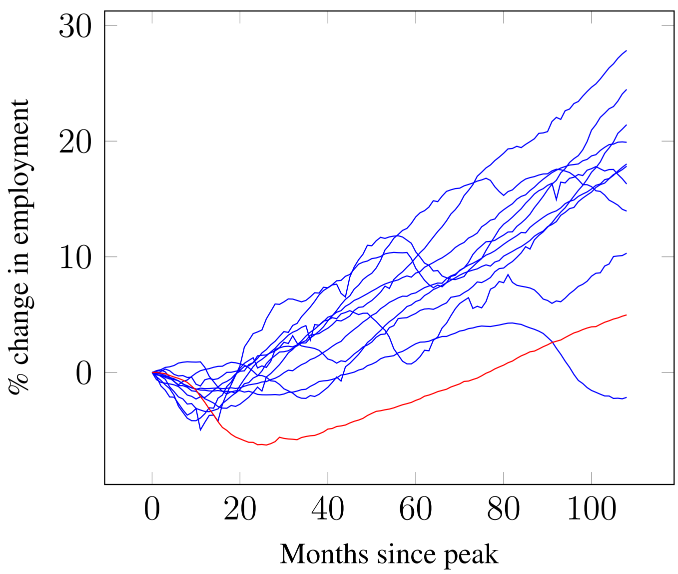


Figure 3: High debt and low debt recessions



Source: Duncan and Nolan (2018b), constructed from the Jorda et al. (2017) dataset.

Figure 4: The Great Recession (red) and other post war US recessions (blue).

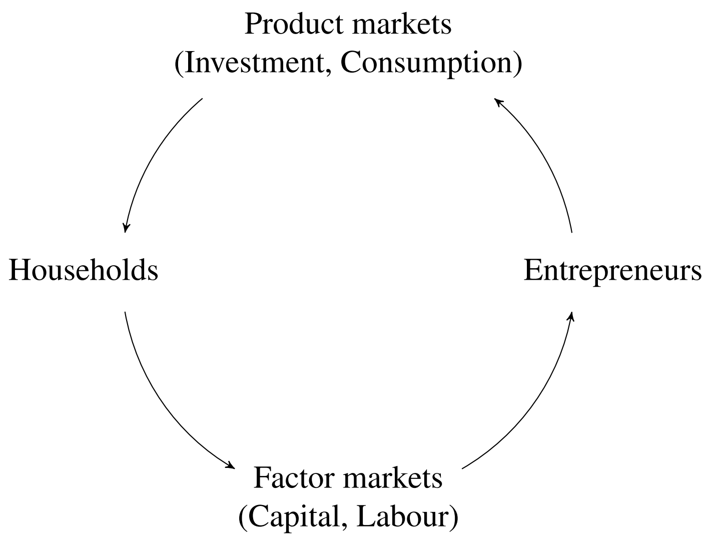


Source: Minneapolis Federal Reserve (2018) and author's calculations

2 Key features of financial macro models

Financial macroeconomic models introduce a simple form of heterogeneity between agents. The first class of agents, *households*, supply capital and labour in factor markets. The second class of agents, *entrepreneurs*, purchase capital and labour from factor markets, they combine these factors with their own productive technologies and capital endowments, and they use these factors to produce goods. The basic structure is provided as a diagram in Figure 5.

Figure 5: Entrepreneurs and households



The term *entrepreneur* should be interpreted liberally. At some level, most of the models in the literature are sufficiently abstract for the entrepreneur to be interpreted as an owner-manager of a firm, as a manager or executive of a firm, or as the collection of contracts that embodies the firm itself. Traditionally, entrepreneurs are thought to manage productive firms, but there is a growing body of work that treats the entrepreneur as a banker.

Entrepreneurs fund purchases of capital goods with loans from the households—perhaps intermediated by a financial sector. Importantly, these loan markets are incomplete. This market incompleteness is typically modeled as endogenously motivated by *financial frictions*. The two most commonly relied upon classes of financial frictions are *limited commitment* and *private information*.

Friction 1 *Limited commitment. Entrepreneurs cannot commit to factor payments exceeding their* pledgeable share *of income or assets.*

Friction 2 *Private information. Entrepreneurs cannot share idiosyncratic productive risks with households.*

Both of these frictions prevent the opening of markets for arrow securities contingent on income. Under limited commitment, these markets are open but are rationed with a limit determined by the entrepreneurs' ability to pledge future earnings. Under private information, trade in these markets is constrained by the need for the relative prices of these Arrow securities to motivate truthful income reporting in all states.

Remark 1 *Failure of the welfare theorems. As a result of the incompleteness of financial markets, the first and second welfare theorems of economics do not hold.*

In the benchmark perfect markets environment, pecuniary externalities—externalities transmitted through the price system—can have negative effects on individual agents but do not cause deviations from Pareto efficiency. For example, when I purchase a orange instead of an apple, the resulting increase in prices harms other orange consumers (negative pecuniary externality) but it helps orange producers (positive pecuniary externality) and it helps equate the orange-apple consumption marginal rate of substitution with its respective productive marginal rate of transformation (increase in allocative efficiency).

In settings with incomplete markets, this story doesn't always work. Figure 6 presents the basic intuition behind the credit cycle mechanism. When firm A reduces investment, this reduces the wealth of firm B. This lowers the amount of income that firm B can pledge to outside capital owners, reducing the return to capital further below its marginal product. This works against allocative efficiency.

The question then, of whether market allocations are constrained efficient (second best) in financial macroeconomic models, is a challenging one. Kilenthong and Townsend (2016) provide conditions under which constrained efficiency is guaranteed, essentially describing a Coase theorem for financial macro. Their mechanism includes the production of a rich set of auxiliary property rights and markets, and whether these mechanisms are more easily implemented than the Pareto Improving Taxes described by Geanakoplos and Polemarchakis (2008) is probably the big unanswered question in the literature.

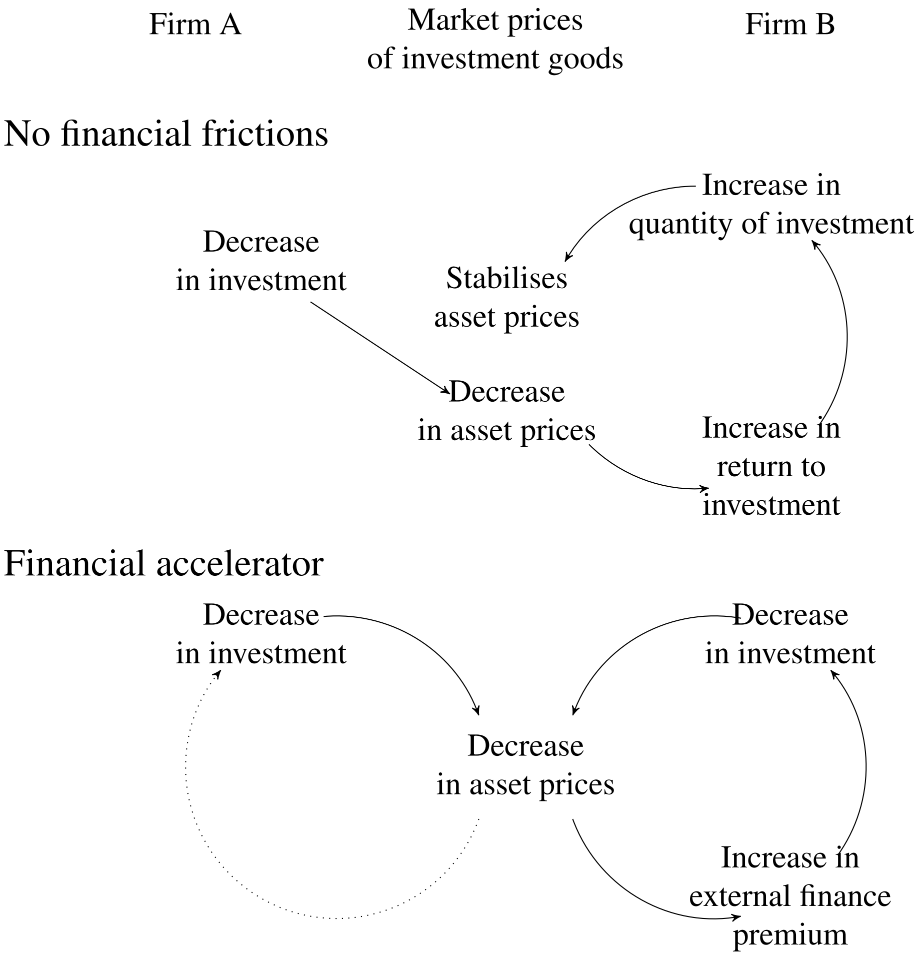
3 Why do financial crises cause recessions?

The first generation flexible price financial macroeconomics models of Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) were a major step forward in formalising the debt-deflation arguments of earlier authors, notably including Fisher (1933). But calibrated versions of these models did not generate large recessions. In particular, they didn't generate large movements in employment.

To a large extent, this is predictable. In these benchmark models, while financial frictions reduced the share of income that could be pledged to capital owners, they did not directly affect the relationship between wages and the marginal product of capital. At business cycle frequencies, the capital stock is inelastic. Reduced demand for capital shifts production from investment to consumption but doesn't have a large disemployment effect.

The frictions in financial macroeconomic models drive a wedge of inefficiency between the returns to savings of working households and the marginal product of capital.

Figure 6: Credit cycles as Pecuniary Externalities (Duncan and Nolan, 2018b)



Specifically, the household consumption-savings marginal rate of substitution is less than the consumption savings productive marginal rate of transformation, which is in turn less than the entrepreneurs' consumption-savings marginal rate of substitution.

Chari, Kehoe, and McGrattan (2007) present a real business cycle with time varying wedges in the capital market, the labour market and productive efficiency. The capital market wedge—or *investment wedge*—represents financial frictions. The authors calibrate the model to the US economy, and use this to estimate the time varying paths of the three wedges. They find that the investment wedge has little effect on US output dynamics, even in the Great Depression. They find that the labour and efficiency wedges are more important. According to their estimates, during the Great Depression, the movement in the labour wedge is equivalent to a 30 percentage point increase in payroll taxes. This study posed a serious challenge to the financial macroeconomics literature. On the face of it, their results suggested that financial frictions were unimportant even in the Great Depression.

When we turn to welfare calculations, the importance of labour and efficiency wedges is amplified. At business cycle frequencies, the supply of capital is inelastic. The supply of labour is elastic and so is the efficiency wedge. By standard Ramsey taxation arguments, the welfare losses of wedges are greater when they impact elastic margins. So, if we think financial frictions are important for business cycle dynamics, then we need theories that can generate labour and investment wedges from these financial frictions.

THE LABOUR WEDGE

$$\frac{\text{marginal product of labour}}{\text{consumption-leisure MRS}} = 1 - [\text{labour wedge}]$$

We can decompose the labour wedge into a demand component and a supply component. The labour demand wedge reduces posted wages below the marginal product of labour (the consumption-leisure marginal rate of transformation). The labour supply wedge is the difference between real wages and labour supply (the consumption-leisure marginal rate of substitution).

$$\frac{\text{marginal product of labour}}{\text{real wages}} = 1 - [\text{labour demand wedge}]$$

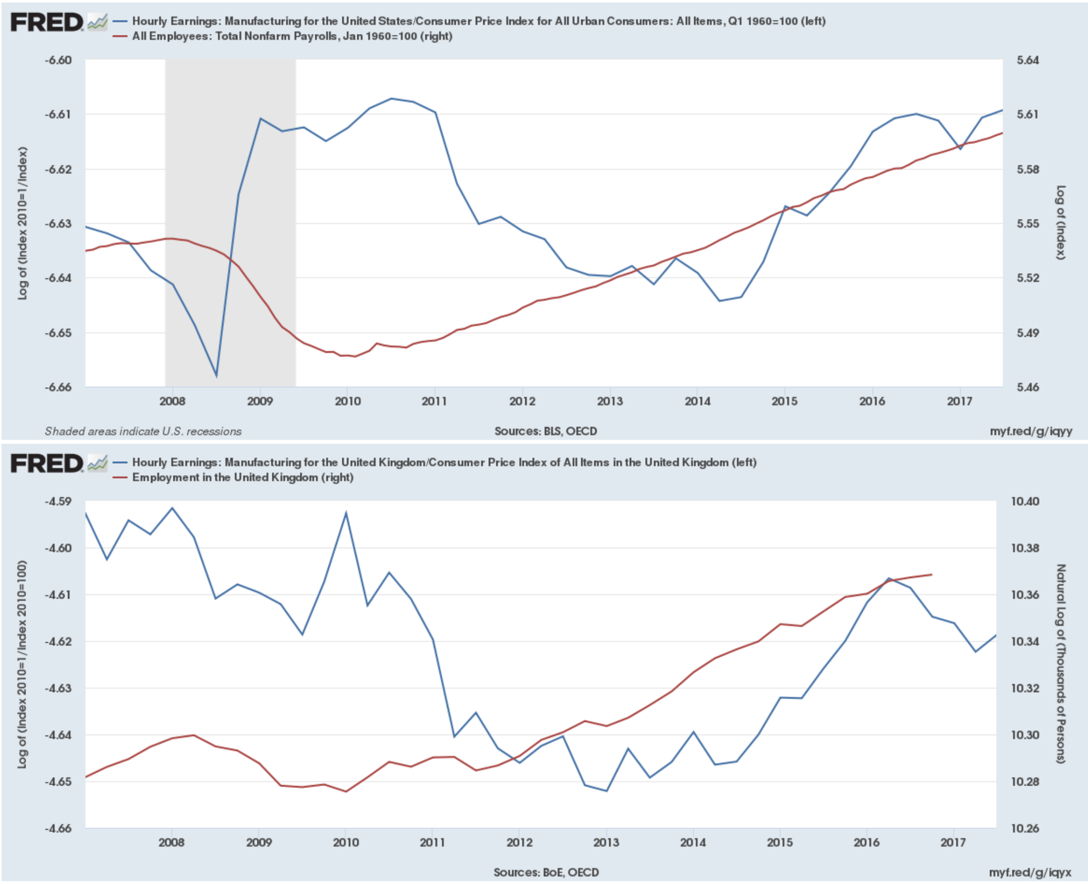
$$\frac{\text{real wages}}{\text{consumption-leisure MRS}} = 1 - [\text{labour supply wedge}]$$

How this works out in practice varies across episodes and countries. To pick a stark example, Figure 8 compares the labour market experiences of the US and UK during the Great Recession. In the US, real wages were largely unchanged throughout the recession. Employment however fell dramatically. In the UK, real wages fell dramatically and employment remained largely unchanged. In both cases, there appears to be a widening of the labour demand wedge: an increase in the marginal product of labour in the US without commensurate increases in wages, and a decrease in wages in the UK without a commensurate fall in the marginal product of labour. The large fall in employment during a period of stable wages in the US is suggestive of an increase in the labour supply wedge.

THE LABOUR DEMAND WEDGE AND FINANCIAL FRICTIONS

The first major breakthrough in generating large labour wedges and volatility in employment and wages was to combine the flexible price models of Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) with New Keynesian models of price setting rigidities. This approach has become standard for quantitative studies of the importance of financial frictions for business cycle dynamics. During periods of financial stress, demand falls. The slow adjustment of prices to the fall in demand results in an increase in markups of prices over marginal costs—equivalently, wages fall below marginal revenue products. Examples of papers taking this approach include Bernanke, Gertler, and Gilchrist (1999), Christiano, Motto, and Rostagno (2014) and Nolan and Thoenissen (2009).

Figure 7: Great recession labour outcomes in the US and UK



In normal times, and in the papers cited above, the response of monetary policy acts to counterract volatility in the labour wedge generated through New Keynesian markups. These effects are amplified in models with the zero lower bound or fixed exchange rates where the monetary transmission mechanism is broken—Farhi and Werning (2013) and Schmitt-Grohe and Uribe (2012) base their theories of macroprudential regulation on disruption of the monetary transmission mechanism for this reason.

More recent work has looked at adapting the financial friction itself, rather than just combining it with New Keynesian price setting frictions. One approach is to model *working capital loans*—firms must borrow to pay wages before receiving their revenues. This approach, in combination with standard loan contract models of Bernanke and Gertler (1989) and Kiyotaki and Moore (1997), generates a financial friction that acts directly on labour demand. Jermann and Quadrini (2012) is an influential example of this approach.

Another approach is presented by Duncan and Nolan (2018a). They study a model with risk averse entrepreneurs. In this model, entrepreneurs hire labour before realising their firm-specific productivity shock. The risk aversion of entrepreneurs reduces their valuation of the risky marginal revenue product below its expectation. Consequently, a wedge opens between the marginal product of labour and firms' wage offers.

The risk bearing model of Duncan and Nolan (2018a) and the working capital loan model of Jermann and Quadrini (2012) will generate a vacancy posting wedge in labour search and matching models, through the same mechanisms that hold down wages. Whether the resulting vacancy posting wedge results in a labour demand wedge (low wages) or a labour supply wedge (low employment / non-price labour market rationing) will depend on the specifics of your search and matching frictions.

The labour supply wedge and financial frictions

Normally, economists would think of unemployment as non-price rationing in the labour market—unemployed workers would be willing to work at posted wage rates. Again, the most popular way to generate labour supply wedges is through New Keynesian rigidities; this is a feature of Christiano, Motto, and Rostagno (2014).

4 The external finance contract

One of many entrepreneure combines their own capital k^e with external factors. Entrepreneurs combine their capital with externally owned capital goods k^h and with labour n.

Entrepreneurs' productivity is contingent on individual specific shock θ, where outturn θ' occurs with discrete probability $\Delta(\theta')$, with $\sum_\theta \Delta(\theta) = 1$. All agents know the distribution of outturns under all of the models we consider below.

Entrepreneurs make factor payments at the end of the period, determined by contracts specified at the beginning of the period. Wage contracts are non-contingent, W. Capital factor repayments are state-contingent, $R(\theta)$. Capital factor owners have an outside option in the form of a risk free deposit earning gross return R^f.

At the end of the period, the entrepreneur enjoys consumption c^e according to utility function u, where $u', -u'' > 0$.

4.1 Perfect markets

The entreprneur solves the following problem:

$$\max_{k^h,n,c,R(\theta)} \mathbb{E}[u(c^e(\theta))],$$

subject to the budget constraints,

$$c^e(\theta) \leq \theta f(k^e + k^h, n) - R(\theta)k^h - Wn, \qquad \forall\theta \tag{1}$$

and the lenders' participation constraint,

$$\mathbb{E}[R(\theta)] \geq R^f. \tag{2}$$

After inspection, it is clear that the constraints will bind with equality, and the problem is convex (why?). The entrepreneur's Lagrangian can be written as follows:[2]

$$\begin{aligned}\mathcal{L} = &\ \mathbb{E}[u(c^e(\theta))] \\ &+ \mathbb{E}[\lambda(\theta)[\theta f(k^e + k^h, n) - R(\theta)k^h - Wn - c^e(\theta)]] \\ &+ \nu[\mathbb{E}[R(\theta)] - R^f]\end{aligned}$$

The first order conditions are

$$\begin{aligned}\mathcal{L}_{k^h} &: \quad 0 = \mathbb{E}[\lambda(\theta)[\theta f_1 - R(\theta)]] \\ \mathcal{L}_{R(\theta)} &: \quad 0 = \Delta(\theta)[-\lambda(\theta)k^h + \nu] \\ \mathcal{L}_n &: \quad 0 = \mathbb{E}[\lambda(\theta)[\theta f_2 - W]] \\ \mathcal{L}_c &: \quad 0 = \Delta(\theta)[u'(c^e(\theta)) - \lambda(\theta)]\end{aligned}$$

The key here is $\mathcal{L}_{R(\theta)}$, which we re-write as

$$\lambda(\theta) = \frac{\nu}{k^h} \qquad \forall\theta.$$

The Lagrange multiplier $\lambda(\theta)$ is a constant, implying by $\mathcal{L}_c$ that marginal utility and therefore consumption is constant. Given that $\lambda(\theta)$ is a constant, we can eliminate it from $\mathcal{L}_{k^h}$,

$$0 = \mathbb{E}[\theta f_1] - \mathbb{E}[R(\theta)].$$

Combined with the participation constraint, (2), we have

$$\mathbb{E}[\theta f_1] = R^f. \tag{3}$$

The left hand side of Equation 3 is the expected marginal product of capital for an individual firm—or the aggregate marginal product of capital across firms. The solution to the entrepreneur's problem equates the aggregate marginal product of capital to the capital factor price R^f.

4.2 LIMITED PLEDGEABILITY I

Now, assume that the entrepreneur first makes their capital borrowing decision and then decides (a) whether or not to abscond with wealth $(k^e + k^h)$ providing exit utility $w(k^h + k^e)$ and if not then (b) how much labour to hire, n.

The new limited commitment constraint is defined by the following programme

$$w(k^h + k^e) \leq \max_{n,c^e} \mathbb{E}[u(c^e(\theta))] \tag{4}$$

$$\text{s.t.} \quad 0 \leq \theta f(n; k^e + k^h) - R(\theta)k^h - Wn - c^e(\theta).$$

[2] I prefer to present state contingent Lagrange multipliers in the form $\Delta(\theta)\lambda(\theta)$, rather than $\lambda(\theta)$. Typically, this yields a more natural interpretation of the Lagrange multiplier as a shadow cost.

This has the solution

$$n = [f']^{-1}(W; k^e + k^h), \tag{5}$$

By 5, the marginal product of labour is equal to the wage rate.

$$w(k^h+k^e) \leq \mathbb{E}[u(\theta f([f']^{-1}(W;k^e+k^h);k^e+k^h)-R(\theta)k^h-W[f']^{-1}(W;k^e+k^h))] \tag{6}$$

The entrepreneur's Lagrangian is now

$$\begin{aligned}\mathcal{L} = {} & \mathbb{E}[u(c^e(\theta))] \\ & + \mathbb{E}[\lambda(\theta)[\theta f(k^e + k^h, n) - R(\theta)k^h - Wn - c^e(\theta)]] \\ & + \nu[\mathbb{E}[R(\theta)] - R^f] \\ & + \phi[n - [f']^{-1}(W; k^e + k^h)] \\ & + \psi[\mathbb{E}[u(c^e(\theta))] - w(k^e + k^h)]\end{aligned}$$

The problem is no longer guaranteed to be convex. In addition, we cannot be sure that the incentive constraint is binding.

The first order necessary conditions are

$$\begin{aligned}\mathcal{L}_{k^h} &: \quad 0 = \mathbb{E}[\lambda(\theta)[\theta f_1 - R(\theta)]] - \psi w'(k^e + k^h) \\ \mathcal{L}_{R(\theta)} &: \quad 0 = \Delta(\theta)[-\lambda(\theta)k^h + \nu] \\ \mathcal{L}_c &: \quad 0 = \Delta(\theta)[(1+\psi)u'(c^e(\theta)) - \lambda(\theta)]\end{aligned}$$

The optimality condition for labour was determined earlier by Equation 5. The complementary slackness condition is

$$0 = \psi[\mathbb{E}[u(c^e(\theta))] - w(k^e + k^h)].$$

From $\mathcal{L}_{R(\theta)}$, we know that $\lambda(\theta)$ is constant, $\lambda(\theta) = \nu/k^h$. Combining this with $\mathcal{L}_c$, we see that consumption is constant across states—all idiosyncratic risk is passed on to the capital owners.

From $\mathcal{L}_{k^h}$ we now have

$$\underbrace{\mathbb{E}[\theta f_1]}_{MPK} = R^f + \underbrace{\frac{\psi}{\lambda} w'(k^e + k^h)}_{\text{investment wedge}}$$

In this model, the only wedge of inefficiency is the investment wedge. For the other margins in the model (consumption across states, labour) allocations equate MRS with MRT.

4.3 LIMITED PLEDGEABILITY II

Now, lets assume that we can represent the limited commitment model of the previous section with just a leverage constraint, specified as follows

$$k^h \le \zeta k^e. \tag{7}$$

The term ζ is referred to as the pledgeable share of assets. This is a more ad-hoc formulation than in Section 4.2. As we will see, the results generated are very similar.

The entrepreneur's Lagrangian is now

$$\begin{aligned}\mathcal{L} = \ & \mathbb{E}[u(c^e(\theta))] \\ & + \mathbb{E}[\lambda(\theta)[\theta f(k^e + k^h, n) - R(\theta)k^h - Wn - c^e(\theta)]] \\ & + \nu[\mathbb{E}[R(\theta)] - R^f] \\ & + \xi[\zeta k^e - k^h]\end{aligned}$$

The problem is convex.

The first order necessary conditions are

$$\begin{aligned}\mathcal{L}_{k^h} &: \quad 0 = \mathbb{E}[\lambda(\theta)[\theta f_1 - R(\theta)]] - \xi \\ \mathcal{L}_{R(\theta)} &: \quad 0 = \Delta(\theta)[-\lambda(\theta)k^h + \nu] \\ \mathcal{L}_c &: \quad 0 = \Delta(\theta)[u'(c^e(\theta)) - \lambda(\theta)] \\ \mathcal{L}_n &: \quad 0 = \mathbb{E}[\lambda(\theta)[\theta f_2 - W]]\end{aligned}$$

The complementary slackness condition is

$$0 = \xi[\zeta(k^e + k^h) - k^h].$$

From $\mathcal{L}_{R(\theta)}$, we know that $\lambda(\theta)$ is constant, $\lambda(\theta) = \nu/k^h$. Combining this with $\mathcal{L}_c$, we see that consumption is constant across states—all idiosyncratic risk is passed on to the capital owners.

From $\mathcal{L}_{k^h}$ we now have

$$\underbrace{\mathbb{E}[\theta f_1]}_{MPK} = R^f + \underbrace{\frac{\xi}{\lambda}}_{\text{investment wedge}}$$

In this model, the only wedge of inefficiency is the investment wedge. For the other margins in the model (consumption across states, labour) allocations equate MRS with MRT.

This solution is certainly a lot easier to work with than the solution from Section 4.2. It carries the same main features with a more natural interpretation of the Lagrange multiplier ξ.[3] This type of pledgeability constraint commonly stands in for more rigourously microfounded formulations.

4.4 Limited pledgeability III

The specification of pledgeable income and assets is important. Now assume that the entrepreneur cannot pledge more than fraction χ of their revenue in any given state across all factor payments:

$$R(\theta)k^h + Wn \leq \chi\theta f(k^e + k^h, n) \qquad \forall\theta. \tag{8}$$

The entrepreneur's Lagrangian is now

$$\begin{aligned}\mathcal{L} = &\mathbb{E}[u(c^e(\theta))] \\ &+ \mathbb{E}[\lambda(\theta)[\theta f(k^e + k^h, n) - R(\theta)k^h - Wn - c^e(\theta)]] \\ &+ \nu[\mathbb{E}[R(\theta)] - R^f] \\ &+ \mathbb{E}[\mu(\theta)[\chi\theta f(k^e + k^h, n) - R(\theta)k^h - Wn]]\end{aligned}$$

The problem remains convex, but now we have the added complexity that some of the incentive constraints (8) may be non-binding. The problem is now a Kuhn-Tucker problem.

The first order necessary conditions are

$$\begin{aligned}\mathcal{L}_{k^h} &: \quad 0 = \mathbb{E}[\lambda(\theta)[\theta f_1 - R(\theta)]] + \mathbb{E}[\mu(\theta)[\chi\theta f_1 - R(\theta)]] \\ \mathcal{L}_{R(\theta)} &: \quad 0 = \Delta(\theta)[-\lambda(\theta)k^h + \nu - \mu(\theta)k^h] \\ \mathcal{L}_n &: \quad 0 = \mathbb{E}[\lambda(\theta)[\theta f_2 - W] + \mu(\theta)[\chi\theta f_2 - W]] \\ \mathcal{L}_c &: \quad 0 = \Delta(\theta)[u'(c^e(\theta)) - \lambda(\theta)]\end{aligned}$$

The complementary slackness conditions are

$$\mu(\theta)[\chi\theta f(k^e + k^h, n) - R(\theta)k^h - Wn] \qquad \forall\theta.$$

From $\mathcal{L}_{R(\theta)}$, we have

$$\lambda(\theta) + \mu(\theta) = \frac{\nu}{k^h}.$$

This is a constant, and we can use it to simplify the factor quantity optimality conditions. From $\mathcal{L}_{k^h}$ we have

$$\mathbb{E}[\theta]f_1 = R_f + \underbrace{\mathbb{E}\left[k^h \frac{\mu(\theta)}{\nu}(1-\chi)\theta f_1\right]}_{\text{investment wedge}}$$

The investment wedge remains positive when any of the pledgeability constraints are

[3] When the entrepreneur is risk neutral, the shadow cost of income is equal one, $\lambda = 1$, and therefore the investment wedge is equal to the shadow cost of the incentive constraint, ξ.

binding—that is, when there is some θ for which $\mu(\theta) > 0$. Similarly, from $\mathcal{L}_n$ we have

$$\mathbb{E}[\theta] f_2 = W + \underbrace{\mathbb{E}\left[k^h \frac{\mu(\theta)}{\nu}(1-\chi)\theta f_2\right]}_{\text{labour wedge}}$$

Also, from $\mathcal{L}_c$ we have

$$u'(c^e(\theta)) - u'(c^e(\theta')) = \underbrace{\mu(\theta') - \mu(\theta)}_{\text{consumption risk wedge}}$$

4.5 PRIVATE INFORMATION

Now, assume that the entrepreneur can commit to repayments in future states, but that only the entrepreneur can observe the realisation of the state θ. According to the *revelation principle* there exists an optimal contract that elicits truth-telling in all states.

Proposition 1 The revelation principle *(adapted from Laffont and Martimort, 2002, Proposition 2.2). The allocations obtained any contract can be obtained by a contract that elicits truth-telling as an optimal strategy in all states.*

This is a powerful result. It makes our lives much easier. Be aware of what it is saying and what it is not saying. Proposition 1 does not state that optimality implies truth-telling. What it does state is that the optimal allocations can be obtained through a contract that elicits truth-telling. There may be other contracts that achieve optimal allocations in equilibria with misreporting. Using the revelation principle, we can analyse the effects of fraudulent reporting on allocations even in models that don't generate fradulent reporting in equilibrium.[4]

OK. Back to our problem. Our incentive compatibility constraint (or truth-telling constraint) for an entrepreneur receiving idiosyncratic shock θ:

$$\underbrace{u(c^e(\theta))}_{\text{truth-telling}} \geq \underbrace{u(c^e(\theta') + (\theta - \theta') f(k^e + k^h, n))}_{\text{misreporting } \theta'} \qquad \forall \theta, \theta' \tag{9}$$

On the left hand side is their utility attained by truthfully reporting θ. On the right hand side is their utility attained by instead reporting θ'. In this case, they get the consumption bundle due to a truth-telling entrepreneur earning θ', $(c^e(\theta'))$, plus the difference in revenue between an entrepreneur receiving shock θ and an entrepreneur receiving shock θ', $((\theta - \theta') f(k^e + k^h, n))$. [5]

[4]Many researchers are not happy with this approach, and would prefer to work with models that generate fraud in equilibrium. Personally I'm not too bothered about it. In my view, the most important thing is that models can generate the main properties of allocations seen in the data.

[5]If you would like some more detail on the steps here, I suggest you take a look at Duncan and Nolan (2017), which is a related problem. Alternatively, the standard textbook treatments are Laffont and Martimort (2002), Salanié (2005) and Bolton and Dewatripont (2005).

Fortunately for us, in our problem the reporting occurs after all of the risk has been realised. So, we can eliminate the utility functions from equation 9 and work with consumption allocations directly:

$$c^e(\theta) \geq c^e(\theta') + (\theta - \theta')f(k^e + k^h, n) \qquad \forall \theta, \theta' \tag{10}$$

Depending on the specifics of $f(\cdot)$, this constraint is non-convex. Also, many of the constraints specified by 10 will be non-binding.

So we don't necessarily want to jump straight into the Lagrangian. Lets first reconsider the budget constraint:

$$0 = \theta f(k^e + k^h, n) - R(\theta)k^h - Wn - c^e(\theta)$$

Substituting 10 into the budget constraint gives us

$$R(\theta) = R(\theta') \qquad \forall \theta, \theta'.$$

Combining this result with the participation constraint we get

$$R(\theta) = R^f \qquad \forall \theta.$$

The contract space is restricted to non-contingent (risk free) contracts. We can now just plug this into the budget constraint and write down the entrepreneur's Lagrangian:

$$\begin{aligned} \mathcal{L} = {} & \mathbb{E}[u(c^e(\theta))] \\ & + \mathbb{E}[\lambda(\theta)[\theta f(k^e + k^h, n) - R^f k^h - Wn - c^e(\theta)]] \end{aligned}$$

The first order necessary conditions are

$$\begin{aligned} \mathcal{L}_{k^h} &: \quad 0 = \mathbb{E}[\lambda(\theta)[\theta f_1 - R^f]] \\ \mathcal{L}_n &: \quad 0 = \mathbb{E}[\lambda(\theta)[\theta f_2 - W]] \\ \mathcal{L}_c &: \quad 0 = \Delta(\theta)[u'(c^e(\theta)) - \lambda(\theta)]. \end{aligned}$$

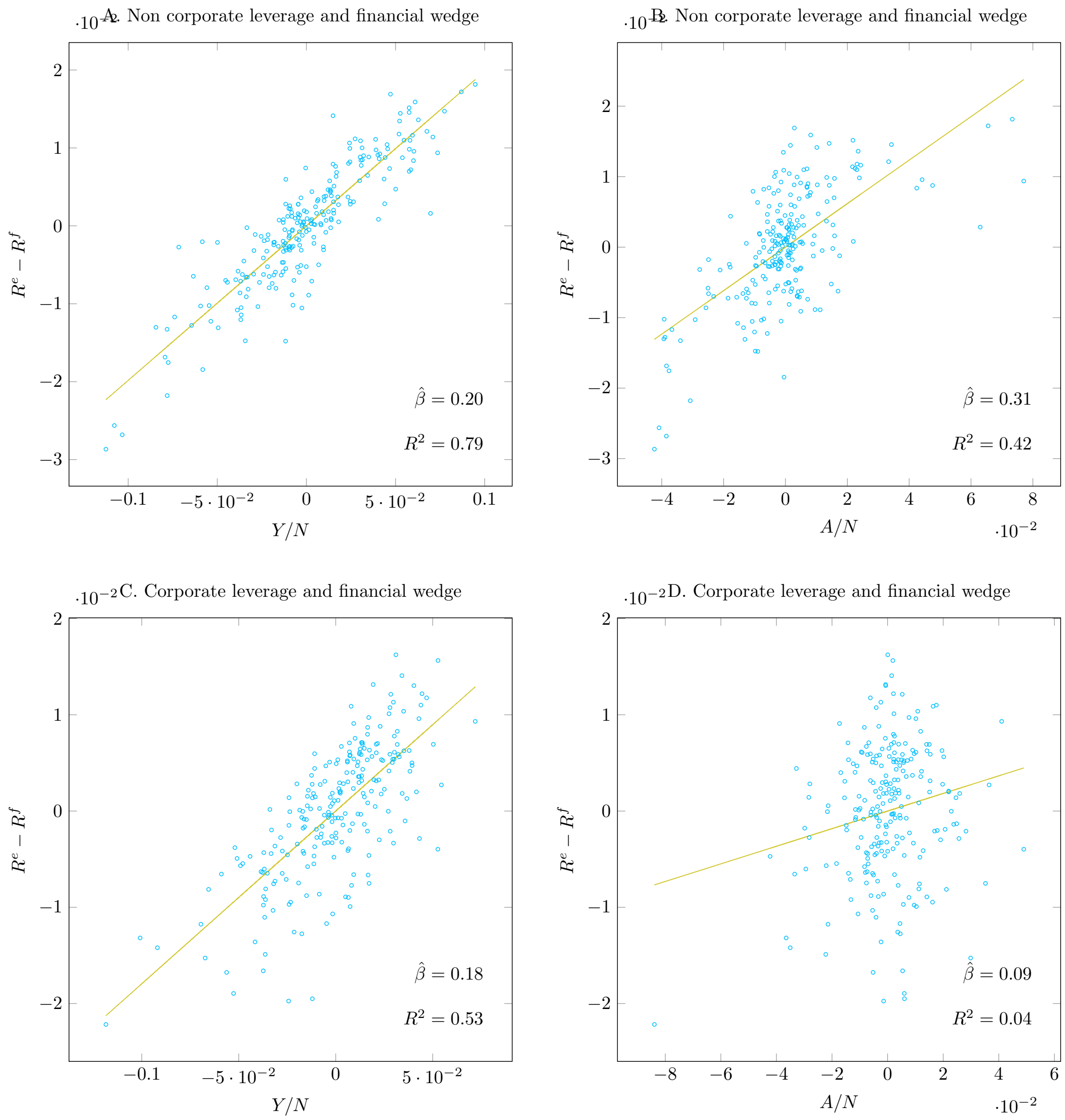
For any concave utility function, we have it from $\mathcal{L}_c$ that $\lambda(\theta) > \lambda(\theta')$ iff $\theta < \theta'$. It follows that $\text{cov}(\lambda(\theta), \theta) < 0$, and by $\mathcal{L}_{k^h}$ we have

$$\begin{aligned} 0 &= \mathbb{E}[\lambda(\theta)[\theta f_1 - R^f]] \\ &= \mathbb{E}[\lambda(\theta)\theta]f_1 - \mathbb{E}[\lambda(\theta)]R^f \\ &= [\mathbb{E}[\lambda(\theta)]\mathbb{E}[\theta] + \text{cov}(\lambda(\theta), \theta)]\, f_1 - \mathbb{E}[\lambda(\theta)]R^f \\ &= \left[1 + \frac{\text{cov}(\lambda(\theta), \theta)}{\mathbb{E}[\lambda(\theta)]\mathbb{E}[\theta]}\right] \mathbb{E}[\theta]f_1 - R^f \end{aligned}$$

$$\mathbb{E}[\theta f_1] > R^f,$$

$\frac{\text{cov}(\lambda(\theta), \theta)}{\mathbb{E}[\lambda(\theta)]\mathbb{E}[\theta]}$ is the investment wedge. Similarly, this model generates a labour wedge and idiosyncratic risk wedges.

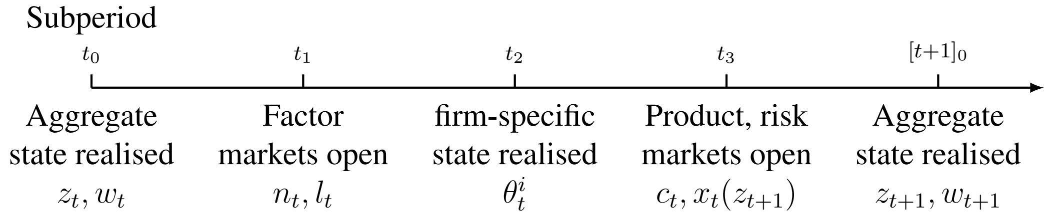
Figure 8: Leverage and the investment wedge (Duncan and Nolan, 2018a)



5 HEDGING AND FINANCIAL STABILITY (DUNCAN AND NOLAN, 2018A)

Krishnamurthy (2003), Carlstrom, Fuerst, and Paustian (2014) and Nikolov (2014) prove that in standard financial macroeconomic models, the assumption that households and firms cannot trade securities contingent on aggregate risks is (1) not microfounded by the financial friction, and (2) crucial to generating financial amplification within these models. (Duncan and Nolan, 2018a) presents a general decomposition of equilibrium under trade in aggregate risk markets. They show that the combination of trade in aggregate risk markets and financial amplification can only occur in models where the entrepreneur is risk averse and cannot pass on all of their productive risk to outside investors. The following is a summary of their analysis:

Figure 9: Timeline



The expectation operator $\mathbb{E}_t[\cdot]$ will be shorthand for expectations formed at time t_0, after the realisation of the aggregate state z_t. When the expectation $\mathbb{E}_t$ is formed, individual entrepreneurs remain unaware of the realisation of their firm-specific state θ_t^i. We solve optimisation problems in period t, subperiods 1 and 3. To simplify notation, we will on occasion use the fact that $\mathbb{E}[z_{t+1}|\Omega(t_3^i)] = \mathbb{E}[z_{t+1}|\Omega(t_0^i)] = \mathbb{E}_t[z_{t+1}]$ where $\Omega(t_k^i)$ is the information set available to agent i in period t, subperiod k.

Assumption 1 *Anonymity: Loan contracts written in subperiod t_1 can only be made contingent on public signals and messages revealed in subperiod t_2.*

Assumption 1 states that lenders cannot use future consumption and savings behaviour of entrepreneurs as evidence of false statements made relating to entrepreneurs' firm-specific states in subperiod 2. As soon as loan contracts are settled in subperiod 2, entrepreneurs become anonymous.

5.1 Entrepreneurs

A unit measure of entrepreneurs exists, indexed by i. Entrepreneur i enjoys consumption c^{ei} with utility function $\mathcal{U}^e(c^{ei})$, where $\mathcal{U}^{e'} > 0$, $\mathcal{U}^{e''} < 0$. Entrepreneurs are infinitely lived, and remain as entrepreneurs indefinitely. They discount their future utility by constant discount factor β^e. Entrepreneur i's subperiod t_1 problem is:

$$\mathcal{V}_t^e(w_t^{ei}) = \max_{c^{ei}, x^{ei}, w^{ei}, \mathcal{R}^{ei}} \mathbb{E}_t \sum_{k=0}^{\infty} (\beta^e)^k \mathcal{U}^e(c_{t+k}^{ei}). \tag{11}$$

subject to

$$w_{t+1}^{ei} = \mathcal{R}_t^{ei}(\theta_t^i) w_t^{ei} - c_t^{ei} + \underbrace{x_t^{ei}(z_{t+1}) - \int \mathcal{P}_t(z) x_t^{ei}(z) d\mathcal{F}(z_{t+1}|z_t)}_{\text{trade in business cycle risk markets}} \tag{12}$$

The gross return to entrepreneurs' wealth, $\mathcal{R}_t^{ei}(\theta_t^i)$, is an indirect function determined by the combination of the realisation of entrepreneurs' firm-specific risks θ_t^i and optimisation over entrepreneurs' production and external finance decisions. In period t subperiod 3, entrepreneur i has settled contracts contingent on their firm-specific state θ^i. Denote the entrepreneur's value function at subperiod t_3 as $\hat{\mathcal{V}}_t^e(w_t^{ei};\theta_t^i)$. Entrepreneur i solves the following problem:

$$\hat{\mathcal{V}}_t^e(w_t^{ei};\theta_t^i) = \max_{c_t^{ei},x_t^{ei},w_{t+1}^{ei}} \mathcal{U}^e(c_t^{ei}) + \beta^e \mathbb{E}_t \mathcal{V}_{t+1}^e(w_{t+1}^{ei}) \qquad \text{subject to } (12).$$

The first order necessary conditions of entrepreneur i can be summarised as follows:

$$\frac{\beta^e \mathcal{V}^{e\prime}(w_{t+1}^{ei})}{\mathcal{U}^{e\prime}(c_t^{ei})} = \mathcal{P}_t(z_{t+1}), \tag{13}$$

$$\mathcal{U}^{e\prime}(c_t^{ei}) = \beta^e \mathbb{E}[\mathcal{V}^{e\prime}(w_{t+1}^{ei})|\Omega(t_3^i)], \tag{14}$$

$$\mathcal{V}^{e\prime}(w_t^{ei}) = \mathbb{E}_t[\mathcal{R}_t^{ei}(\theta_t^i)\mathcal{U}^{e\prime}(c_t^{ei})]. \tag{15}$$

5.2 HOUSEHOLDS

Household j's subperiod t_1 problem is:

$$\mathcal{V}_t^h(w_t^{hj}) = \max_{c^{hj},n^{hj},x^{hj},w^{hj}} \mathbb{E}_t \sum_{k=0}^{\infty} (\beta^h)^k \mathcal{U}^h(c_{t+k}^{hj}, n_{t+k}^{hj}) \tag{16}$$

subject to

$$w_{t+1}^{hj} = R_t^h w_t^{hj} + \underbrace{W_t n_t^{hj}}_{\text{wages}} - c_t^{hj} + \underbrace{x_t^{hj}(z_{t+1}) - \int \mathcal{P}_t(z) x_t^{hj}(z) d\mathcal{F}(z_{t+1}|z_t)}_{\text{trade in business cycle risk markets}} \tag{17}$$

The first order necessary conditions of household j that pertain to financial market allocations can be summarised as follows:

$$\frac{\beta^h \mathcal{V}^{h\prime}(w_{t+1}^{hj})}{\mathcal{U}_c^h(c_t^{hj}, n_t^{hj})} = \mathcal{P}_t(z_{t+1}) \tag{18}$$

$$\mathcal{U}_c^h(c_t^{hj}, n_t^{hj}) = \beta^h \mathbb{E}_t[\mathcal{V}^{h\prime}(w_{t+1}^{hj})] \tag{19}$$

$$\mathcal{V}^{h\prime}(w_t^{hj}) = R_t^h \mathcal{U}_c^h(c_t^{hj}, n_t^{hj}) \tag{20}$$

MARKET CLEARING

$$\int_i x_t^{ei}(z)di + \int_j x_t^{hj}(z)dj = 0 \quad \forall z. \tag{21}$$

Definition 1 *A* competitive equilibrium *is a mapping from exogenous states* (z^t, θ^t) *to* *allocations* $\{c^{hj}(z^t), n^{hj}(z^t), w^{hj}(z^t), x^{hj}(z^t), c^{ei}(z^t, [\theta^i]^t), w^{ei}(z^t, [\theta^i]^t), x^{ei}(z^t, [\theta^i]^t)\}_{t=0}^{\infty}$ *and prices* $\{W(z^t), R^h(z^t), \mathcal{P}(z_{t+1}; z^t)\}_{t=0}^{\infty}$ *such that the market for aggregate risk securities clears (21), budget constraints (12,17) are satisfied, first order necessary conditions (13,14,15,18,19,20) are satisfied, and the distribution of returns to entrepeneurial wealth at time* t*,* $\mathcal{R}^{ei}(z^t, [\theta^i]^t)$*, is the solution to entrepreneur* i*'s individually optimal financing and employment decisions in period* t*.*

Let the ex-post intertemporal consumption marginal rates of substitution be denoted as follows:

$$\Lambda_{t,t-1}^{hj} = \frac{\beta^h \mathcal{U}_c^h(c_t^{hj}, n_t^{hj})}{\mathcal{U}_c^h(c_{t-1}^{hj}, n_{t-1}^{hj})}, \qquad \Lambda_{t,t-1}^{ei} = \frac{\beta^e \mathbb{E}_t[\mathcal{U}^{e\prime}(c_t^{ei})]}{\mathcal{U}^{e\prime}(c_{t-1}^{ei})}$$

Theorem 1 provides a decomposition of the equilibrium condition for business cycle risk insurance, characterising the forces underlying business cycle risk insurance trade.

Theorem 1 *In any competitive equilibrium with business cycle risk markets open, the following condition is satisfied:* [6]

$$\underbrace{\frac{\Lambda_{t,t-1}^{hj}}{\Lambda_{t,t-1}^{ei}}}_{(I)} = \underbrace{\frac{\mathbb{E}_t[\mathcal{R}_t^{ei}(\theta_t^i)]}{R_t^h}}_{(II)} \underbrace{\left(1 + \frac{\text{cov}(\mathcal{R}_t^{ei}(\theta_t^i), \mathcal{U}^{e\prime}(c_t^{ei}))}{\mathbb{E}_t[\mathcal{R}_t^{ei}(\theta_t^i)]\mathbb{E}_t[\mathcal{U}^{e\prime}(c_t^{ei})]}\right)}_{(III)} \tag{22}$$

The three forces:

(I) The gross deviation from full consumption insurance.

(II) The ratio of expected returns to entrepreneurs' and households' wealth.

(III) The idiosyncratic risk premium contribution to the entrepreneurs' stochastic discount factor of the entrepreneurs.

Holding all else equal, a one-off transfer of wealth from worker households to entrepreneurs will raise the left hand side (increasing household marginal utility relative to entrepreneurs') and reduce the right hand side, as the increased entrepreneur wealth reduces leverage and factor market distortions. Under the first best efficient allocations, both left and right hand sides would be equal to one.

[6]**Proof.** Combining the entrepreneur i and household j's first order necessary conditions (13) and (18) we obtain

$$\frac{\beta^h \mathcal{V}^{h\prime}(w_t^{hj})}{\mathcal{U}_c^h(c_{t-1}^{hj}, n_{t-1}^{hj})} = \frac{\beta^e \mathcal{V}^{e\prime}(w_t^{ei})}{\mathcal{U}^{e\prime}(c_{t-1}^{ei})} = \mathcal{P}_{t-1}(z_t).$$

Using conditions (15) and (20) yields

$$\frac{\beta^h \mathcal{U}_c^h(c_t^{hj}, n_t^{hj})}{\mathcal{U}_c^h(c_{t-1}^{hj}, n_{t-1}^{hj})} = \frac{\beta^e \mathbb{E}_t[\mathcal{R}_t^{ei}(\theta_t^i)\mathcal{U}^{e\prime}(c_t^{ei})]}{R_t^h \mathcal{U}^{e\prime}(c_{t-1}^{ei})}.$$

From here we can apply the definition of covariance to complete the proof. ■

5.3 EXAMPLE 1: RISK NEUTRAL AGENTS

Proposition 2 *In any competitive equilibrium with business cycle risk markets open and where entrepreneurs and worker households are risk neutral over consumption, the inefficiency wedge between entrepreneurs' and households' expected returns to net worth is constant.*

Proof. Proposition 2 follows from inspection of Equation 22. When all agents are risk neutral, the left hand side of Equation 22 is equal to β^h/β^e and the right hand side is equal to $\frac{\mathbb{E}_t[\mathcal{R}_t^{ei}(\theta_t^i)]}{R_t^h}$. ■

What Proposition 2 shows is that in order for financial amplification to be present, it must be the case that either business cycle risk markets are closed, or agents are risk averse, or both. This is the case regardless of the underlying causes of the financial frictions present.

EXAMPLE 2: FIRM-SPECIFIC MARGINAL UTILITY RISK

Assumption 2 *Entrepreneurs can borrow in non-contingent loans in unlimited amounts at risk free interest rates R_t^h.*

Assumption 2 is typical in models of private information where leverage is limited by entrepreneurs' desire to limit consumption risk, rather than by an externally imposed borrowing constraint (See Section 4.5 and Duncan and Nolan, 2018a for examples). In equilibrium, the entrepreneurs' consumption Euler condition will bind with respect to the risk free interest rate.

It follows that

$$R_t^h \cdot \mathbb{E}_t[\mathcal{U}^{e\prime}(c_t^{ei})] = \mathbb{E}_t[\mathcal{R}_t^{ei}(\theta_t^i)\mathcal{U}^{e\prime}(c_t^{ei})].$$

Competitive equilibrium in the insurance market implies

$$\frac{\Lambda_{t,t-1}^{hj}}{\Lambda_{t,t-1}^{ei}} = 1. \tag{23}$$

The insurance market does not act to offset fluctuations in financial wedges that characterise financial amplification. The increased cost of firm-specific risk bearing during downturns completely offsets the high expected returns to entrepreneurial wealth within the period.

6 POLICY

Greenwald and Stiglitz (1986) show us how market incompleteness generated by information asymmetries of the type studied in financial macroeconomics can motivate a role for government intervention. Simply put, governments should tax the complement of the moral hazard, and subsidise the complements of truth-telling. The tax/subsidy wedge has a second order allocative efficiency cost, but the benefit of deterring the moral hazard is first order.[7] An example of this would be that in a market with private health insurance, taxing pizza and subsidising broccoli would generate a welfare gain. The divergence in the relative prices of pizza and broccoli from their productive marginal rate of transformation would be a second order cost—the reduced incentive to consume unhealthy food would reduce the moral hazard inherent in health insurance markets.

In some cases, markets can replicate this tax policy. Around the world, health insurance companies bundle their policies with gym membership subsidies. This means that policyholders have lower costs of gym services than other consumers. In a sense, the policyholders trade in a different market for gyms than the non-policyholders. In the case of gym memberships, partnerships between gyms and insurance companies mean that databases and identification can be shared, so a policyholder cannot give their gym subsidy to a friend or family member. This could be more challenging in other markets. In South Africa, health insurance companies are more aggressive than elsewhere in the world. In South Africa, your grocery shop can be refunded by up to 20% from your health insurance company if it is filled with broccoli. This involves quite a lot of data sharing between supermarket chains and insurance companies. It does mean however that policyholders trade in different markets than non-policyholders for broccoli. Non-policyholders are excluded from trading in the policyholder market, and face a different price vector. This exclusion is a type of Kilenthong and Townsend (2016) mechanism. Exclusions of this form are typically difficult to enforce in private markets. It is hard to stop the policyholders from re-selling their low-cost goods to non-policyholders.

Green and Oh (1991) and Duncan (2016) generate Greenwald-Stiglitz style motivations for policy in markets of endogenous market incompleteness. They show that savings assets and assets that covary with aggregate outcomes are complements with misreporting individual specific shocks. In Green and Oh (1991), this generates credit rationing as a constrained efficient response to a recession. In Duncan (2016), this motivates restrictions on exposure to business cycles among low wealth households. But there is a long way from here to financial macroeconomic models. Typically, policy analysis in financial macro models relies on models with exogenous market incompleteness. This means that we lose the original intuition of Greenwald-Stiglitz.

7 EXERCISES

Please feel free to work together on these.

Exercise 1 *Write down a two period model with the following features: In period one, the entrepreneurs hire labour n at wage rate W; they borrow capital k^h at gross interest rate R^h. Factor payments are made at the end of period 1, immediately prior to consumption.*

They combine this capital and labour with their own capital k^e using a constant returns to scale production function to produce output goods $y = z(k^h + k^e)^\alpha n^{1-\alpha}$. Capital

[7] See Dixit (2003) for an intuitive discussion and critique.

fully depreciates during period 1. Output y can be consumed (c^h, c^e) or stored (s^h, s^e) for period 2.

Stored output earns gross return R. For the exercises below, we'll be holding total capital constant, but we may vary the fraction of capital that is initially endowed to entrepreneurs, $\kappa = k^e/(k^e + k^h), k = (k^e + k^h)$.

Answer questions (a-c) for models (i-iii):

a. *How does a change in TFP z affect output, factor prices and consumption allocations?*

b. *How does a change in the distribution of capital κ affect output, factor prices and consumption allocations?*

c. *For model (ii) only, how does a change in the pledgeable share of capital affect output, factor prices and consumption allocations?*

d. *For model (iii) only, how does a change in risk $\theta_h - \theta_l$, holding $\mathbb{E}[\theta]$ constant, affect output, factor prices and consumption allocations?*

i. *Perfect capital markets.*

ii. *Limited pledgeability as in Section 4.3.*

iii. *Private information as in Section 4.5, where the production function contains an idiosyncratic component θ, drawn from a high-low distribution $\theta \in \{\theta_l, \theta_h\}$.*

$$y = z\theta(k^h + k^e)^\alpha n^{1-\alpha}.$$

Exercise 2 *One of the central features of financial macroeconomic models is that when asset prices fall, the losses are concentrated within the firm sector, rather than the rentier household sector.*

The US flow of funds dataset contains aggregated balance sheet data for nonfinancial corporate business and for the household and nonprofit sector (`https://fred.stlouisfed.org/categories/32251` *). Does this data support this central mechanism of financial macroeconomics?*

Exercise 3 *Gilchrist and Zakrajsek (2012) decompose US corporate bond spreads into two components. The first component is a measure of the credit spread that is explained by the creditworthiness of borrowers and is constructed from estimates of the probability of default and the loss given default. The second component, what they term the* excess bond premium, *is a residual term that captures changes in financial conditions that are external to the borrowing firms. The authors provide their constructed data set here:* `http://people.bu.edu/sgilchri/Data/data.htm`

Assume that the excess bond premium is exogenous. Using a Cholesky scheme, generate VAR impulse responses for inflation and output in response to a shock to the excess bond premium. (Obtain the inflation and output data from the St Louis Federal Reserve FRED Database `https://fred.stlouisfed.org/` *)*

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