NBER WORKING PAPER SERIES

ADVERSE SELECTION AND SELF-FULFILLING BUSINESS CYCLES

Jess Benhabib
Feng Dong
Pengfei Wang

Adverse Selection and Self-fulfilling Business Cycles
Jess Benhabib, Feng Dong, and Pengfei Wang
NBER Working Paper No. 20642
October 2014
JEL No. E32,E44,G01

ABSTRACT

We develop a macroeconomic model with adverse selection. A continuum of households purchase goods from a continuum of anonymous producers. The quality of products can only be learned after trade. Adverse selection arises as low-quality goods deliver higher profits for producers but are less desirable for households. Higher aggregate demand induces more high-quality goods, raises average quality, and drives up household demand. We show that this demand externality can generate multiple equilibria or indeterminacy even when the steady state equilibrium is unique, making self-fulfilling expectation driven business cycles possible. Indeterminacy arising from adverse selection in credit markets is also constructed.

Jess Benhabib
Department of Economics
New York University
19 West 4th Street, 6th Floor
New York, NY 10012
and NBER
jess.benhabib@nyu.edu

Feng Dong
Shanghai Jiao Tong University
Fahuazhen Rd 535
Changning District, Shanghai, China
fengdong@sjtu.edu.cn

Pengfei Wang
Department of Economics
Business School
Hong Kong University of Science & Technology
pfwanghkust@gmail.com

1   Introduction

The seminal work of Wilson (1980) shows that in a static model, adverse selection can generate multiple equilibria because of asymmetric information about product quality. The aim of this paper is to analyze how adverse selection can give rise to demand externalities to generate multiple equilibria and indeterminacies in a dynamic general equilibrium model of business cycles with otherwise standard features.

To make this point, we incorporate a simple type of adverse selection into the standard textbook real business cycle model. The model features a continuum of households and a continuum of anonymous producers. The quality of each producer's product is assumed to be her private information. In addition, the cost of production is assumed to be an increasing function of product quality. As a consequence, producers with low-quality products enjoy a competitive advantage in the goods market: low-quality products are more likely to be produced for a given price. This give rise to adverse selection. In such an environment, an increase in household demand would push up the price, encourage more high-quality producers to produce, and boost total production as well as the average quality of goods in the market. The rise in the average quality in turn stimulates the demand from households for goods. In our baseline model in Section 2, we show that this demand externality not only generates two steady state equilibria with low and high average product quality, but also gives rise to a continuum of equilibria around one of the steady states. We calibrate our model and show that indeterminacy is easily and plausibly obtained under reasonable parameters.

Our model has several implications supported by empirical evidence. First, the average product quality is procyclical, which is consistent with the recent findings of Broda and Weinstein (2010). Second, our model delivers a countercyclical markup, an important empirical regularity well documented in the literature. In our model, because of information asymmetry, low-quality products enjoy an informational rent. But when the average quality increases due to higher demand, this informational rent is diluted. So the measured markup declines, which is critical to sustaining indeterminacy by bringing about higher real wages, a positive labor supply response, and a higher output that dominates the income effect on leisure. Third, our extended model in Section 4 can explain the well-known procyclical variation in productivity. The procyclicality of average quality implies that resources are reallocated toward producers with higher quality products when aggregate output increases. The improved resource allocation then raises productivity endogenously. The procyclical endogenous TFP immediately

implies that increases in inputs lead to a more than proportional increase in total aggregate output, in other words, aggregate increasing returns. The increasing returns to scale arises only at the aggregate level in our model helps solve the puzzle documented by Basu and Fernald (1997), who find a slightly decreasing returns to scale for a typical two-digit industry in the United States but strong increasing returns to scale at the aggregate level. Finally, anecdotal evidence suggests that adverse selection is more prevalent in developing countries, possibly due to poor law enforcement and low product reputation. This may explain extensive findings in the marketing literature that products from developing countries are stereotypically perceived as being inferior to those from industrialized countries (see Schooler (1971) for an influential study). An important insight of our study is that indeterminacy arises only if adverse selection is severe enough, which then implies that developing countries are more prone to indeterminacy and self-fulfilling expectation-driven business cycles. This also helps to explain another well-established stylized fact that developing countries typically exhibit larger output volatility than developed countries (see e.g., Ramey and Ramey (1995) and Easterly, Islam, and Stiglitz (2000)).

In a dynamic setting market forces and competition can mitigate adverse selection through warranty contracts or reputation effects that are absent in our baseline model in Section 2. We therefore examine whether indeterminacy is robust to the introduction of warranties and reputational effects. In Section 3, following Priest (1981), and Cooper and Ross (1985), we introduce partial warranty contracts, typically justified by the double moral hazard problem when product performance depends on the buyer as well. We show that our indeterminacy results remain robust. Then, following Klein and Leffler (1981), we extend our model to allow reputation effects: a seller producing and marketing a lemon may, with some probability, lose reputation, and be excluded from the market forever. In this case we show that the steady state equilibrium becomes unique and no lemons are produced in equilibrium. Nevertheless, perhaps surprisingly, indeterminacy in the form of a continuum of equilibria may continue to exist.

Our paper is closely related to two branches of literature in macroeconomics. First, our paper builds on a large strand literature on the possibility of indeterminacy in RBC models. Benhabib and Farmer (1994) point out that increasing returns to scale can generate indeterminacy in an RBC model. The required degree of increasing returns to scale for indeterminacy, however, is considered be implausibly large by empirical evidence (see Basu and Fernald (1995, 1997)). Subsequent work in the literature has introduced additional features to the Benhabib-

Farmer model that reduce the degree of increasing returns required for indeterminacy. In an important contribution, Wen (1998) adds variable capacity utilization and shows that indeterminacy can arise with a magnitude of increasing returns similar to that in the data. Gali (1994) and Jaimovich (2007) explore the possibility of indeterminacy via countercyclical markup due to output composition and firm entry respectively. The literature has also shown that models with indeterminacy can replicate many of the standard business cycle moments as the standard RBC model (see Farmer and Guo (1994)). Furthermore, indeterminacy models may outperform the standard RBC models in many other dimensions. For instance, Benhabib and Wen (2004), Wen and Wang (2008), and Benhabib and Wang (2014) show that models with indeterminacy can explain the hump-shaped output dynamics and relative volatility of labor and output, which are challenges for the standard RBC models. Our paper complements this strand of literature by adding adverse selection as a different source of indeterminacy. The adverse selection approach also provides a micro-foundation to the aggregate increasing returns to scale. Indeed, if we specify a Pareto distribution for firm productivity, our model in Section 4 is isomorphic to those that have a representative-firm economy with increasing returns, such as the one studied by Benhabib and Farmer (1994) and Wen (1998). It therefore inherits the ability of reproducing the business cycle features mentioned above without having to rely on increasing returns.[1]

Second, our paper is closely related to a small but rapidly growing literature that study the macroeconomic consequences of adverse selection. Kurlat (2013) builds a dynamic general equilibrium with adverse selection in the second-hand market for capital assets. Kurlat (2013) shows that the degree of adverse selection varies countercyclically. Since adverse selection reduces the efficiency of resource allocation, a negative shock that lowers aggregate output will exacerbate adverse selection and worsen resource allocation efficiency. So the impact of the initial shocks on aggregate output is propagated through time. Like Kurlat (2013), Bigio (2014) develops an RBC model with adverse selection in the capital market. As firms must sell the existing capital to finance investment and employment, adverse selection distorts both capital and labor markets. Bigio (2014) shows that the adverse selection shock widens a dispersion of capital quality, exacerbates the distortion, and leads to a recession with a quantitative pattern similar to that observed during the Great Recession of 2008. Our model generates similar predictions as Kurlat (2013) and Bigio (2014). First, adverse selection is also countercyclical in

---

[1]Liu and Wang (2014) provides an alternative mechanism to generate increasing returns via financial constraints.

our model, so the propagation of fundamental shocks via adverse selection effects highlighted by Kurlat (2013) exist also in our model. Second, adverse selection in the goods market in our model naturally creates the distortions to both capital and labor inputs. A dispersion shock to the quality of products in our extended model in Section 4 aggravates adverse selection, and makes the economy more vulnerable to self-fulfilling expectation-driven fluctuations. While Kurlat (2013) and Bigio (2014) emphasize the role of adverse selection in propagating business cycles shocks, our paper complements their work by showing that adverse selection can generate indeterminacy and hence can be a source of business cycles.[2] Our extended model in section (3) with reputation effects is also related to that of Chari, Shourideh and Zeltin-Jones (2014), who build a model of a secondary loan market with adverse selection and show how reputation effects can generate persistent adverse selection. Multiple equilibria also arise in their model as in the classic signaling model by Spence (1973). In contrast, multiple equilibria in our model take the form of indeterminacy, and are generated by a different mechanism of endogenously countercyclical markups that translate into aggregate increasing returns.

To make a closer connection to the recent macroeconomic literature that focuses on adverse selection in credit markets, in Section 5 we also explore the existence of indeterminacy in an alternative model with adverse selection in credit markets. In our alternative model of Section 5, a continuum of final good firms must borrow to finance their working capital (intermediate goods input). The production involves uncertainty: with probability p a firm can produce $a(p)$ units of final goods from one unit of the intermediate good. We assume that $a(p)$ is decreasing in p but the expected return $a(p)p$ is increasing in p. Under complete information, only firms whose expected return is high enough would be financed. However with asymmetric information and limited liability, firms with lower p, *i.e.*, those with lower expected return $a(p)p$, get funded, generating a well known adverse selection problem as in the seminal works of Stiglitz and Weiss (1981) and many others. We prove that indeterminacy is indeed possible here. In the presence of adverse selection in the credit markets, we show that there exists a lending externality similar to the demand externality in our baseline model. When other creditors extend more credits, they create a downward pressure on interest rate. This encourages more high-quality lenders (firms with high p) to borrow, which in turn lowers the average default risk. The decline in default risk, if strong enough, can then stimulate more lending from each creditor, making self-fulfilling expectation-driven credit cycles possible. More specifically, we show that under

---

[2]Many other papers have also addressed adverse selection in a dynamic environment. Examples include Eisfeldt (2004), House (2006), Guerrieri, Shimer, and Wright (2010), Chiu and Koeppl (2012), Daley and Green (2012), Chang (2014), Camargo and Lester (2014), and Guerrieri and Shimer (2014).

certain probabilty distributions parametrized by p, this alternative model is isomorphic to the model in Section 4. The tight connection between these models indicates that adverse selection may be a rich source of self-fulfilling booms and busts in dynamic models of credit markets, and that it can be related to the literature on credit constraints and the financial accelerator pioneered by Bernanke and Gertler (1989) and Kiyotaki and Moore (1997).

The rest of the paper is organized as follows. Section 2 describes the baseline model and characterizes the conditions for indeterminacy. Section 3 incorporates warranties and reputation effects into the baseline model and shows indeterminacy may still arise. In Section 4 we introduce a continuous distribution of product quality and show that adverse selection can induce endogenous TFP, amplification, and aggregate increasing returns to scale. Section 5 present an alternative model with adverse selection in the credit market. Section 6 concludes. The appendix collects some of the proofs.

2   The Baseline Model

Time is continuous and proceeds from zero to infinity. There is an infinitely-lived representative household and a continuum of firms. Firms use capital and labor to produce a final good which is then sold to the household. We make two assumptions to introduce adverse selection into our model. First, the quality of a firm's product is unobservable to the household prior to purchase. Second, firms with lower-quality products enjoy a lower production cost. The household purchases goods from firms for consumption and investment, and supplies labor and capital to firms, taking the adverse selection problem into consideration. At this point we also explicitly assume that all trade is anonymous and exclude the possibility of warranty contracts between household and firms or of reputation effects. We relax these strong assumptions in Section 3.

2.1   Households

The representative household has a lifetime utility function

$$\int_0^\infty e^{-\rho t}\left[\log\left(C_t\right)-\psi\frac{N_t^{1+\gamma}}{1+\gamma}\right]dt \tag{1}$$

where $\rho > 0$ is the subjective discount factor, C_t is the consumption, N_t is the hours worked, $\psi > 0$ is the utility weight for labor, and $\gamma \geq 0$ is the inverse Frisch elasticity of labor supply.

The household faces three constraints. First, the resource constraint for the household is

$$C_t + I_t \leq Q_t X_t \equiv Y_t, \tag{2}$$

where I_t denotes investment in physical capital, Q_t the average quality of goods, and X_t the total units of goods purchased by the household. Here $Q_t X_t$ represents the quality adjusted final goods which can be consumed, invested, or lent to other households.

Denote by P_t the price of final goods. Then the household also faces the following budget constraint:

$$P_t X_t \leq \tilde{R}_t u_t K_t + \tilde{W}_t N_t + \tilde{\Pi}_t, \tag{3}$$

where K_t is capital, $\tilde{R}_t$ is the capital rental rate, $\tilde{W}_t$ is wage, and $\tilde{\Pi}_t$ is the total profits collected from all firms. These two constraints can be simplified as

$$(C_t + I_t) \frac{P_t}{Q_t} = \tilde{R}_t u_t K_t + \tilde{W}_t N_t + \tilde{\Pi}_t. \tag{4}$$

Note that $P_{Ct} = \frac{P_t}{Q_t}$ is then the price of consumption goods for the representative household. The budget constraint can then simply be rewritten as

$$C_t + I_t \leq R_t u_t K_t + W_t N_t + \Pi_t, \tag{5}$$

where $R_t = \tilde{R}_t/P_{Ct}$, $W_t = \tilde{W}_t/P_{Ct}$ and Π_t/P_{Ct} denote respectively the rental price, wage and total profit in consumption units. In an important contribution, Wen (1998) shows that introducing an endogenous capacity utilization rate u_t makes indeterminacy empirically more plausible in models with production externalities. We will show that capacity utilization serves a similar role in our model. As is standard in the literature, the depreciation rate of capital increases with the capacity utilization rate according to

$$\delta(u_t) = \delta^0 \frac{u_t^{1+\theta}}{1+\theta}, \tag{6}$$

where $\delta^0 > 0$ is a constant and $\theta > 0$.[3] Finally, the law of motion for capital is governed by

$$\dot{K}_t = -\delta(u_t) K_t + I_t. \tag{7}$$

The households choose a path of consumption X_t, C_t, N_t, u_t, and K_t to maximize the utility function (1), taking R_t, W_t and Π_t as given. The first-order conditions are

$$\frac{1}{C_t} W_t = \psi N_t^\gamma, \tag{8}$$

---

[3] Dong, Wang, and Wen (2014) develop a search-based theory to offer a micro-foundation for the convex depreciation function.

$$\frac{\dot{C}_t}{C_t} = u_t R_t - \delta(u_t) - \rho, \tag{9}$$

and

$$R_t = \delta^0 u_t^\theta. \tag{10}$$

The left-hand side of Equation (8) is the marginal utility of consumption obtained from an additional unit of work, and the right-hand side is the marginal disutility of a unit of work. Equation (9) is the usual Euler equation. Finally, a one-percent increase in the utilization rate raises the total rent by $R_t K_t$ but also increases total depreciation by $\delta_0 u_t^\theta K_t$, so Equation (10) states that the marginal benefit is equal to the marginal cost of utilization.

2.2 Firms

There is unit measure of firms indexed by i. Firms differ in the quality of their products. In the baseline model, we assume quality is exogenously given. More specifically, let $q_t(i)$ be the quality of firm $i's$ product, assumed to i.i.d across firms and over time, with a cumulative distribution function $F(q)$. The production function for the ith firm is

$$X_t(i) = \frac{A}{q_t^\chi(i)} K_t^\alpha(i) N_t^{1-\alpha}(i), \tag{11}$$

where A is the aggregate productivity, $0 < \chi < 1$ is a parameter measuring the sensitivity of the cost of product quality, and $K_t(i)$ and $N_t(i)$ are the capital and labor inputs for firm i. Since the production function exhibits constant returns to scale, the average cost and marginal cost are the same, and are both given by $\tilde{\phi}_t(i) = \frac{q_t^\chi(i)}{A_t} \left(\frac{\tilde{W}_t}{1-\alpha}\right)^{1-\alpha} \left(\frac{\tilde{R}_t}{\alpha}\right)^\alpha$. Firm $i's$ profit is $\tilde{\Pi}_t(i) = (P_t - \tilde{\phi}_t(i))X_t(i)$. Rewriting the firm's profit in consumption units yields

$$\Pi_t(i) = \left(\frac{P_t}{P_{Ct}} - \frac{\tilde{\phi}_t(i)}{P_{Ct}}\right) X_t(i) = (Q_t - \phi_t(i)) X_t(i) \tag{12}$$

where $\phi_t(i) = \frac{q_t^\chi(i)}{A_t} \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha} \left(\frac{R_t}{\alpha}\right)^\alpha$ is the marginal cost of firm i in consumption units. Note that lower quality goods are produced at lower cost. Since firm i produces goods of quality $q_t(i)$, the quality-adjusted average cost is given by $\phi_t(i)/q_t(i) = \frac{q_t^{\chi-1}(i)}{A_t} \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha} \left(\frac{R_t}{\alpha}\right)^\alpha$. Since $\chi < 1$, the marginal costs of producing quality-adjusted goods are decreasing with quality.

To simplify the analysis as much as possible, we assume for the moment that $q_t(i) = 0$ with probability $\pi \in (0,1)$ and $q_t(i) = 1$ with probability $1 - \pi$. Hence firms with $q_t(i) = 0$

produce pure lemons. To prevent the production of an infinite amount of lemons, we impose a restriction on the production capacity for lemons such that

$$X_t(i) \leq \Phi < \infty. \tag{13}$$

For firms with $q_t(i) = 1$ the marginal cost is $\phi_t(i) = \phi_t = \frac{1}{A}\left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}(\frac{R_t}{\alpha})^\alpha$. Constant returns to scale then imply $P_t = \phi_t$. The marginal cost is zero for firms with $q_t(i) = 0$ and thus their supply is Φ. We summarize the decision rule for production by firms as follows:

$$X_t(i) = \begin{cases} \Phi & \text{if } q_t(i) = 0 \\ \infty & \text{if } Q_t > \phi_t, \ q_t(i) = 1 \\ \in [0, \infty) & \text{if } Q_t = \phi_t, \ q_t(i) = 1 \\ 0 & \text{if } Q_t < \phi_t, \ q_t(i) = 1 \end{cases}. \tag{14}$$

Given production $X_t(i)$, we can use cost minimization to determine the factor demand for firms with $q_t(i) = 1$. The total cost $\phi_t X_t(i)$ is determined by

$$\phi_t X_t(i) \equiv \min_{K_t(i), N_t(i)} \{R_t K_t(i) + W_t N_t(i)\}$$
$$\text{s.t. } A K_t^\alpha(i) N_t^{1-\alpha}(i) \geq X_t(i) \tag{15}$$

with first-order conditions

$$R_t = \phi_t \alpha \frac{X_t(i)}{K_t(i)}, \tag{16}$$

$$W_t = \phi_t (1-\alpha) \frac{X_t(i)}{K_t(i)}. \tag{17}$$

Finally the average quality is determined by

$$Q_t = \frac{\int_{q_t(i)=1}^\infty X_t(i) di}{\pi \Phi + \int_{q_t(i)=1}^\infty X_t(i) di}. \tag{18}$$

Notice that the absolute value of P_{Ct} does not affect any first order conditions, so it is irrelevant. Therefore we can simply normalize $P_{Ct} = 1$, or equivalently, let $P_t = Q_t$, for all t.

2.3 Equilibrium

Equilibrium includes prices $\{R_t, W_t, P_t\}_{t=0}^\infty$ and allocations $\{C_t, N_t, K_t, Y_t, u_t, Q_t, X_t(i), K_t(i), N_t(i)\}_{t=0}^\infty$ such that for all t, given R_t, W_t, P_t and Q_t, the first order conditions (8) to (10) hold for the households, Equation (14), (16) and (17) hold for final goods producers, the average quality Q_t is given by Equation (18), and all markets clear, namely

$$C_t + \dot{K}_t = Y_t - \delta(u_t)K_t, \tag{19}$$

8

$$\int_{q_t(i)=1}^{\infty} K_t(i)di = u_t K_t, \tag{20}$$

and

$$\int_{q_t(i)=1}^{\infty} N_t(i)di = N_t. \tag{21}$$

To characterize the equilibrium, we first re-write the aggregate final goods production as

$$Y_t = \int_{q_t(i)=1}^{\infty} X_t(i)di, \tag{22}$$

which immediately implies

$$P_t = Q_t = \frac{\int_{q_t(i)=1}^{\infty} X_t(i)di}{\pi\Phi + \int_{q_t(i)=1}^{\infty} X_t(i)di} = \frac{Y_t}{\pi\Phi + Y_t} = \phi_t. \tag{23}$$

Using Equation (16) yields

$$\int_{q_t(i)=1}^{\infty} K_t(i)di = \frac{\alpha\phi_t}{R_t} \int_{q_t(i)=1}^{\infty} X_t(i)di = \frac{\alpha\phi_t}{R_t}Y_t,$$

which together with Equation (20) yields

$$R_t = \phi_t \cdot \left(\frac{\alpha Y_t}{u_t K_t}\right). \tag{24}$$

Likewise, using Equations (17) and (21), we obtain

$$W_t = \phi_t \cdot \left(\frac{(1-\alpha)\,Y_t}{N_t}\right). \tag{25}$$

Equation (8), (9) and (10) then become

$$\psi N_t^\gamma = \left(\frac{1}{C_t}\right)(1-\alpha)\phi_t\frac{Y_t}{N_t}, \tag{26}$$

$$\frac{\dot{C}_t}{C_t} = \alpha\phi_t\frac{Y_t}{K_t} - \delta(u_t) - \rho, \tag{27}$$

$$\alpha\phi_t\frac{Y_t}{u_t K_t} = \delta^0 u_t^\theta = (1+\theta)\,\delta\,(u_t) \tag{28}$$

Using the expression for marginal cost, $\phi_t = \frac{1}{A}\left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}(\frac{R_t}{\alpha})^\alpha$, the proceeding two equations jointly suggest

$$Y_t = A\,(u_t K_t)^\alpha\,N_t^{1-\alpha}. \tag{29}$$

Finally, the total profit is $\Pi_t = P_t\Phi\pi = \phi_t\Phi\pi$. Equation (23) then implies

$$R_t u_t K_t + W_t N_t + \Pi_t = \phi_t Y_t + \phi_t\Phi\rho = Y_t, \tag{30}$$

9

that is, the household budget constraint yields the following resource constraint:

$$C_t + \dot{K}_t = Y_t - \delta(u_t)K_t. \tag{31}$$

In short, the equilibrium can be characterized by equations (26), (27), (28), (29), (31) and (23). These six equations fully determine the dynamics of the six variables C_t, K_t, Y_t, u_t, N_t and ϕ_t.

Equation (23) implies that ϕ_t increases with aggregate output. Notice that $\frac{1}{\phi_t} = \frac{Y_t}{R_t u_t K_t + W_t N_t}$ is the aggregate markup in our model economy. Therefore the endogenous markup in our model is countercyclical, which is consistent with the empirical regularity well documented in the literature.[4]

The countercyclical markup has important implications. For example, it can make hours and the real wage move in the same direction. To see this, suppose N_t increases, so output increases. Then according to Equation (23), marginal cost ϕ_t increases as well, which in turn raises the real wage (25). If the markup is a constant, then the real wage would be proportional to the marginal product of labor and would fall when hours increase. Note also that when $\pi = 0$, *i.e.*, there is no adverse selection, Equation (23) implies that $\phi_t = 1$ and our model simply collapses into a standard real business cycle model. The markup is $1/\phi_t > 1$ if and only if lemon producers obtain an information rent arising from the information asymmetry on product quality.

2.4 Steady State

We first study the steady state of the model. We use Z to denote the steady state of variable Z_t. To solve the steady state, we first express all other variables in terms of ϕ and then we solve ϕ as a fixed point problem. Combining Equation (27) and (28) yields

$$\delta^0 u^{\theta+1} - \frac{\delta^0 u^{\theta+1}}{1+\theta} = \rho,$$

or $u = \left[\frac{1}{\delta^0} \frac{\rho}{\theta}(1+\theta) \right]^{1+\theta}$. Notice that u only depends on δ^0, ρ and θ. Therefore, without loss of generality, we can set $\delta^0 = \frac{\rho}{\theta}(1+\theta)$ so that $u = 1$ at the steady state. The depreciation rate

---

[4]See e.g., Bils (1987) and Rotemberg and Woodford (1999).

at steady state is then $\delta(u) = \rho/\theta$. Given ϕ, we have

$$k_y = \frac{K}{Y} = \frac{\alpha\phi}{\rho + \rho/\theta} = \frac{\alpha\phi\theta}{\rho(1+\theta)},$$

$$c_y = 1 - \delta k_y = 1 - \frac{\alpha\phi}{1+\theta},$$

$$N = \left[\frac{(1-\alpha)\phi}{1 - \frac{\alpha\phi}{1+\theta}} \frac{1}{\psi} \right]^{\frac{1}{1+\gamma}},$$

$$Y = A^{\frac{1}{1-\alpha}} \left[\frac{\alpha\phi\theta}{\rho(1+\theta)} \right]^{\frac{\alpha}{1-\alpha}} \left[\frac{(1-\alpha)\phi}{1 - \frac{\alpha\phi}{1+\theta}} \frac{1}{\psi} \right]^{\frac{1}{1+\gamma}} \equiv Y(\phi).$$

Then we can use Equation (23) to pin down ϕ from

$$\bar{\Phi} \equiv \pi\Phi = \left(\frac{1-\phi}{\phi} \right) \cdot Y(\phi) \equiv \Psi(\phi), \tag{32}$$

where the left-hand side is the total supply of lemon products and the right hand-side is the maximum amount of lemon that the market can accommodate, given that the average product quality is $q = \phi$. When $\alpha/(1-\alpha) + \frac{1}{1+\gamma} > 1$, $\Psi(\phi)$ is a non-monotonic function of ϕ since $\Psi(0) = 0$ and $\Psi(1) = 0$. On the one hand, if the average quality is 0, the household demand would be zero, and hence no lemon will be needed. On the other hand, if the average quality is one, i.e., $\phi = q = 1$, then by definition no lemon will be sold. So given $\bar{\Phi}$, there may exist two steady state values of ϕ.

Denote $\Psi^* \equiv \max_{0 \le \phi \le 1} \Psi(\phi)$, and $\phi^* \equiv \arg\max_{0 \le \phi \le 1} \Psi(\phi)$. Then we have the following lemma regarding the possibility of multiple steady state equilibria.

Lemma 1 *When $0 < \bar{\Phi} < \Psi^*$, there exist two steady state ϕ that solve $\bar{\Phi} = \Psi(\phi)$.*

Proof: *The proof is straightforward. First, from the explicit form of $Y(\phi)$, we can easily prove that $\Psi(\phi) \equiv \left(\frac{1-\phi}{\phi} \right) \cdot Y(\phi)$ strictly increases with ϕ when $\phi \in (0, \phi^*)$ but strictly decreases with ϕ when $\phi \in (\phi^*, 1)$. Second, since $\Psi(0) < \bar{\Phi} < \Psi^* = \Psi(\phi^*)$, there exists a unique solution between zero and ϕ^*, denoted by $\bar{\phi}_L$, that solves $\Psi(\phi) = \bar{\Phi}$. Likewise, there also exists a unique solution between ϕ^* and 1, denoted by $\bar{\phi}_H$ that solves $\Psi(\phi) = \bar{\Phi}$.* ∎

It is well known that adverse selection can generate multiple equilibria in a static model (see e.g. Wilson (1980)). So it is not surprising that our model has multiple steady state equilibria. The demand for goods depends on the households' expectation of the average quality of the final goods. By Equation (23), however, the average quality of goods depends on the total demand from households, so there is a demand externality. More specifically, if households

11

increase their demand for goods, then the price rises. In turn, more-high quality goods will be produced, and thus the average quality of goods will increase. If the average quality increases faster than the price, each household will then increase their demand as well. We will show that this type of demand externality generates a new type of multiplicity, which shares some similarity with the indeterminacy literature following Benhabib and Farmer (1994).

2.5 Local Dynamics

A number of studies have explored the role of endogenous markup in generating local indeterminacy and endogenous fluctuations (see e.g., Jaimovich (2006) and Benhabib and Wang (2013)). Following the standard practice, we study the local dynamics around the steady state.

Note that at the steady state ϕ and $\bar{\Phi}$ are linked by $\bar{\Phi} = \Psi(\phi)$, so we can parametrize the steady state either by $\bar{\Phi}$ or ϕ. We will use ϕ as it is more convenient for the study of local dynamics. We denote $\hat{x}_t = \log X_t - \log X$ as the percent deviation from its steady state. First, we log-linearize Equation (23) to obtain

$$\hat{\phi}_t = (1 - \phi)\hat{y}_t \equiv \tau \hat{y}_t, \tag{33}$$

which states that the percent deviation of the marginal cost is proportional to output. Log-linearizing Equations (29) and (28) yields

$$\hat{y}_t = \frac{\alpha\theta\hat{k}_t + (1 + \theta)(1 - \alpha)\hat{n}_t}{1 + \theta - (1 + \tau)\alpha} \equiv a\hat{k}_t + b\hat{n}_t, \tag{34}$$

where $a \equiv \frac{\alpha\theta}{1+\theta-(1+\tau)\alpha}$ and $b \equiv \frac{(1+\theta)(1-\alpha)}{1+\theta-(1+\tau)\alpha}$. We assume that $1+\theta-(1+\tau)\alpha > 0$, or equivalently $\tau < \frac{1+\theta}{\alpha} - 1$, to make $a > 0$ and $b > 0$. In general these restrictions are easily satisfied.

It is worth mentioning that $a + b = \frac{1+\theta-\alpha}{1+\theta-(1+\tau)\alpha} = 1$ if $\tau = 0$. Recall that $\tau = 0$ corresponds to the case without adverse selection. Thus endogenous capacity utilization alone does not generate increasing returns to scale at the aggregate level. However, $a + b = \frac{1+\theta-\alpha}{1+\theta-(1+\tau)\alpha} > 1$ if $\tau > 0$; that is, adverse selection combined with endogenous capacity utilization generates increasing returns to scale. Furthermore, if $\tau > \theta$, then $b > 1$. The model would then be able to explain the procyclical movements in labor productivity $\hat{y}_t - \hat{n}_t$ without resorting to exogenous TFP shocks.

We can substitute out $\hat{n}_t$ after log-linearizing equation (26) to express $\hat{y}_t$ as

$$\hat{y}_t = \frac{a(1 + \gamma)}{1 + \gamma - b(1 + \tau)}\hat{k}_t - \frac{b}{1 + \gamma - b(1 + \tau)}\hat{c}_t \equiv \lambda_1\hat{k}_t + \lambda_2\hat{c}_t. \tag{35}$$

12

According to Equation (34), a one-percent increase in capital directly increases output and the marginal product of labor by a percent and, from Equation (33), reduces the markup by $a\tau$ percent. Thanks to its higher marginal productivity, the labor supply also increases. A one-percent increase in labor supply then increases output by b percent. The precise increase in labor supply depends on the Frisch elasticity γ. This explains why the equilibrium output elasticity with respect to capital, λ_1, depends on parameters a, b and through them on γ and τ. On the household side, since both leisure and consumption are normal goods, an increase in consumption has a wealth effect on labor supply. The effect of a change in labor supply on output induced by a change in consumption, as seen from Equation (35) obtained after substituting for labor in (34), works through the same channels in marginal cost, and depends also on τ. Again since both a and b increase with τ, output elasticities with respect to capital and consumption are increasing functions of τ. In other words, the presence of adverse selection makes equilibrium output more sensitive to changes in capital and to changes in autonomous consumption, and creates an amplification mechanism for business fluctuations.

Using Equation (35) and the log-linearized Equations (27) and (31), we can then characterize the local dynamics as follows:

$$
\begin{bmatrix} \dot{\hat{k}}_t \\ \dot{\hat{c}}_t \end{bmatrix} = \delta \begin{bmatrix} \left(\frac{1+\theta}{\alpha\phi}\right)\lambda_1 - (1+\tau)\lambda_1 & \left(\frac{1+\theta}{\alpha\phi}\right)(\lambda_2 - 1) + 1 - (1+\tau)\lambda_2 \\ \theta\left[(1+\tau)\lambda_1 - 1\right] & \theta(1+\tau)\lambda_2 \end{bmatrix} \begin{bmatrix} \hat{k}_t \\ \hat{c}_t \end{bmatrix} \tag{36}
$$

$$
\equiv J \begin{bmatrix} \hat{k}_t \\ \hat{c}_t \end{bmatrix},
$$

where $\delta = \rho/\theta$ is the steady state depreciation rate. The local dynamics around the steady state is determined by the roots of J. The model exhibits local indeterminacy if both roots of J are negative. Note that the sum of the roots equals the trace of J, and the product of the roots equals the determinant of J. Thus the sign of the roots of J can be observed from the signal of its trace and determinant of J. The following lemma specifies the sign for the trace and determinant condition for local indeterminacy.

Lemma 2 *Denote* $\tau_{\min} \equiv \frac{(1+\theta)(1+\gamma)}{(1+\theta)(1-\alpha)+\alpha(1+\gamma)} - 1$ *and* $\tau_{\max} \equiv 1 - \phi^*$, *then* $Trace(J) < 0$ *if and only if* $\tau > \tau_{\min}$, *and* $\det(J) > 0$ *if and only if* $\tau_{\min} < \tau < \tau_{\max}$.

According to Lemma 2, our baseline model will be indeterminate if and only if $\tau_{\min} < \tau < \tau_{\max}$. In this case, trace$(J) < 0$ and $\det(J) > 0$ jointly imply that both roots of J are negative. We summarize this result in the following proposition.

Proposition 1 *The model exhibits local indeterminacy around a particular steady state if and only if*

$$\tau_{\min} < \tau < \tau_{\max}. \tag{37}$$

Equivalently, indeterminacy emerges if and only if $\phi \in (\phi_{\min}, \phi_{\max})$, where $\phi_{\min} \equiv 1 - \tau_{\max} = \phi^*$, and $\phi_{\max} \equiv 1 - \tau_{\min}$.

To understand this intuition, first notice that if $\tau > \tau_{\min}$, we have

$$1 + \gamma - b(1 + \tau) < 1 + \gamma - \frac{(1 + \theta)(1 - \alpha)}{1 + \theta - (1 + \tau_{\min})\alpha}(1 + \tau_{\min}) = 0.$$

Then the equilibrium elasticity of output with respect to consumption λ_2 becomes positive, namely, an autonomous change in consumption will lead to an increase in output. Since capital is predetermined, labor must increase by Equation (34). To induce an increase in labor, the real wage must increase enough to overcome the income effect, which is only possible if the markup is large enough. In other words, τ has to be large enough according to Equation (33).

We can also understand Proposition 1 from the equilibrium conditions of the goods market. On the one hand, since $P_t = Q_t = \phi_t$, Equation (33) can be rewritten as

$$\hat{p}_t = \tau \hat{y}_t. \tag{D-D}$$

We treat the above equation as the demand curve in the goods market. When prices increase, the average quality also increases. If the increase in quality dominate the increase in price, the effective prices declines, which then translates into a higher demand. This explains why the demand curve has a positive slope. On the other hand, combining Equations (26), (29), and (28) yields

$$\widehat{p}_t = \tau_{\min} \cdot \hat{y}_t + \left[\frac{(1 - \alpha)(1 + \theta)}{\alpha(1 + \gamma) + (1 - \alpha)(1 + \theta)}\right] \cdot \hat{c}_t - \left[\frac{\alpha\theta(1 + \gamma)}{\alpha(1 + \gamma) + (1 - \alpha)(1 + \theta)}\right] \cdot \hat{k}_t \tag{S-S}$$

where $\tau_{\min} \equiv \frac{(1 + \theta)(1 + \gamma)}{(1 + \theta)(1 - \alpha) + \alpha(1 + \gamma)} - 1$. We interpret the above equation as the supply curve in the goods market. When price increases, output increases. The position of the supply curve depends on $\hat{c}_t$ and $\hat{k}_t$. Everything else being equal, an increase in $\hat{c}_t$ will reduce the willingness to work. Hence it shifts the supply curve to the left. In contrast, an increase in capital will increase production at any given price, leading to a rightward shift of the supply curve.

If $\tau > \tau_{\min}$, the demand curve is steeper than the supply curve, which makes indeterminacy possible. Figure 1 gives a graphic explanation of this. The lines labeled with D and S represent
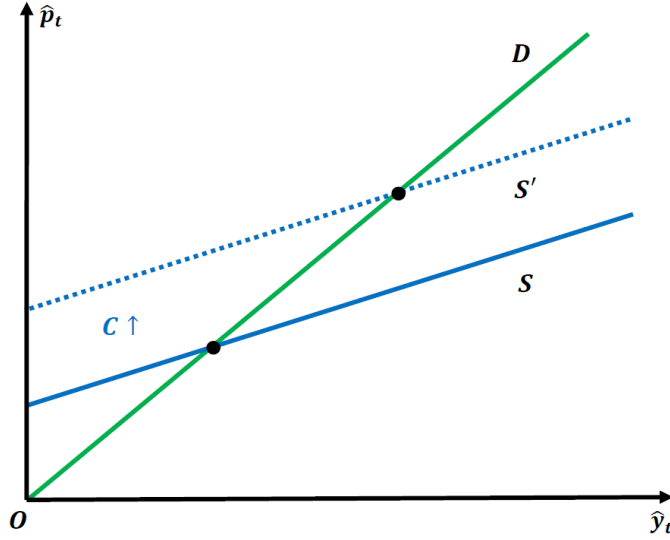
14

Figure 1: Demand and Supply

the demand and supply curves respectively. An optimistic belief of higher income induces households to increase their consumption. Since leisure is a normal good, the increased income would shifts the supply curve to the left. If the demand curve is negatively sloped, a leftward shift of the supply curve decreases the equilibrium output. The realized output and income would then be lower, and contradict the initial optimistic belief. However, if the demand curve is positively sloped and steeper than the supply curve, an upward shift of the supply curve leads to an increase in the equilibrium output. Therefore the initial optimistic belief is consistent with rational expectations.

The economic interpretation of $\tau > \tau_{\min}$ therefore is analogous to that of Benhabib and Farmer (1994), Wen (1998), Jaimovich (2006), and Benhabib and Wang (2013) who show that indeterminacy is possible if the labor demand curve is steeper than the labor supply curve.[5] However the source of indeterminacy is quite different. In Benhabib and Farmer(1994), and Wen (1998), the existence of an upward sloping labor demand curve is due to a production externality that generates increasing returns to scale. Jaimovich (2006) constructs a model in which markups decline due to firm entry. Benhabib and Wang (2013) generate countercyclical markups via borrowing constraints. In our model, the source of indeterminacy comes from adverse selection. In a booming market, a higher demand for goods increases the price and

---

[5]The labor demand curve in our model is $\hat{w}_t = (a\hat{k}_t + b\hat{n}_t)(1+\tau) - \hat{n}_t$. The labor supply curve is $\hat{w}_t = \hat{c}_t + \gamma\hat{n}_t$. The slope of the labor demand curve exceeds that of the labor supply curve if and only if $\tau > \tau_{\min}$.
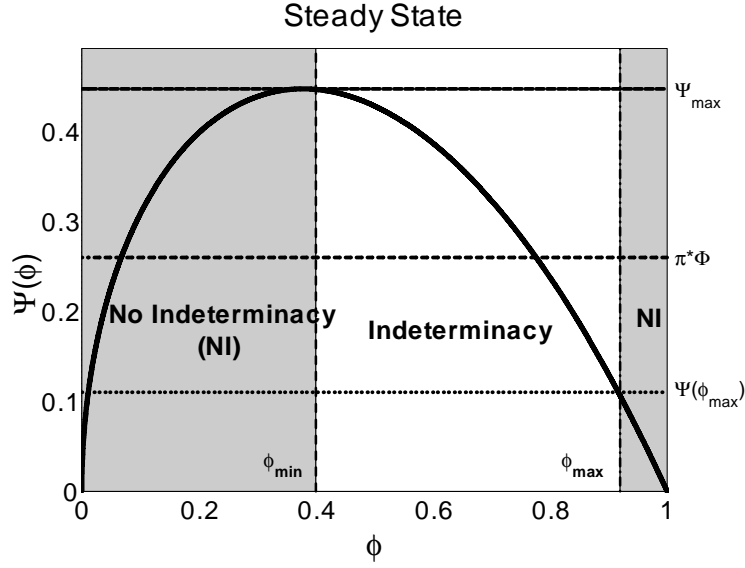
15

Figure 2: Multiple Steady States and the Indeterminacy Region

hence stimulates the production of higher quality goods. As a result, the information rent of lemon producers declines, giving rise to a fall in the markup.

We have used the mapping between τ and steady state output to characterize the indeterminacy condition in terms of the model's deep parameter values. Notice $\tau_{\max} = 1 - \phi^*$, where $\phi^* \equiv \arg\max_{0 \leq \phi \leq 1} \Psi(\phi)$. Since $1 - \bar{\phi}_L > 1 - \phi^* = \tau_{\max}$, the local dynamics around the steady state associated with $\phi = \bar{\phi}_L$ are determinate according to Proposition 1. Indeterminacy is only possible in the neighborhood of the steady state associated with $\phi = \bar{\phi}_H$. The following corollary formally characterizes the indeterminacy condition in terms of $\bar{\Phi}$.

Corollary 1 *If $\Psi(\phi_{\max}) < \bar{\Phi} < \Psi_{\max}$, the local dynamics around the steady state $\phi = \bar{\phi}_H$ exhibits indeterminacy, while the local dynamics around the steady state $\phi = \bar{\phi}_L$ is a saddle. If $0 < \bar{\Phi} < \Psi(\phi_{\max})$, both steady states are saddles.*

When $\Psi(\phi_{\max}) < \bar{\Phi} < \Psi_{\max}$, we have $\phi_{\min} = \phi^* < \bar{\phi}_H < \phi_{\max}$, and $\bar{\phi}_L < \phi_{\min}$. As a result, according to Proposition 1, the steady state $\bar{\phi}_H$ exhibits indeterminacy. And for the steady state $\phi = \bar{\phi}_L$, by Lemma 2, we can conclude that the determinant of J is negative. So the two roots of J must have opposite signs and this implies a saddle. But, if $0 < \bar{\Phi} < \Psi(\phi_{\max})$, we have $\bar{\phi}_H > \phi_{\max}$ and $\bar{\phi}_L < \phi_{\min}$. In this case, the determinants of J at both steady states are negative. So both steady states are a saddle.

The different scenarios are summarized in Figure 2. The inverted U curve illustrates the

16

relationship between ϕ and $\bar{\Phi}$ specified in Equation (32). In Figure 2, ϕ is on the horizontal axis and $\bar{\Phi}$ is on the vertical axis. For a given $\bar{\Phi}$, the two steady states $\bar{\phi}_L$ and $\bar{\phi}_H$ can be located from the intersection between the inverted U curve and a horizontal line through point $(0, \bar{\Phi})$. The two vertical lines passing points $(\phi_{\min}, 0)$ and $(\phi_{\max}, 0)$ divide the diagram into three regions. In the left and right regions, the determinant of the Jacob matrix J is negative, implying one of the roots is positive and the other is negative. So if a steady state ϕ falls into either of these two regions, it is a saddle. In the middle region, $\det(J) > 0$ and $\mathrm{Trace}(J) < 0$, and thus both roots are negative. So if the steady state ϕ falls into the middle region it is a sink which supports self-fulfilling expectation-driven multiple equilibria, or indeterminacy.

Since $\bar{\Phi} = \pi\Phi$, we can revisit the above corollary in term of π, the proportion of lemon producers. Without loss of generality, assume Φ is big enough such that $\Phi > \Psi_{\max}$. Denote $\pi_L = \Psi(\phi_{\max})/\Phi$ and $\pi_H = \Psi(\phi_{\min})/\Phi$, and thus $0 < \pi_L < \pi_H < 1$. Then we know that (i) if $\pi \in (0, \pi_L]$, then there are two equilibria, both of which are stable; (ii) if $\pi \in (\pi_L, \pi_H)$, the steady state with $\phi = \bar{\phi}_L$ is saddle stable while the steady state with $\phi = \bar{\phi}_H$ is a sink, and (iii) if $\pi \in [\pi_H, 1]$, then there exist no non-degenerate equilibria, and the model economy collapses. The third case is the least interesting, and thus we focus on the scenarios in which $\pi < \pi_H$. Then the model is indeterminate if the adverse selection problem is severe enough, *i.e.*, $\pi > \pi_L$. We summarize the above argument in the following corollary.

Corollary 2 *The likelihood of indeterminacy increases with π, the proportion of firms producing lemons.*

Arguably, adverse selection is more severe in developing countries, which may help explain the findings in a large volume of the marketing literature that suggests a relationship between country-of-orgin effects and level of economic development. That is, products from developing countries are stereotypically perceived as being inferior to those from industrialized countries (see Schooler (1971) for example). Our study then suggests that developing countries are more likely to be subject to self-fulfilling expectation-driven fluctuations and hence exhibit higher economic volatility, which is in line with the empirical regularity emphasized by Ramey and Ramey (1995) and Easterly, Islam, and Stiglitz (2000).

2.6 Empirical Possibility of Indeterminacy

We have proved that our model with adverse selection can generate self-fulfilling equilibria in theory. We now examine the empirical plausibility of self-fulfilling equilibria under calibrated

parameter values. The frequency is quarterly. We set $\rho = 0.01$, implying an annual risk-free interest rate of 4%. We set $\theta = 0.3$ so the depreciation rate at steady state is 0.033 and the annualized investment-to-capital ratio is 12% (see Cooper and Haltiwanger (2006)). We set $\alpha = 0.33$ as in standard RBC models. We assume labor supply is elastic, and thus set $\gamma = 0$. We normalize the aggregate productivity $A = 1$. We set $\psi = 1.75$ so that $N = \frac{1}{3}$ in the "good" steady state. We set $\overline{\Phi} = \pi\Phi = 0.13$ so that $\phi = \bar{\phi}_H = 0.9$, which is consistent with average profit rate in the data. The associated $\bar{\phi}_L = 0.011$. If we further set $\pi = 0.1$, *i.e.*, the lemon proportion is around 10%, then $\Phi = 1.3$. Consequently, based on our calibration and the indeterminacy condition (37), we conclude that our baseline model does generate self-fulfilling equilibria.

Parameter	value	Description
ρ	0.01	Discount factor
θ	0.3	Utilization elasticity of depreciation
δ	0.033	Depreciation rate
α	0.33	Capital income share
γ	0	Inverse Frisch elasticity of labor supply
ψ	1.75	Coefficient of labor disutility
π	0.1	Proportion of firms that produce lemons
Φ	1.3	Maximum firm capacity

Table 1: Calibration

3 Warranties and Reputation

We now study the sensitivity of the propagation mechanism to adverse selection as well as of the indeterminacy results by considering warranty contracts and reputation effects. We first examine the implications of warranties, which are prevalent in goods markets, especially for consumption durables. If firms are not anonymous in the market, they may refrain from selling low-quality products, but instead build a brand name, or reputation. Buyers may also refrain from buying from firms that knowingly market inferior quality products. Arguably, these market forces can alleviate the asymmetric information problem. So it is natural for us to examine whether the indeterminacy results obtained in the baseline would survive if such market forces are taken into account.

3.1 Warranty

Intuitively, if warranties can perfectly ensure product quality, then there is no adverse selection and thus no indeterminacy in our model economy. However, real-life warranties are typically imperfect. They often provide partial insurance with limited duration against unsatisfactory performance. Priest (1981) observes that the extent of warranty protection appears to bear no relation to the quality of the product. In other words a warranty itself is not a good signal of product quality. Sellers who provide more warranty protection are not necessarily more reliable than those who provide less. Cooper and Ross (1985) show that these observations can be explained by double moral hazard. That is, the performance of the product can be affected by the unobserved actions of both the buyer and the seller. If a perfect warranty is provided, a moral hazard problem will arise if the actions of the buyer may damage the product and are not detectable by the seller. Instead of giving a full micro-structure that generates the limited warranty in our model, we take a shortcut by simply assuming a reduced-form of limited warranties. More specifically, if a proportion m of the purchased goods turn out to be lemons, the households could be reimbursed a fraction $m\mu < m$ of lemons by incurring some cost. That is, the households endogenize μ by balancing its benefit and cost.

Suppose the household initially purchase X_t at price P_t, and among them $m_t < X_t$ are lemons. We assume that the household can pay a legal cost $\frac{\mu_t^{1+\chi}}{\xi(1+\chi)} m_t P_t$ to the government for reimbursing a fraction $\mu_t < 1$ of lemons. We assume that the legal cost is proportional to the initial payment $m_t P_t$. The optimal μ_t is then obtained by solving

$$\max_{\mu \in [0,1]} \left\{ m_t \mu_t P_t - \frac{\mu_t^{1+\chi}}{\xi^\chi (1+\chi)} m_t P_t \right\}, \tag{38}$$

First-order conditions yield

$$\mu_t = \xi.$$

We have assumed that ξ is small enough such that $\mu_t = \xi < 1$ so we have $m_t \mu_t P_t - \frac{\mu_t^{1+\chi}}{\xi^\chi(1+\chi)} m_t P_t = \frac{\chi \xi}{1+\chi} m_t P_t$. Since $m_t = \pi \Phi$ in equilibrium, the households pay $\left(1 - \frac{\chi \xi}{1+\chi}\right) \pi \Phi P_t$ for lemons after taking the reimbursement and legal fee into account. The price for consumption is again by $P_{Ct} = P_t/Q_t$, where the average quality Q_t is obtained from $Q_t = \frac{Y_t}{\left(1 - \frac{\chi \xi}{1+\chi}\right)\pi\Phi + Y_t}$. Again, since the absolute price P_{Ct} does not matter, without loss of generality we can normalize $P_{Ct} = 1$. So Equation (23) becomes

$$P_t = \frac{Y_t}{\left(1 - \frac{\chi \xi}{1+\chi}\right) \pi \Phi + Y_t} = \phi_t. \tag{39}$$

19

We assume that the government rebates all the legal fees to the households in equilibrium. Thus the resource constraint (31) does not change. The equilibrium system of equations is then the same as in the baseline model, except that Equation (23) is replaced by Equation (39).

3.2 Reputation

Unlike in our baseline model, in this section a firm can choose to produce lemons at low cost so that the quality of its product becomes endogenous. We maintain the assumption that product quality is a firm's private information, and it cannot be observed before the household make a purchase. It thus generates an incentive for firms to sell low-quality goods at high-quality prices. A large literature has developed theories of reputation that can alleviate such a moral hazard problem (see e.g., Klein and Leffler (1981), Shapiro (1982) and Allen (1984)). We follow Klein and Leffler (1981) closely in modeling reputation. Firms are infinitely-lived, and can choose to produce high quality products or lemons. Firms that produce lemons acquire, with some probability, a bad reputation and are excluded from production forever. In equilibrium, the fear of loosing all future profits from production discourages firms from producing lemons. We will show that self-fulfilling equilibria still exist even if no lemons are produced in equilibrium.

To keep the model analytically tractable, we assume that all firms are owned by a representative entrepreneur. The entrepreneur's utility function is given by

$$U(C_{et}) = \int_0^\infty e^{-\rho_e t} \log(C_{et}) dt, \tag{40}$$

where C_{et} is the entrepreneur's consumption and ρ_e her discount factor. For tractability, we follow Liu and Wang (2014) by assuming that $\rho_e << \rho$ such that the entrepreneur does not accumulate capital. The entrepreneur's consumption equals the firm's profits.

$$C_{et} = \int_0^1 \Pi_t(i) di \equiv \Pi_t, \tag{41}$$

where $\Pi_t(i)$ denotes the profit of firm i.

Since profit from selling lemons tends to be higher, the price must exceed the marginal cost (also the average cost) for high-quality products to be profitable. Unlike Klein and Leffler (1981), firms' production in our model exhibits constant returns to scale. If the price exceeds the marginal cost, each firm will then have an incentive to produce an infinite amount. To overcome this problem, we assume firms produce according to orders received from households. At each moment, firms receive orders randomly from the households. Suppose that now households

place an order of size Φ to a proportion η_t of firms at moment t at unit price P_t. The households then face the following constraint:[6]

$$C_t + I_t \leq (1 - P_t)\eta_t\Phi + R_t u_t K_t + W_t N_t. \tag{42}$$

To illustrate the reputation problem, let us consider a short time interval from t to $t + dt$. We use V_{1t} (V_{0t}) to denote the value of a firm that receives an order (no orders). We can then formulate V_{1t} recursively as

$$V_{1t} = (P_t - \phi_t)\Phi dt + e^{-\rho_e dt}\left(\frac{C_{e,t}}{C_{e,t+dt}}\right)[\eta_{t+dt}V_{1t+dt} + (1 - \eta_{t+dt})V_{0t+dt}]. \tag{43}$$

where ϕ_t is the unit production cost. If $P_t > \phi_t$, then the firm receives a positive profit from producing high-quality products. The second term on the right-hand side is the continuation value of the firms. Since firms are owned by the entrepreneur, the future value is discounted by the marginal utility of the entrepreneur.

The firm can also choose to produce Φ units of lemons upon receiving the order and sell them at price P_t. By doing so, the firm receives revenue $P_t\Phi dt$, which is also the profit as lemon production does not require any input. However, producing lemons comes with the risk of acquiring a bad reputation. When lemons are produced, we assume the probability of acquiring a bad reputation during the short time interval is λdt. In that case, the firm will be excluded from production forever. The payoff for producing lemons is then given by

$$V_t^d = P_t\Phi dt + e^{-\rho_e dt}(1 - \lambda dt)E_t\left(\frac{C_{e,t}}{C_{e,t+dt}}\right)[\eta_{t+dt}V_{1t+dt} + (1 - \eta_{t+dt})V_{0t+dt}]. \tag{44}$$

The value of a firm that does not receive any order is given by

$$V_{0t} = e^{-\rho_e dt}E_t\left(\frac{C_{e,t}}{C_{e,t+dt}}\right)[\eta_{t+dt}V_{1t+dt} + (1 - \eta_{t+dt})V_{0t+dt}]. \tag{45}$$

Define $V_t = \eta_t V_{1t} + (1 - \eta_t)V_{0t}$ as the expected value of the firm. The firm has no incentive to produce lemons if and only if $V_{1t} \geq V_t^d$, or

$$P_t\Phi dt \leq (P_t - \phi_t)\Phi dt + \lambda dt e^{-\rho_e dt}\left(\frac{C_{e,t}}{C_{e,t+dt}}\right)V_{t+dt}. \tag{46}$$

---

[6]First the households face $C_t + I_t \leq \eta_t\Phi$, and $\eta_t\Phi P_t \leq R_t u_t K_t + W_t N_t$. We can write these two as a single constraint $C_t + I_t \leq (1 - P_t)\eta_t\Phi + R_t u_t K_t + W_t N_t$. Alternatively, we can assume that the households do not purchase the goods from the firms directly. But instead, they purchase them from competitive retailers. The retailers place an order of size Φ to η_t firms at price P_t. They then sell the goods to the households at price 1. So $(1 - P_t)\eta_t\Phi$ is the total profit of the retailers.

In the limit $dt \to 0$, the incentive compatibility condition becomes $\phi_t \Phi \leq \lambda V_t$.[7] Then the expected value of the firm is given by the present discounted value of all future profits as

$$V_t = \int_0^\infty e^{-\rho_e s} \frac{C_{et}}{C_{es}} \Pi_s ds. \tag{47}$$

In equilibrium, the households purchase Y_t units of goods. Hence $\eta_t = \frac{Y_t}{\Phi}$. For simplicity, we assume Φ is big enough such that $\eta_t < 1$ always holds. The average profit is then obtained as $\Pi_t = (P_t - \phi_t)Y_t$. In turn, we have

$$V_t = \frac{(P_t - \phi_t)Y_t}{\rho_e}. \tag{48}$$

Then the incentive constraint (46) becomes

$$\phi_t \Phi \leq \lambda \frac{(P_t - \phi_t)Y_t}{\rho_e}. \tag{49}$$

From the household budget constraint (42), we know that household utility decreases with P_t and thus the incentive constraint (49) must be binding. The household's first-order condition with respect to η_t for an interior solution also requires $P_t = 1$. Then Equation (49) can be simplified as

$$\phi_t = \frac{Y_t}{\pi \Phi + Y_t} < 1, \tag{50}$$

where now $\pi \equiv \frac{\rho_e}{\lambda}$. Similar to the baseline model, here firms also receive an information rent. However, the rent in the baseline is derived from hidden information while the rent here arises from hidden action. As indicated in Equation (50), ϕ_t is procyclical and hence the markup is countercyclical. When output is high, the total profit from production is high. Therefore the value of a good reputation is high and the opportunity cost of producing a lemon also increases. This then alleviates the moral hazard problem since high output dilutes informational rent.

The cost minimization problem again yields the factor prices given by Equation (24) and (25). Since households do not own firms, their budget constraint is modified as

$$C_t + \dot{K}_t = \phi_t Y_t - \delta\left(u_t\right) K_t. \tag{51}$$

The equilibrium system of equations is the same as in the baseline model except that Equation (31) is replaced by Equation (51). The steady state can be computed similarly. The steady state output is given by

$$Y = A^{\frac{1}{1-\alpha}} \left[\frac{\alpha \phi \theta}{\rho\left(1 + \theta\right)} \right]^{\frac{\alpha}{1-\alpha}} \left[\left(\frac{1 - \alpha}{1 - \frac{\alpha}{1+\theta}} \right) \cdot \frac{1}{\psi} \right]^{\frac{1}{1+\gamma}} \equiv Y(\phi), \tag{52}$$

---

[7]Under the incentive compatibility condition we can consider one step deviations since V_{1t}, V_{0t} are then optimal value functions.

and ϕ can be solved from

$$\bar{\Phi} \equiv \pi\Phi \equiv \Psi(\phi) = \left(\frac{1-\phi}{\phi}\right) \cdot Y(\phi). \tag{53}$$

Unlike the baseline model, the steady state equilibrium is unique. We summarize the result in the following lemma.

Lemma 3 *If $\alpha < \frac{1}{2}$, a consistently standard calibrated value of α, then the steady state equilibrium is unique for any $\bar{\Phi} > 0$.*

We can now study the possibility of self-fulfilling equilibria around the steady state. Since ϕ and $\bar{\Phi}$ form a one-to-one mapping, we will treat ϕ as a free parameter in characterizing the indeterminacy condition. We can then use Equation (53) to back out the corresponding value of $\bar{\Phi}$. The following proposition specifies the condition under which self-fulfilling equilibria arises.

Proposition 2 *Let $\tau = 1 - \phi$. Then indeterminacy emerges if and only if*

$$\tau_{\min} < \tau < \min\left\{\frac{1+\theta}{\alpha} - 1, \tau_H\right\} \equiv \tau_{\max},$$

where $\tau_{\min} \equiv \frac{(1+\theta)(1+\gamma)}{(1+\theta)(1-\alpha)+\alpha(1+\gamma)} - 1$, and τ_H is the positive solution to $A_1\tau^2 - A_2\tau - A_3 = 0$, where

$$
\begin{aligned}
A_1 &\equiv s(1+\theta)(2+\alpha+\alpha\gamma) \\
A_2 &\equiv (1+\theta)(1+\alpha\gamma) - s[(1+\theta)(1-\alpha)(1-\gamma) + (1+\gamma)\alpha] \\
A_3 &\equiv (1+\theta)(1-\alpha)[s+(1-s)\gamma].
\end{aligned}
$$

The necessary condition for indeterminacy turns out to be the same as in our baseline model. It is easy to verify that under $\tau > \tau_{\min}$, the labor demand curve slopes upward and is steeper than the labor supply curve. So the intuition for indeterminacy is similar to that in the baseline. Indeterminacy implies that the model exhibits multiple expectation-driven equilibria around the steady state. The steady state equilibrium is now unique however, which suggests that the continuum of equilibria implied by indeterminacy cannot be obtained in a static model as in the previous literature. So far, the condition to sustain indeterminacy is given in terms of ϕ and τ. The following lemma specifies the underlying condition in terms of ρ_e, λ and Φ.

Lemma 4 *Indeterminacy emerges if and only if $\frac{\Psi(1-\tau_{\min})}{\Phi} < \frac{\rho_e}{\lambda} < \frac{\Psi(1-\tau_{\max})}{\Phi}$.*

23

Given the other parameters, a decrease in ρ_e or an increase in λ increases the steady state ϕ. According to the above lemma, it makes indeterminacy less likely. The intuition is straightforward. A large λ means the opportunity cost of producing lemon increases, as the firm becomes more likely to be excluded from future production. This alleviates the moral hazard problem, which is the source of indeterminacy. Similarly, a decrease of ρ_e means that the entrepreneurs become more patient. So the future profit flow from production is more valuable to them, which again increases the opportunity cost of producing lemons and thus alleviates the moral hazard problem.

4 Endogenous TFP and Indeterminacy

To keep the baseline model as simple as possible, so far we have assumed that product quality can take only two values. To study whether the indeterminacy results are robust, we now extend the baseline model with a continuous distribution of quality. We will show that the extended model generates a new source of indeterminacy. More specifically, we will show that adverse selection generates endogenous and procyclical TFP with a strong amplification mechanism. The model becomes indeterminate if this mechanism is sufficiently strong.

The household problem is unchanged, and thus the first order conditions are still Equations (8), (9) and (10). The production function of each firm is still given by Equation (11). However, we now assume that $q_t(i)$ is a random variable drawn from an $i.i.d.$ cumulative distribution function F. As in the baseline model, we assume a capacity limitation such that

$$X_t(i) \leq \Phi < \infty, \tag{54}$$

We solve the firm's profit maximization problem. The unit cost of firm i with $q_t(i)$ is given by $\phi_t(i) = \frac{q_t^\chi(i)}{A_t}\left(\frac{R_t}{\alpha}\right)^\alpha \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}$. Cost minimization yields

$$R_t = \phi_t(i)\frac{A_t}{q_t^\chi(i)}\alpha K_t^{\alpha-1}(i)N_t^{1-\alpha}(i). \tag{55}$$

$$W_t = \phi_t(i)\frac{A_t}{q_t^\chi(i)}(1-\alpha)K_t^\alpha(i)N_t^{-\alpha}(i). \tag{56}$$

The profit maximization problem for firm i is then given by

$$\max_{0\leq X_t(i)\leq \Phi} P_t X_t(i) - \phi_t(i)X_t(i). \tag{57}$$

The decision rule for production is immediately obtained as

$$X_t(i) = \begin{cases} 0 & \text{if } q_t(i) > \left[\dfrac{P_t}{A \left(\frac{R_t}{\alpha}\right)^\alpha \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}} \right]^{\frac{1}{\chi}} \equiv q_t^* \\ \Phi & \text{otherwise} \end{cases} \tag{58}$$

Adverse selection is evident from the decision rule: for a given price P_t only firms with quality below a certain threshold will produce. Firms with high-quality products are driven out of the market. Given the production decision, we can use Equations (55) and (56) to obtain the demand for capital and labor respectively as follows:

$$N_t(i) = \frac{q_t^\chi(i) X_t(i)}{A \left(\frac{\alpha W_t}{(1-\alpha)R_t}\right)^\alpha}, \tag{59}$$

$$K_t(i) = \frac{q_t^\chi(i) X_t(i)}{A \left(\frac{(1-\alpha)R_t}{\alpha W_t}\right)^{1-\alpha}}. \tag{60}$$

Finally, the average quality is given by

$$Q_t = \frac{\displaystyle\int_0^1 q_t(i) X_t(i) di}{\displaystyle\int_0^1 X_t(i) di}. \tag{61}$$

To characterize the equilibrium in this extended model, we need to aggregate the decisions of all firms.

4.1 Aggregation

The market clearing condition is $\int_0^1 N_t(i) di = N_t$ for the labor market and $\int_0^1 K_t(i) di = u_t K_t \equiv K_t^*$ for the capital market. Equations (59) and (60) implies that $N_t(i) \propto q_t^\chi(i)$ and $K_t(i) \propto q_t^\chi(i)$ for $q_t(i) \leq q_t^*$. This in turn implies that

$$N_t(i) = \frac{q_t^\chi(i)}{\displaystyle\int_0^{q_t^*} q^\chi dF(q)} N_t, \tag{62}$$

$$K_t(i) = \frac{q_t^\chi(i)}{\displaystyle\int_0^{q_t^*} q^\chi dF(q)} K_t^*. \tag{63}$$

for $q_t(i) \leq q_t^*$ and $N_t(i) = K_t(i) = 0$ for $q_t(i) > q_t^*$. It then follows that $N_t(i)/K_t(i) = N_t/K_t^*$ for $q_t(i) \leq q_t^*$. We now use this relationship to aggregate production. Recall that aggregate

output is $Y_t = \int_0^1 q_t(i)X_t(i)di$ and $q_t(i)X_t(i) = Aq_t^{1-\chi}(i)K_t^\alpha(i)N_t^{1-\alpha} = Aq_t^{1-\chi}(i)\left(\frac{K_t^*}{N_t}\right)^\alpha N_t(i)$. Using Equation (62) we obtain

$$q_t(i)X_t(i) = \frac{q_t(i)}{\displaystyle\int_0^{q_t^*} q^\chi dF(q)} AK_t^{*\alpha}N_t^{1-\alpha} \text{ if } q_t(i) \le q_t^*, \tag{64}$$

and $q_t(i)X_t(i) = 0$ otherwise. Then we have

$$Y_t = \Gamma\left(q_t^*, \chi\right)AK_t^{*\alpha}N_t^{1-\alpha} = \Gamma\left(q_t^*, \chi\right)A(u_tK_t)^\alpha N_t^{1-\alpha}, \tag{65}$$

where $\Gamma\left(q^*, \chi\right) \equiv \frac{E(q|q\le q^*)}{E(q^\chi|q\le q^*)}$ depends on the threshold q_t^* and the distribution. Based on Equation (65), measured TFP is obtained as

$$TFP_t = \frac{Y_t}{(u_tK_t)^\alpha N_t^{1-\alpha}} = \Gamma\left(q_t^*, \chi\right)A, \tag{66}$$

where the cutoff level of quality q_t^* varies endogenously. Firms producing high-quality output are more efficient if $\chi < 1$. However, these firms are inactive in equilibrium due to adverse selection. In this sense, adverse selection creates a misallocation of resources, the magnitude of which is captured by the cutoff level of quality q_t^*. It is easy to prove that $\frac{\partial\Gamma(q^*,\chi)}{\partial q^*} > 0$.[8] The intuition is as follows. When q_t^* increases, more high-quality products are produced. Some of the resources must shift from firms with low productivity to more efficient firms with high productivity. This resource reallocation therefore improves aggregate efficiency, leading to a higher total production for any fixed amount inputs. In other words, measured TFP increases.

To determine q_t^*, recall that $X_t(i) = \Phi$ if $q_t(i) \le q_t^*$ and aggregate output can be written as

$$Y_t = \int_0^1 q_t(i)X_t(i)di = \Phi \cdot \int_{q_{\min}}^{q_t^*} q dF(q). \tag{67}$$

This implies that q_t^* increases with aggregate production.

---

[8] Here is a formal proof:

$$\frac{\partial\Gamma\left(q^*,\chi\right)}{\partial q^*} = \frac{\partial}{\partial q^*}\left(\frac{\int_{q_{\min}}^{q_{\max}} q 1_{\{q\le q^*\}} dF(q)}{\int_{q_{\min}}^{q_{\max}} q^\chi 1_{\{q\le q^*\}} dF(q)}\right)$$

$$= \frac{\left[\int_{q_{\min}}^{q_{\max}} q^\chi 1_{\{q\le q^*\}} dF(q)\right]\left(\frac{d\int_{q_{\min}}^{q_{\max}} q 1_{\{q\le q^*\}} dF(q)}{dq^*}\right) - \left[\int_{q_{\min}}^{q_{\max}} q 1_{\{q\le q^*\}} dF(q)\right]\left(\frac{d\int_{q_{\min}}^{q_{\max}} q^\chi 1_{\{q\le q^*\}} dF(q)}{dq^*}\right)}{\left[\int_{q_{\min}}^{q_{\max}} q^\chi 1_{\{q\le q^*\}} dF(q)\right]^2}$$

$$= \frac{(q^*)^\chi f(q^*)\int_{q_{\min}}^{q_{\max}}\left[(q^*)^{1-\chi} - q^{1-\chi}\right]q^\chi 1_{\{q\le q^*\}} dF(q)}{\left[\int_{q_{\min}}^{q_{\max}} q^\chi 1_{\{q\le q^*\}} dF(q)\right]^2} > 0.$$

Lemma 5 *TFP is endogenous and increasing in Y, namely $\frac{\partial \Gamma(q^*, \chi)}{\partial Y} > 0$.*

We have therefore established that the endogenous TFP, $\Gamma(q^*, \chi)$, is procyclical. Notice that the procyclicality of endogenous TFP holds generally for continuous distributions. So without loss of generality, we now assume $F(q) = (q/q_{\max})^\eta$ for tractability. Notice that firm-level measured productivity, $\frac{1}{q}$, then follows a Pareto distribution with the shape parameter of η, which is consistent with the findings of a large literature (see, e.g., Melitz (2003) and references therein).

4.2 Aggregate Increasing Returns and Indeterminacy

Thanks to the power distribution, we have $\Gamma(q_t^*, \chi) = \frac{\chi + \eta}{1 + \eta} q_t^{*1-\chi}$ and $q_t^* = \left(\frac{1+\eta}{\eta} \frac{Y_t}{\Phi}\right)^{\frac{1}{\eta+1}} q_{\max}^{\frac{\eta}{\eta+1}}$. Then the aggregate production (65) can be simplified as

$$Y_t = \left(\Delta A^{1+\sigma}\right) \cdot \left[(u_t K_t)^\alpha N_t^{1-\alpha}\right]^{1+\sigma}, \tag{68}$$

where $\sigma = \frac{1-\chi}{\chi+\eta} > 0$ and $\Delta \equiv \left[\left(\frac{\eta}{1+\eta}\right)\left(\frac{\chi+\eta}{\eta}\right)^{\frac{1+\eta}{\chi+\eta}} (q_{\max})^{\frac{\eta(1-\chi)}{\chi+\eta}} \Phi^{-\frac{1-\chi}{\chi+\eta}}\right]$ is a constant. Equation (68) reveals that the aggregate technology in our model exhibits increasing returns. Note that $\sigma = 0$ if either $\eta = \infty$ or $\chi = 1$. When $\eta = \infty$, the firms' product quality is homogeneous. Hence there is no asymmetric information and adverse selection. Firms are equally productive if $\chi = 1$. It therefore does not matter how the resources are allocated among firms. We formally state this result in the following proposition.

Proposition 3 *The reduced-form aggregate production in our model exhibits increasing returns to scale if and only if there exists adverse selection, i.e., $\chi < 1$ and $\eta < \infty$.*

Proof: The proof is obvious since $\sigma = \frac{1-\chi}{\chi+\eta} > 0$ if and only if $\chi < 1$ and $\eta < \infty$. ∎

To understand how increasing returns to scale in aggregate production can arise, consider a proportional increase in both utilized capital and labor. The increased resources create pressure to dampen the wage and interest rates. So some of the initially inactive firms with high marginal costs, the ones producing high-quality products, will now find it profitable to produce. This diverts some resources from the incumbent firms. Since these newly active firms are more productive, their total production from diverted resources can more than compensate for the loss of the incumbent firms. As a consequence, total output will rise proportionately more than total inputs.

In an important contribution, Basu and Fernald (1997) document that increasing returns to scale exist in aggregate production but not at the micro level. In a recent paper, Liu and Wang (2014) show how financial frictions can generate endogenous variation in TFP, and hence aggregate increasing returns. Our focus here is adverse selection. Arguably, the inefficiency generated by both of these frictions are important in developing countries. Therefore we view our contribution as an addition to the understanding of low TFP in these countries. We will show in the following that adverse selection and variable capacity utilization together raise the magnitude of the impact of TFP on output.

We now proceed to solve for the prices P_t, R_t and W_t. Once P_t, R_t and W_t are determined, we can then fully characterize the equilibrium. First, notice that the average Q_t (61) is determined by

$$Q_t = \frac{1}{F(q_t^*)} \int_0^{q_t^*} q \, dF(q) = E\left(q_t | q_t \leq q_t^*\right) = P_t. \tag{69}$$

Recall that $\phi_t(i) X_t(i) = W_t N_t(i) + R_t K_t(i)$. Denote by $\phi_t^* = \frac{q_t^{*\chi}}{A_t} \left(\frac{R_t}{\alpha}\right)^\alpha \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}$ the unit cost for firms exactly at the cutoff. Then $\phi_t(i)$ n can be written as $\phi_t(i) = \phi_t^* \left(\frac{q_t}{q_t^*}\right)^\chi = P_t \left(\frac{q_t}{q_t^*}\right)^\chi$. By definition of the cutoff, $\phi_t^* = P_t = Q_t$. We hence know that

$$W_t N_t + R_t K_t^* = \int \phi_t(i) X_t(i) \, di = \Phi \phi_t^* \int_0^{q_t^*} \left(\frac{q}{q_t^*}\right)^\chi dF(q). \tag{70}$$

The fact $\phi_t^* = Q_t$ and Equation (67) together then yields

$$W_t N_t + R_t K_t^* = Y_t \frac{1}{F(q_t^*)} \int_0^{q_t^*} \left(\frac{q}{q_t^*}\right)^\chi dF(q) < Y_t, \tag{71}$$

which means that the total profit is non-zero. Again, this is due to the informational rents arising from the existence of firms with low productivity.

It is easy to verify that $\frac{W_t N_t}{R_t K_t^*} = \frac{1-\alpha}{\alpha}$ from Equations (59) and (60). The aggregate marginal cost is given by

$$\phi_t = \frac{W_t N_t + R_t K_t^*}{Y_t} = \frac{1}{F(q_t^*)} \int_0^{q_t^*} \left(\frac{q}{q_t^*}\right)^\chi dF(q), \tag{72}$$

which can be either increasing, decreasing, or unchanging in q_t^*. In the case with power distribution, ϕ_t is a constant such that $\phi_t = \frac{\eta}{\chi + \eta} = \phi$. Thus W_t and R_t are given by $W_t = \phi \frac{(1-\alpha)Y_t}{N_t}$ and $R_t = \phi \frac{\alpha Y_t}{u_t K_t}$ respectively. Together with Equations (8), (9), (10), (68), and (31), we can determine the seven variables, C_t, Y_t, N_t, u_t, K_t, W_t and R_t.

The steady state can be obtained as in the baseline model. As in the baseline model, we can express the other variables in terms of the steady state ϕ. Since $\phi = \frac{\eta}{\chi + \eta}$, unlike in the

baseline, the steady state here is unique. We assume that Φ is large enough so that an interior solution to q^* is always guaranteed. We state this result formally in the following corollary.

Corollary 3 *The steady state is unique in the extended model with $F(q) = (q/q_{\max})^\eta$.*

A large literature following Benhabib and Farmer (1994) have shown that increasing returns can give rise to self-fulfilling expectations (see e.g., Wen (1998), Liu and Wang (2014)). The following proposition summarizes the conditions for indeterminacy in this extended model.

Proposition 4 *The model is indeterminate if and only if*

$$\sigma_{\min} < \sigma < \sigma_{\max} \tag{73}$$

where $\sigma \equiv \frac{1-\chi}{\chi+\eta}$, $\sigma_{\min} \equiv \left(\frac{1}{\frac{1-\alpha}{1+\gamma} + \frac{\alpha}{1+\theta}} \right) - 1$ and $\sigma_{\max} \equiv \frac{1}{\alpha} - 1$.

To better understand the proposition, we first consider how output responds to a fundamental shock, such as a change in A, the true TFP. Holding factor inputs constant, we have

$$1 + \tilde{\sigma} \equiv \frac{d \log Y_t}{d \log A} = (1 + \sigma) \left[\frac{1 + \theta}{1 + \theta - \alpha (1 + \sigma)} \right] > 1, \tag{74}$$

The above equations shows that adverse selection and variable capacity utilization can significantly amplify the impact of a TFP shock on output. Let us define $1 + \tilde{\sigma}$ as the multiplier of adverse selection. Note that the necessary condition $\sigma > \sigma_{\min}$ can be written as

$$(1 + \tilde{\sigma})(1 - \alpha) - 1 > \gamma. \tag{75}$$

Here the left-hand side turns out to be the slope of the labor demand curve while the right-hand side is the slope of the labor supply curve. The economic interpretation is then similar to that in our baseline model. In other words, the model will be indeterminate if the multiplier effect of adverse selection is sufficient large. The restriction $\sigma < \sigma_{\max}$ is typically automatically satisfied. The restriction $\sigma < \frac{1}{\alpha} - 1$ simply requires that $\alpha(1 + \sigma) < 1$, which is the condition to rule out explosive growth in the model.

It is worth pointing out that a decrease in η will increase σ. No matter the model is indeterminate or not, Equation (74) then implies that the response of output to TFP shocks will be amplified. In addition, by Proposition 4, the economy will more likely be indeterminate. A smaller η means that there is more dispersion in quality, making it more difficult to distinguish between high and low quality products. In other words, adverse selection problems become

29

more severe. Our results are in similar spirit to Kurlat (2013) and Bigio (2014), who both that show a dispersion in the quality will strengthen the amplification effect of adverse selection.

Empirical Possibility of Indeterminacy To empirically evaluate the possibility of indeterminacy, we set the same value to ρ, θ, δ, α and γ as in Table 1.[9] We have new parameters in this extended model (χ, η). We use two moments to pin them down. We set χ and η to match the steady state markup $\tau = 1 - \phi = \frac{\chi}{\chi + \eta} = 0.9$. Basu and Fernald (1997) estimate aggregate increasing returns to scale for manufacturing to be around 1.1. So we set $\sigma = 0.1$. This leads to $\chi = \frac{1 - \phi}{1 - \phi + \sigma} = \frac{1}{2}$ and $\eta = \frac{\phi}{1 - \phi + \sigma} = 4.5$. We have $\sigma_{\min} = 0.083$ and $\sigma_{\max} \equiv 2$, which meet the indeterminacy conditions. Hence, with these parameters the model exhibits self-fulfilling equilibria. Again, since the steady state equilibrium is unique, such multiple equilibria must come from the dynamic nature of the model.

4.3 Endogenous Production Limit

We now further extend the continuous-distribution model to allow the firm to choose capacity Φ. We assume that if a firm pays $\xi \frac{\Phi_t^{1+\zeta}}{1+\zeta} dt$ unit of capital at time t before the realization of its shock $q_t(i)$, it can produce a maximum flow quantity Φ_t from t to $t + dt$. The shock $q_t(i)$ is assumed to follow a power distribution, namely $F(q) = \left(\frac{q}{q_{\max}}\right)^\eta$. Φ_t is then determined by solving

$$\max_{\Phi_t} \left\{ -\xi \frac{\Phi_t^{1+\zeta}}{1+\zeta} + \Phi_t P_t \int_{q_{\min}}^{q_t^*} \left[1 - \left(\frac{q}{q_t^*}\right)^\chi \right] dF(q) \right\}$$

$$= \max \left\{ -\xi \frac{\Phi_t^{1+\zeta}}{1+\zeta} + \Phi_t P_t \left(\frac{q_t^*}{q_{\max}}\right)^\eta \frac{\chi}{\chi + \eta} \right\}$$

where the second equality follows the distribution $F(q) = \left(\frac{q}{q_{\max}}\right)^\eta$. The first-order condition yields $\xi \Phi_t^\zeta = P_t \left(\frac{q_t^*}{q_{\max}}\right)^\eta \frac{\chi}{\chi+\eta}$. Note that $\Phi_t P_t \left(\frac{q_t^*}{q_{\max}}\right)^\eta = P_t X_t = Q_t X_t = Y_t$. Hence the above first order condition can be written as

$$\xi \frac{\Phi_t^{1+\zeta}}{1+\zeta} = \frac{\chi}{\chi + \eta} \frac{Y_t}{1+\zeta} \tag{76}$$

Since Φ_t is time varying, the aggregate production (68) now becomes

$$Y_t = \Upsilon \Phi_t^{-\frac{1-\chi}{\chi+\eta}} \cdot (u_t K_t)^{\alpha(1+\sigma)} N_t^{(1-\alpha)(1+\sigma)}, \tag{77}$$

where Υ is a constant. The resource constraints is accordingly adjusted to

$$C_t + \dot{K}_t = Y_t - \delta(u_t) K_t - \zeta \frac{\Phi_t^{1+\tau}}{1+\tau} \tag{78}$$

---

[9] $q_{\max}$ and Φ do not affect the indeterminacy condition, so we do not need to specify their value.

Equations (76), (77), and (78) together with Equations (8), (9), (10) jointly determine C_t, Y_t, N_t, u_t, K_t and Φ_t. The following proposition shows that the indeterminacy results are robust to this extension.

Proposition 5 *Indeterminacy arises if and only if* $\varsigma(\sigma) \equiv \frac{\zeta\sigma}{1+\zeta+\sigma} > \frac{1}{\frac{1-\alpha}{1+\gamma}+\frac{\alpha}{1+\theta}} - 1$ *and* $1+\varsigma(\sigma) < \frac{1}{\alpha}$.

The proof is similar to that of Proposition 4, and thus we omit it. When Φ_t is endogenous, by substituting out Φ_t from production by Equation (76), overall increasing returns to scale become $\varsigma(\sigma) = \frac{1+\sigma}{1+\sigma/(1+\zeta)} - 1 = \frac{\zeta\sigma}{1+\zeta+\sigma}$. As we have shown, $\sigma_{\min} = \frac{1}{\frac{1-\alpha}{1+\gamma}+\frac{\alpha}{1+\theta}} - 1$ is the minimum increasing returns required for indeterminacy. Note that $\frac{\zeta\sigma}{1+\zeta+\sigma} < \sigma$. In other words, endogenous capacity reduces the degree of increasing returns to scale. To see this, consider a proportional increase in total inputs. When firms anticipate a rise in aggregate output, they will opt to build up capacity. If capacity increases quickly enough, the newly increased inputs can largely be absorbed by the incumbent. So there is little resource reallocation toward more efficient firms. As a consequence, the resulting increase in output becomes smaller. In other words, the magnitude of aggregate increasing returns to scale is dampened and as a consequence, indeterminacy is less likely.

5   Adverse Selection in Credit Markets and Indeterminacy

To further explore the possibility of indeterminacy or expectations driven business cycles due to information asymmetries in credit markets, we now modify our model in Section 4 as follows. The households' problems are the same as in Section 4. The production side now has two types of firms: the final goods firms and intermediate goods firms. The intermediate goods firms use labor and capital to produce an intermediate goods, which is then sold to the final goods firms as production input. Final goods firms do not have resources to make upfront payments to the intermediate goods firms until production takes place and revenues from sales are realized. They therefore must borrow from the competitive financial intermediates to finance their working capital.[10] We index the final good firms with $j \in [0, 1]$. The loan is risky as the final goods firms' production may not be successful. More specifically, we assume that final good firm j's

---

[10]Altenatively we can assume that the intermediate goods firms provide working capital loans as credit to the final goods firms and finance their production. The results will be the same.

output is governed by

$$y_{jt} = \begin{cases} a_{jt}x_{jt}, & \text{with probability } q_{jt} \\ 0, & \text{with probability } 1 - q_{jt} \end{cases}, \tag{79}$$

where x_{jt} is the intermediate input for firm j and a_{jt} the firm's productivity. We assume q_{jt} conforms to a power distribution, namely $F(q) = q^\eta$ and $a_{jt} = a_{\min}q_{jt}^{-\tau}$. Notice that expected productivity is given by $q_{jt}a_{jt} = a_{\min}q_{jt}^{1-\tau}$. We assume that $\tau < 1$, *i.e.*, a firm with a higher success probability enjoys a higher expected productivity. As in the model of Section 4, we assume that each final good firm can manage Φ units of intermediate goods at most.[11] Denote P_t as the price of intermediate goods. Then the total borrowing is given by $P_t x_{jt}$. Denote R_{ft} be the market interest rate. Then the final good firm $j's$ profit maximization problem becomes

$$\max_{0 \leq x_{jt} \leq \Phi} q_{jt}[a_{jt}x_{jt} - R_{ft}P_t x_{jt}], \tag{80}$$

Note that, due to limited liability, the final goods firm pays back the working capital loan only if the project is successful. This implies that, given R_{ft} and P_t, the demand for x_{jt} is simply given by

$$x_{jt} = \begin{cases} \Phi & \text{if } a_{jt} > R_{ft}P_t \equiv a_t^* \\ 0 & \text{otherwise} \end{cases}, \tag{81}$$

or equivalently,

$$a_{\min}q_{jt}^{-\tau} > a_t^*, \ q_{jt} < \left[\frac{a_t^*}{a_{\min}}\right]^{-\frac{1}{\tau}} = q_t^* = \left[\frac{R_{ft}P_t}{a_{\min}}\right]^{-\frac{1}{\tau}}. \tag{82}$$

This establishes that only firms with risky production opportunities will enter the credit markets. Since financial intermediaries are assumed to be fully competitive, we have

$$R_{ft}P_t\Phi \int_0^{q_t^*} q dF(q) = P_t\Phi \int_0^{q_t^*} dF(q), \tag{83}$$

where the left-hand side is the actual repayment from the final goods firms, and the right-hand side the actual lending. We obtain

$$R_{ft} = \frac{1}{\int_0^{q_t^*} q dF(q) / \int_0^{q_t^*} dF(q)} = \frac{1}{E(q|q \leq q_t^*)} > 1, \tag{84}$$

where the denominator is average success rate. The total production of intermediate goods is $X_t = \Phi \int_0^{q_t^*} dF(q)$ and total production of final goods is $Y_t = \Phi a_{\min} \int_0^{q_t^*} q^{1-\tau}dF(q)$. Finally the intermediate goods are produced according to $X_t = A_t(u_t K_t)^\alpha N_t^{1-\alpha}$, where $u_t K_t$ is the

---

[11]In our model the final good firms exhibit constant returns to scale, so the firms' problem will not be well defined without a maximum input limit. Alternatively we can put a borrowing constraint such that $P_t x_{jt} \leq \Phi$, where P_t is the price for intermediate goods.

capital rented from the households. Using the power distribution, we substitute out q_t^* in the expression for Y_t to obtain

$$Y_t = a_{\min} \frac{\eta}{\eta - \tau + 1} \Phi^{-\frac{1-\tau}{\eta}} \left[A_t u_t^\alpha K_t^\alpha N_t^{1-\alpha} \right]^{1 + \frac{1-\tau}{\eta}} . \tag{85}$$

Notice that the aggregate output again exhibits increasing returns to scale. The intuition is analogous to that in the model in Section 4. Here a lending externality kicks in because of adverse selection in the credit markets. Suppose that the total lending from financial intermediaries increases. This creates a downward pressure on interest rate R_{ft}, which increases the cutoff q_t^* according to the definition at Equation (82). Firms with higher q have smaller risk of default. A rise in the cutoff q_t^* therefore reduces the average default rate. If it is strong enough, it can in turn stimulate more lending from the financial intermediaries. Since firms with higher q are also more productive on average, the increased efficiency in re-allocating credit implies that resources are better allocated across firms. We already showed in Section 4 that this generates aggregate increasing returns to scale. Both the credit spread, measured by $R_{ft} - 1$, and the expected default risk, $1 - E(q|q \leq q_t^*)$, are countercyclical in our model. These predictions are consistent with the empirical regularities by Gilchrist and Zakrajšek (2012) and many others.

Finally perfect competition implies that real wage is $W_t = P_t \frac{(1-\alpha)X_t}{N_t}$ and rental rate is $R_t = P_t \frac{\alpha Y_t}{u_t K_t}$. Under the power distribution, it is easy to see that $P_t X_t = \frac{\eta - \tau + 1}{\eta + 1} Y_t$. Therefore we have established the observational equivalence of this model to the model in Section 4. If we define $\sigma = \frac{1-\tau}{\eta}$, we can directly evoke Proposition 4 for the indeterminacy conditions.

6 Conclusion

We have argued that in a dynamic general equilibrium model, adverse selection in the goods market can generate a new type of multiplicity of equilibria in the form of indeterminacy, either through endogenous markups or endogenous TFP. Adverse selection can therefore potentially explain some of the apparently excessive output volatility in the absence of fundamental shocks. For example, an RBC model with a negative TFP shock cannot fully explain the increase in labor productivity during the Great Recession (see Ohanian (2010)). However this feature of the Great Recession is consistent with the prediction of our baseline model in Section 2, and is driven by pessimistic beliefs about aggregate output. The pessimistic beliefs reduce aggregate demand and increase the markups, leading to a lower real wage and a lower labor supply. Labor productivity however rises due to decreasing returns to labor.

Appendix

A Proofs

Proof of Lemma 2: Since $\varphi_1 + \varphi_2 = \text{Trace}(J)$ and $\varphi_1 \varphi_2 = \det(J)$. The model is indeterminate if the trace of J is negative and the determinate is positive. The trace and the determinant of J are

$$\frac{\text{Trace}(J)}{\delta} = \left(\frac{1+\theta}{\alpha\phi}\right)\lambda_1 - (1+\tau)\lambda_1 + \theta(1+\tau)\lambda_2, \tag{A.1}$$

$$\frac{\text{Det}(J)}{\delta^2\theta} = [(1+\tau)\lambda_1 - 1 + \lambda_2]\left(\frac{1+\theta}{\alpha\phi} - 1\right) - \tau\lambda_2, \tag{A.2}$$

respectively. Substituting out λ_1 and λ_2 we obtain

$$\frac{\text{Trace}(J)}{\delta} = \left[\frac{1}{\gamma + 1 - (1+\tau)b}\right] \cdot \left[\left(\frac{1+\theta}{\alpha\phi} - 1 - \tau\right)a(1+\gamma) - \theta(1+\tau)b\right] \tag{A.3}$$

$$= \left[\left(\frac{\theta}{\phi}\right)\left(\frac{\alpha(1+\gamma) + (1+\theta)(1-\alpha)}{1+\theta - (1+\tau)\alpha}\right)\right] \cdot \left[\frac{\frac{(1+\gamma)(1+\theta)}{\alpha(1+\gamma)+(1+\theta)(1-\alpha)} - \phi(1+\tau)}{\gamma + 1 - (1+\tau)b}\right]$$

$$= \left[\left(\frac{\theta}{\phi}\right)\left(\frac{\alpha(1+\gamma) + (1+\theta)(1-\alpha)}{1+\theta - (1+\tau)\alpha}\right)\right] \cdot \left[\frac{\frac{(1+\gamma)(1+\theta)}{\alpha(1+\gamma)+(1+\theta)(1-\alpha)} - 1 + \tau^2}{\gamma + 1 - (1+\tau)b}\right]$$

Notice that $\gamma + 1 - (1+\tau)b < 0$ is equivalent to

$$\tau > \tau_{\min} \equiv \frac{(1+\gamma)(1+\theta)}{\alpha(1+\gamma) + (1+\theta)(1-\alpha)} - 1.$$

Since $\tau_{\min} > 0$, we know that

$$\frac{(1+\gamma)(1+\theta)}{\alpha(1+\gamma) + (1+\theta)(1-\alpha)} - 1 + \tau^2 > 0.$$

Therefore $\text{Trace}(J) < 0$ if and only if $\tau > \tau_{\min}$. It remains for us to pin down the condition under which $\det(J) > 0$. Note that $\det(J)$ can be rewritten as

$$\frac{\det(J)}{\delta^2\theta} = \left[\frac{1}{\gamma + 1 - (1+\tau)b}\right] \cdot \left[\left(\frac{1+\theta}{\alpha\phi} - 1\right)((1+\gamma)[a(1+\tau) - 1] + \tau b) + \tau b\right] \tag{A.4}$$

$$= \frac{1+\theta}{(1+\tau)b - (\gamma+1)}\left\{(1+\gamma)(1-\alpha) - \left[\frac{(1-\alpha)(1+\theta)}{(1+\theta - \alpha\phi)} + (1+\gamma)\alpha\right]\tau\right\}$$

If $\tau < \tau_{\min}$, then we immediately have $\det(J) < 0$. Thus to guarantee that $\det(J) > 0$, we must have $\tau > \tau_{\min}$, which then implies that $(1+\tau)b - (\gamma+1) > 0$. As a result, given that $\tau > \tau_{\min}$, $\det(J) > 0$ if and only if

$$(1+\gamma)(1-\alpha) - \left[\frac{(1-\alpha)(1+\theta)}{1+\theta - \alpha\phi} + (1+\gamma)\alpha\right]\tau > 0,$$

which can be further simplified as

$$\tau < \frac{(1+\gamma)(1-\alpha)}{\frac{(1-\alpha)(1+\theta)}{1+\theta-\alpha\phi} + (1+\gamma)\alpha}.$$

Since $\phi = 1 - \tau$, the above inequality can be reformulated as

$$\Delta(\tau) \equiv \alpha^2\tau^2 + \left[\alpha\theta + \frac{(1-\alpha)(1+\theta)}{(1+\gamma)}\right]\tau - (1-\alpha)(1+\theta-\alpha) < 0.$$

Denote $\xi \equiv \alpha\theta + \frac{(1-\alpha)(1+\theta)}{(1+\gamma)}$. Then $\det(J) > 0$ if and only if $\tau > \tau_{\min}$ and

$$\tau < \tau_{\max} \equiv \frac{-\xi + \sqrt{\xi^2 + 4\alpha^2(1-\alpha)(1+\theta-\alpha)}}{2\alpha^2}.$$

It remains for us to prove $\tau_H = 1 - \phi^*$, where $\phi^* = \arg\max_{0\leq\phi\leq 1} \Psi(\phi)$. FOC of $\log\Psi(\phi)$ suggests

$$\left(\frac{1}{1+\gamma} + \frac{2\alpha-1}{1-\alpha}\right)\left(\frac{1}{\phi}\right) + \left(\frac{1}{1+\gamma}\right)\left(\frac{\alpha}{1+\theta}\right)\left(\frac{1}{1-\frac{\alpha\phi}{1+\theta}}\right) - \frac{1}{1-\phi} = 0,$$

which is equivalent to

$$\Gamma(\phi) \equiv \alpha^2\phi^2 - \left[\frac{(1-\alpha)(1+\theta)}{1+\gamma} + \alpha\theta + 2\alpha^2\right]\phi + \left[\frac{(1-\alpha)(1+\theta)}{1+\gamma} + (2\alpha-1)(1+\theta)\right] = 0.$$

Besides, we can easily verify that, for $\phi \in (0,1)$, it always holds that

$$\frac{d^2}{d\phi^2}(\log\Psi(\phi)) < 0.$$

Since $\tau \equiv 1 - \phi$, we know that $\Delta(1-\phi) = \Gamma(\phi)$. Denote ϕ_1 and ϕ_2 as the solutions to $\Gamma(\phi) = 0$. Note that $\phi_1 + \phi_2 > 0$, $\phi_1 \cdot \phi_2 > 0$, and $\Gamma(0) > 0$, $\Gamma(1) > 0$. Therefore we know that $0 < \phi_1 < 1 < \phi_2$. Consequently we conclude that

$$\phi^* = \phi_1 = 1 - \tau_{\max} \in (0,1).$$

Proof of Proposition 1: First, notice that, by definition, $\tau_{\max} = 1 - \phi_{\min}$. Therefore we have $\phi_{\min} = \phi^*$. Then by Lemma 2 immediately we reach the conclusion.

Proof of Corollary 1: First, when adverse selection is severe enough, *i.e.*, $\bar{\Phi} = \pi\Phi \geq \Psi_{\max}$, the economy collapses. The only equilibrium is the trivial case with $\phi = 0$. Given that $\bar{\Phi} < \Psi_{\max}$, Lemma 1 implies that there are two solutions, which are denoted as $(\bar{\phi}_H, \bar{\phi}_L)$. It always holds that $\bar{\phi}_L < \phi^* < \bar{\phi}_H$. Then Lemma 2 immediately suggests that the steady state $\bar{\phi}_L$ is always a saddle. Since $\Psi(\phi)$ decreases with ϕ when $\phi > \phi^*$, as shown by Proposition 1, indeterminacy emerges if and only if $\phi \in (\phi^*, \phi_{\max})$. Therefore the local dynamics around the steady state $\phi = \bar{\phi}_H$ exhibits indeterminacy if and only if $\Psi(\phi_{\max}) < \bar{\Phi} < \Psi_{\max}$.

Proof of Corollary 2: Holding Φ constant, $\bar{\Phi}$ increases with π, the proportion of firms producing lemon products. As is proved in Corollary 1, given $\bar{\Phi} < \Psi_{\max}$, indeterminacy emerges if and only if $\bar{\Phi} > \Psi(\phi_{\max})$. Therefore the likelihood of indeterminacy increases with π.

Proof of Lemma 3: Notice that $\Psi(\phi) = \left(\frac{1-\phi}{\phi}\right) \cdot Y(\phi) \propto (1-\phi)\phi^{\frac{2\alpha-1}{1-\alpha}}$. When $\alpha < \frac{1}{2}$, we know that $(1-\phi)\phi^{\frac{2\alpha-1}{1-\alpha}}$ is decreasing in ϕ. It is easy to check that $\lim_{\phi \to 0} \Psi(\phi) = \infty$ and $\lim_{\phi \to 1} \Psi(\phi) = 0$. Hence equation (53) uniquely pins down the steady state ϕ for any $\bar{\Phi} > 0$.

Proof of Proposition 2: The dynamic system of equations is follows:

$$
\begin{aligned}
\psi N_t^\gamma &= \frac{1}{C_t}(1-\alpha)\phi_t \frac{Y_t}{N_t}, \\
\frac{\dot{C}_t}{C_t} &= \alpha\phi_t \frac{Y_t}{K_t} - \delta(u_t) - \rho, \\
\alpha\phi_t \frac{Y_t}{u_t K_t} &= \delta^0 u_t^\theta, \\
C_t + \dot{K}_t + C_t^e &= Y_t - \delta(u_t) K_t, \\
Y_t &= A(u_t K_t)^\alpha N_t^{1-\alpha}, \\
\phi_t &= \frac{Y_t}{\pi\Phi + Y_t}, \\
C_t^e &= (1 - \phi_t) Y_t,
\end{aligned}
$$

where $\pi \equiv \frac{\rho_e}{\lambda}$. Denote $s \equiv 1 - \frac{\alpha}{1+\theta}$. Then some of the key ratios in the steady state can be obtained as

$$
\begin{aligned}
k_y &= \frac{K}{Y} = \frac{\alpha\phi\theta}{\rho(1+\theta)}, \\
c_y &= \frac{C}{Y} = s\phi = \left(1 - \frac{\alpha}{1+\theta}\right)\phi, \\
N &= \left[\frac{(1-\alpha)\phi}{c_y} \cdot \frac{1}{\psi}\right]^{\frac{1}{1+\gamma}} = \left[\left(\frac{1-\alpha}{1 - \frac{\alpha}{1+\theta}}\right) \cdot \frac{1}{\psi}\right]^{\frac{1}{1+\gamma}}, \\
Y &= A^{\frac{1}{1-\alpha}} (k_y)^{\frac{\alpha}{1-\alpha}} N = A^{\frac{1}{1-\alpha}} \left[\frac{\alpha\phi\theta}{\rho(1+\theta)}\right]^{\frac{\alpha}{1-\alpha}} \left[\left(\frac{1-\alpha}{1 - \frac{\alpha}{1+\theta}}\right) \cdot \frac{1}{\psi}\right]^{\frac{1}{1+\gamma}}. \quad\text{(A.5)}
\end{aligned}
$$

We can use Equation (53) to solve for the steady state ϕ and use Equation (A.5) to obtain the steady state Y. Consumption and capital can then be computed by $C = c_y Y$ and $K = k_y Y$, respectively. The log-linearization of the system of equilibrium equations is given by:

$$
\begin{aligned}
0 &= \hat{\phi}_t + \hat{y}_t - (1+\gamma)\,\hat{n}_t - \hat{c}_t, \\
\dot{c}_t &= \rho\left(\hat{\phi}_t + \hat{y}_t - \hat{k}_t\right), \\
\hat{y}_t &= \alpha\left(\hat{u}_t + \hat{k}_t\right) + (1-\alpha)\hat{n}_t, \\
\hat{u}_t &= \frac{1}{1+\theta}(\hat{\phi}_t + \hat{y}_t - \hat{k}_t), \\
\dot{k}_t &= \left(\frac{s\phi}{k_y}\right)\left(\hat{\phi}_t + \hat{y}_t - \hat{k}_t\right) - \left(\frac{c_y}{k_y}\right)\left(\hat{c}_t - \hat{k}_t\right), \\
\hat{\phi}_t &= (1-\phi)\,\hat{y}_t \equiv \tau\hat{y}_t.
\end{aligned}
$$

As in the baseline model, we can substitute $\hat{u}_t$ and $\hat{\phi}_t$ to obtain a reduced form of output in terms of capital and labor as

$$
\hat{y}_t = \frac{\alpha\theta\hat{k}_t + (1+\theta)(1-\alpha)\hat{n}_t}{1+\theta - (1+\tau)\alpha} \equiv a\hat{k}_t + b\hat{n}_t,
$$

where $a \equiv \frac{\alpha\theta}{1+\theta-(1+\tau)\alpha}$ and $b \equiv \frac{(1+\theta)(1-\alpha)}{1+\theta-(1+\tau)\alpha}$. We assume $\tau < \frac{1+\theta}{\alpha} - 1$, which is a reasonable restriction under standard calibration, so that $a > 0$ and $b > 0$. Finally $\hat{n}_t$ can be expressed as a function of $\hat{y}_t$ and $\hat{c}_t$, and thus we have

$$
\hat{y}_t = \frac{a(1+\gamma)}{1+\gamma - b(1+\tau)}\hat{k}_t - \frac{b}{1+\gamma - b(1+\tau)}\hat{c}_t \equiv \lambda_1\hat{k}_t + \lambda_2\hat{c}_t,
$$

where $\lambda_1 \equiv \frac{a(1+\gamma)}{1+\gamma-b(1+\tau)}$ and $\lambda_2 \equiv -\frac{b}{1+\gamma-b(1+\tau)}$. Consequently the local dynamics is characterized by following differential equations:

$$
\begin{aligned}
\begin{bmatrix} \dot{k}_t \\ \dot{c}_t \end{bmatrix} &= \delta \begin{bmatrix} \left(\frac{1+\theta}{\alpha\phi}\right)s\phi(1+\tau)\lambda_1 & \left(\frac{1+\theta}{\alpha\phi}\right)[s\phi(1+\tau)\lambda_2 - (1-s\phi)] \\ \theta\,[(1+\tau)\lambda_1 - 1] & \theta(1+\tau)\lambda_2 \end{bmatrix} \begin{bmatrix} \hat{k}_t \\ \hat{c}_t \end{bmatrix}, \\
&\equiv J \begin{bmatrix} \hat{k}_t \\ \hat{c}_t \end{bmatrix}.
\end{aligned}
\tag{A.6}
$$

where $s \equiv 1 - \frac{\alpha}{1+\theta}$, $c_y = s\phi$, $\delta = \rho/\theta$. The local dynamics around the steady state is determined by the roots of J. Notice that the trace and the determinant of J are

$$
\begin{aligned}
\frac{\text{Trace}(J)}{\delta} &= \left(\frac{1+\theta}{\alpha}\right)s(1+\tau)\lambda_1 + \theta(1+\tau)\lambda_2 < 0, \\
\frac{\det(J)}{\delta^2\theta\left(\frac{1+\theta}{\alpha\phi}\right)} &= s\phi(1+\tau)\lambda_2 + (1-s\phi)(1+\tau)\lambda_1 - (1-s\phi) > 0.
\end{aligned}
$$

Similar to the analysis for the indeterminacy of our baseline model, here $\text{Trace}(J) < 0$ if and only if $\tau > \tau_{\min} \equiv \frac{(1+\theta)(1+\gamma)}{(1+\theta)(1-\alpha)+\alpha(1+\gamma)} - 1$. Given that $\tau > \tau_{\min}$, some algebraic manipulation suggests that $\det(J) > 0$ if and only if $\tau < \frac{1+\theta}{\alpha} - 1$, and

$$A_1\tau^2 - A_2\tau - A_3 < 0,$$

where

$$
\begin{aligned}
A_1 &\equiv s(1+\theta)(2+\alpha+\alpha\gamma) > 0 \\
A_2 &\equiv (1+\theta)(1+\alpha\gamma) - s[(1+\theta)(1-\alpha)(1-\gamma) + (1+\gamma)\alpha] \\
A_3 &\equiv (1+\theta)(1-\alpha)[s + + (1-s)\gamma] > 0.
\end{aligned}
$$

Therefore $A_1\tau^2 - A_2\tau - A_3 < 0$ if and only if $\tau < \tau_H$, where τ_H is the positive solution to $A_1\tau^2 - A_2\tau - A_3 = 0$.

Proof of Lemma 4: Combining Lemma 3 and Proposition 2 immediately yields the desired result.

Proof of Lemma 5: First, using Implicit Function Theorem, Equation (67) suggests that $\frac{\partial q^*}{\partial Y} > 0$. Second, footnote 7 proves that $\frac{\partial TFP}{\partial q^*} > 0$. In turn, the chain rule implies that $\frac{\partial TFP}{\partial Y} = \left(\frac{\partial TFP}{\partial q^*}\right)\left(\frac{\partial q^*}{\partial Y}\right) > 0$.

Proof of Proposition 3: To establish the conditions for indeterminacy, we first log-linearize the equilibrium equations. Substituting $\hat{u}_t$ from the log-linearized Equation (28), we obtain

$$\hat{y}_t = a\hat{k}_t + b\hat{n}_t,$$

where $a = \frac{\theta\alpha(1+\sigma)}{1+\theta-\alpha(1+\sigma)}$ and $b = \frac{(1+\theta)(1-\alpha)(1+\sigma)}{1+\theta-\alpha(1+\sigma)}$. Finally, expressing $\hat{n}_t$ from the log-linearized Equation (26), we obtain

$$\hat{y}_t = \lambda_1\hat{k}_t + \lambda_2\hat{c}_t,$$

where $\lambda_1 \equiv \frac{a(1+\gamma)}{1+\gamma-b}$ and $\lambda_2 \equiv -\frac{a}{1+\gamma-b}$. We hence obtain a two-dimensional system of difference equations

$$
\begin{bmatrix} \dot{k}_t \\ \dot{c}_t \end{bmatrix} = \delta \begin{bmatrix} \left(\frac{1+\theta}{\alpha\phi} - 1\right)\lambda_1 & \left(\frac{1+\theta}{\alpha\phi}\right)(\lambda_2 - 1) + 1 - \lambda_2 \\ \theta(\lambda_1 - 1) & \theta\lambda_2 \end{bmatrix} \begin{bmatrix} \hat{k}_t \\ \hat{c}_t \end{bmatrix} \equiv J \begin{bmatrix} \hat{k}_t \\ \hat{c}_t \end{bmatrix}
$$

where $\delta = \rho/\theta$. The local dynamics around the steady state is determined by the roots of J. The trace and the determinant of J are

$$
\begin{aligned}
\frac{\text{Trace}(J)}{\delta} &= \left(\frac{1+\theta}{\alpha\phi} - 1\right)\lambda_1 + \theta\lambda_2 = \frac{\left(\frac{1+\theta}{\alpha\phi} - 1\right)(1+\gamma)\,a - \theta b}{1+\gamma - b}, \\
\frac{\det(J)}{\delta^2\theta} &= \left(\frac{1+\theta}{\alpha\phi} - 1\right)(\lambda_1 - 1 + \lambda_2) = \left(\frac{1+\theta}{\alpha\phi} - 1\right)\left[\frac{(1+\gamma)(a-1)}{1+\gamma - b}\right].
\end{aligned}
$$

Indeterminacy arises if $\text{Trace}(J) < 0$ and $\det(J) > 0$. Under the assumption $a < 1$, or $\alpha(1+\sigma) < 1$. $\det(J) > 0$ is equivalent to $1 + \gamma - b$, or $\sigma > \sigma_{\min} \equiv \left(\frac{1}{\frac{1-\alpha}{1+\gamma} + \frac{\alpha}{1+\theta}}\right) - 1$. Then $\text{Trace}(J) < 0$ requires $\left(\frac{1+\theta}{\alpha\phi} - 1\right)(1+\gamma)\,a > \theta b$. Rearranging terms yields the requirement, $\frac{(1+\sigma)\eta}{1+\eta} < \left(\frac{1}{\frac{1-\alpha}{1+\gamma} + \frac{\alpha}{1+\theta}}\right)$. Recall $\sigma = \frac{1-\chi}{\chi+\eta}$, or $\frac{(1+\sigma)\eta}{1+\eta} = \frac{\eta}{\chi+\eta}$, so that such a requirement is automatically satisfied.

Proof of Corollary 4: In steady state we have

$$
\begin{aligned}
\frac{K}{Y} &= \frac{\alpha\phi^*}{\rho + \delta} \\
\frac{C}{Y} &= 1 - \delta\left(\frac{K}{Y}\right) = 1 - \frac{\alpha\phi^*\delta}{\rho + \delta} \\
N &= \left[\frac{\phi^*(1-\alpha)}{\psi} \cdot \left(\frac{1}{C/Y}\right)\right]^{\frac{1}{1+\gamma}} = \left[\frac{\phi^*(1-\alpha)}{\psi} \cdot \left(\frac{1}{1 - \frac{\alpha\phi^*\delta}{\rho+\delta}}\right)\right]^{\frac{1}{1+\gamma}}
\end{aligned}
$$

Furthermore,

$$
\begin{aligned}
uR &= \delta + \rho \\
R &= \delta^0 u^\theta = \phi^* \cdot \alpha\left(\frac{Y}{uK}\right).
\end{aligned}
$$

Then we have

$$
u = \left[\frac{\rho(1+\theta)}{\delta^0\theta}\right]^{\frac{1}{1+\theta}}.
$$

We normalize the steady-state utilization rate such that $u = 1$. Then $\delta^0 = \frac{\rho(1+\theta)}{\theta}$, and in turn we have $\delta = \frac{\rho}{\theta}$. Now we characterize the aggregate output in the steady state:

$$
Y = \left(\Delta A^{1+\sigma}\right) K^a N^b = \left(\Delta A^{1+\sigma}\right)\left(\frac{K}{Y}\right)^a Y^a N^b,
$$

and therefore

$$
\begin{aligned}
Y &= \left\{\left(\Delta A^{1+\sigma}\right)\left(\frac{\alpha\phi^*}{\rho+\delta}\right)^a\left[\frac{\phi^*(1-\alpha)}{\psi} \cdot \left(\frac{1}{1 - \frac{\alpha\phi^*\delta}{\rho+\delta}}\right)\right]^{\frac{b}{1+\gamma}}\right\}^{\frac{1}{1-a}} \\
&= \Lambda_2 \cdot \Phi^{-\frac{\sigma}{1-a}}
\end{aligned}
$$

39

where

$$\Delta \equiv \Lambda_1 \cdot \Phi^{-\frac{1-\chi}{\chi+\eta}} = \Lambda_1 \cdot \Phi^{-\sigma}$$

$$\Lambda_1 \equiv \left(\frac{\eta}{1+\eta}\right)\left(\frac{\chi+\eta}{\eta}\right)^{\frac{1+\eta}{\chi+\eta}} (q_{\max})^{\frac{\eta(1-\chi)}{\chi+\eta}}$$

$$\phi^* \equiv \frac{\eta}{\chi+\eta}$$

$$a \equiv \alpha(1+\sigma)$$

$$b \equiv (1-\alpha)(1+\sigma)$$

$$\sigma \equiv \frac{1-\chi}{\chi+\eta} = \left(\frac{1+\eta}{\eta}\right)\phi^* - 1$$

$$\Lambda_2 \equiv \left\{ A^{1+\sigma} \left(\frac{\alpha\phi^*}{\rho+\delta}\right)^a \left[\frac{\phi^*(1-\alpha)}{\psi} \cdot \left(\frac{1}{1-\frac{\alpha\phi^*\delta}{\rho+\delta}}\right)\right]^{\frac{b}{1+\gamma}} \right\}^{\frac{1}{1-a}}.$$

Since we have proved that in each period,

$$Y = \Phi \cdot \left(\frac{\eta}{1+\eta}\right)\left[\frac{(q^*)^{1+\eta}}{(q_{\max})^\eta}\right]$$

then in steady state, the cut-off value q^* is

$$q^* = \left[\left(\frac{(q_{\max})^\eta Y}{\Phi}\right)\left(\frac{1+\eta}{\eta}\right)\right]^{\frac{1}{1+\eta}}$$

In turn, the equilibrium price of the intermediate good, the normalized marginal cost, and the marginal cost of firm i at steady state are

$$P = E(q|q \leq q^*) = \left(\frac{\eta}{1+\eta}\right) \cdot q^*$$

$$\widetilde{\phi} = \frac{P}{(q^*)^\chi} = \left(\frac{\eta}{1+\eta}\right) \cdot (q^*)^{1-\chi}$$

$$\phi(i) = \widetilde{\phi} \cdot (q(i))^\chi = \left(\frac{\eta}{1+\eta}\right) \cdot (q^*)^{1-\chi} \cdot (q(i))^\chi$$

Furthermore, the factor prices are

$$R = \delta + \rho = \frac{\rho(1+\theta)}{\theta}$$

$$W = \phi^* \cdot \alpha \left(\frac{Y}{N}\right)$$

where (Y, N) have been obtained above.

40

Finally, to obtain an interior solution for q^* in the steady state, we need to have

$$
\begin{aligned}
\Phi \;>\; & \frac{A\left(\frac{K}{Y}\right)^{\alpha} Y^{\alpha} N^{1-\alpha}}{E\left(q^{\chi}\right)} \\
=\; & \frac{A\left(\frac{\alpha\phi^*}{\rho+\delta}\right)^{\alpha}\left(\Lambda_2\cdot\Phi^{-\frac{\sigma}{1-a}}\right)^{\alpha}\left[\frac{\phi^*(1-\alpha)}{\psi}\cdot\left(\frac{1}{1-\frac{\alpha\phi^*\delta}{\rho+\delta}}\right)\right]^{\frac{1-\alpha}{1+\gamma}}}{\left(\frac{\eta}{\chi+\eta}\right)\left(q_{\max}\right)^{\chi}} \\
=\; & \Lambda_3\cdot\Phi^{-\frac{\alpha\sigma}{1-a}}
\end{aligned}
$$

where

$$
\Lambda_3 \;\equiv\; \frac{A\left(\frac{\alpha\phi^*}{\rho+\delta}\right)^{\alpha}\left(\Lambda_2\right)^{\alpha}\left[\frac{\phi^*(1-\alpha)}{\psi}\cdot\left(\frac{1}{1-\frac{\alpha\phi^*\delta}{\rho+\delta}}\right)\right]^{\frac{1-\alpha}{1+\gamma}}}{\left(\frac{\eta}{\chi+\eta}\right)\left(q_{\max}\right)^{\chi}}
$$

$$
a \;\equiv\; \alpha\left(1+\sigma\right)
$$

Therefore, in order to guarantee an interior solution to q^* in steady state, we need to assume

$$
\Phi > \widehat{\Phi} \equiv \Lambda_3^{\frac{1-\alpha(1+\sigma)}{1-\alpha}}.
$$

Proof of Proposition 4: From the indeterminacy analysis for the baseline model, we know that

$$
\hat{y}_t = m_1\hat{k}_t + m_2\hat{n}_t,
$$

where

$$
\begin{aligned}
m_1 &\equiv \frac{\theta a}{1+\theta-a} = \frac{\theta\alpha\left(1+\sigma\right)}{1+\theta-\alpha\left(1+\sigma\right)} \\
m_2 &\equiv \frac{(1+\theta)b}{1+\theta-a} = \frac{(1+\theta)(1-\alpha)(1+\sigma)}{1+\theta-\alpha\left(1+\sigma\right)} \\
\sigma &\equiv \frac{1-\chi}{\chi+\eta} = \left(\frac{1+\eta}{\eta}\right)\phi^* - 1
\end{aligned}
$$

To make (m_1, m_2) well defined, we must set $1+\theta-a = 1+\theta-\alpha\left(1+\sigma\right) > 0$, *i.e.*,

$$
\sigma < \sigma_1 \equiv \frac{1+\theta}{\alpha} - 1.
$$

Then we have

$$
\hat{y}_t = \lambda_1\hat{k}_t + \lambda_2\hat{c}_t,
$$

41

where

$$\lambda_1 \equiv \frac{m_1(1+\gamma)}{1+\gamma-m_2}$$

$$\lambda_2 \equiv -\frac{m_2}{1+\gamma-m_2}$$

As a result,

$$\begin{bmatrix} \dot{k}_t \\ \dot{c}_t \end{bmatrix} = \delta \begin{bmatrix} \left(\frac{1+\theta}{\alpha\phi^*}-1\right)\lambda_1 & \left(\frac{1+\theta}{\alpha\phi^*}\right)(\lambda_2-1)+1-\lambda_2 \\ \theta(\lambda_1-1) & \theta\lambda_2 \end{bmatrix} \begin{bmatrix} \hat{k}_t \\ \hat{c}_t \end{bmatrix}$$

$$\equiv J \begin{bmatrix} \hat{k}_t \\ \hat{c}_t \end{bmatrix}.$$

where $\delta = \rho/\theta$. The local dynamics around the steady state is determined by the roots of J. The trace and the determinant of J are

$$\frac{\text{Trace}(J)}{\delta} = \left(\frac{1+\theta}{\alpha\phi^*}-1\right)\lambda_1 + \theta\lambda_2$$

$$\frac{\det(J)}{\delta^2\theta} = \left(\frac{1+\theta}{\alpha\phi^*}-1\right)(\lambda_1-1+\lambda_2)$$

where

$$\phi^* = \frac{\eta}{\chi+\eta} = \left(\frac{\eta}{1+\eta}\right)(1+\sigma)$$

$$\lambda_1 \equiv \frac{m_1(1+\gamma)}{1+\gamma-m_2}$$

$$\lambda_2 \equiv -\frac{m_2}{1+\gamma-m_2}$$

$$m_1 \equiv \frac{\theta\alpha(1+\sigma)}{1+\theta-\alpha(1+\sigma)}$$

$$m_2 \equiv \frac{(1+\theta)(1-\alpha)(1+\sigma)}{1+\theta-\alpha(1+\sigma)}$$

$$\sigma \equiv \frac{1-\chi}{\chi+\eta} = \left(\frac{1+\eta}{\eta}\right)\phi^* - 1$$

The roots of J, x_1 and x_2 satisfy the following constraints

$$x_1 + x_2 = \text{Trace}(J)$$

$$x_1 x_2 = \det(J).$$

If $\text{Trace}(J) < 0$ and $\det(J) > 0$, then both x_1 and x_2 are negative, and the model will admit local indeterminacy around the steady state. First, some algebraic manipulation on $\text{Trace}(J)$

and $\det(J)$ suggests that

$$\frac{\text{Trace}\,(J)}{\delta} = \frac{\left(\frac{1+\theta}{\alpha\phi^*} - 1\right)(1+\gamma)\,m_1 - \theta m_2}{1+\gamma - m_2}$$

$$\frac{\det\,(J)}{\delta^2\theta} = \left(\frac{1+\theta}{\alpha\phi^*} - 1\right)\left[\frac{(1+\gamma)\,(m_1 - 1)}{1+\gamma - m_2}\right]$$

Consequently, $\text{Trace}(J) < 0$ and $\det(J) > 0$, if and only if

$$\frac{1+\theta}{\alpha\phi^*} - 1 \;>\; 0$$

$$1+\gamma - m_2 \;<\; 0$$

$$\left(\frac{1+\theta}{\alpha\phi^*} - 1\right)(1+\gamma)\,m_1 - \theta m_2 \;>\; 0$$

$$m_1 - 1 \;<\; 0$$

Since $\phi^* = \left(\frac{\eta}{1+\eta}\right)(1+\sigma)$, the first inequality suggests

$$1+\sigma < \left(\frac{1+\theta}{\alpha}\right)\left(\frac{1+\eta}{\eta}\right)$$

The second inequality implies that

$$1+\sigma > \frac{(1+\gamma)\,(1+\theta)}{(1+\theta)\,(1-\alpha) + (1+\gamma)\,\alpha} = \frac{1}{\frac{1-\alpha}{1+\gamma} + \frac{\alpha}{1+\theta}}$$

The third inequality requires

$$1+\sigma < \left(\frac{1}{\frac{1-\alpha}{1+\gamma} + \frac{\alpha}{1+\theta}}\right)\left(\frac{1+\eta}{\eta}\right),$$

which is always true since

$$(1+\sigma)\left(\frac{\eta}{1+\eta}\right) = \phi^* < 1 < \frac{1}{\frac{1-\alpha}{1+\gamma} + \frac{\alpha}{1+\theta}}.$$

The last inequality indicates

$$1+\sigma < \frac{1}{\alpha}$$

Consequently, $\text{Trace}(J) < 0$ and $\text{Det}(J) > 0$ if and only if

$$\sigma_{\min} < \sigma < \sigma_{\max} \tag{A.7}$$

where $\sigma_{\min} \equiv \left(\frac{1}{\frac{1-\alpha}{1+\gamma} + \frac{\alpha}{1+\theta}}\right) - 1$ and $\sigma_{\max} \equiv \frac{1}{\alpha} - 1$.

References

Allen, Franklin. "Reputation and Product Quality." *The RAND Journal of Economics* (1984): 311-327.

Akerlof, George A. "The Market for "Lemons": Quality Uncertainty and the Market Mechanism." *The Quarterly Journal of Economics* (1970): 488-500.

Basu, Susanto, and **John G. Fernald.** "Are Apparent Productive Spillovers A Figment of Specification Error?." *Journal of Monetary Economics* 36, no. 1 (1995): 165-188.

Basu, Susanto, and **John G. Fernald.** "Returns to Scale in US Production: Estimates and Implications." *Journal of Political Economy* 105, no. 2 (1997): 249-283.

Benhabib, Jess, and **Roger EA Farmer.** "Indeterminacy and Increasing Returns." *Journal of Economic Theory* 63, no. 1 (1994): 19-41.

Benhabib, Jess, and **Pengfei Wang.** "Financial Constraints, Endogenous Markups, and Self-fulfilling Equilibria." *Journal of Monetary Economics* 60, no. 7 (2013): 789-805.

Benhabib, Jess, and **Yi Wen.** "Indeterminacy, Aggregate Demand, and the Real Business Cycle." *Journal of Monetary Economics* 51, no. 3 (2004): 503-530.

Bernanke, Ben, and **Mark Gertler.** "Agency Costs, Net worth, and Business Fluctuations." *The American Economic Review (1989)*: 14-31.

Bigio, Saki. "Endogenous Liquidity and the Business Cycle." *The American Economic Review*, forthcoming (2014).

Bils, Mark. "The Cyclical Behavior of Marginal Cost and Price." *The American Economic Review* (1987): 838-855.

Broda, Christian, and **David E. Weinstein.** "Product Creation and Destruction: Evidence and Price Implications." *The American Economic Review*, 100(3): 691-723 (2010).

Camargo, Braz, and **Benjamin Lester.** "Trading Dynamics in Decentralized Markets with Adverse Selection." *Journal of Economic Theory*, 153 (2014) 534–568.

Chang, Briana. "Adverse Selection and Liquidity Distortion in Decentralized Markets." Working Paper, University of Wisconsin, Madison (2014).

Chari, V. V., Ali Shourideh, and **Ariel Zeltin-Jones.** "Reputation and Persistence of Adverse Selection in Secondary Loan Markets.", *The American Economic Review*, forthcoming (2014).

Chiu, Jonathan, and **Thorsten V. Koeppl.** "Trading Dynamics with Adverse Selection and Search: Market freeze, Intervention and Recovery." No. 2011-30. Bank of Canada Working Paper, 2011.

Cooper, Russell, and **Thomas W. Ross.** "Monopoly Provision of Product Quality with Uninformed Buyers." *International Journal of Industrial Organization* 3, no. 4 (1985): 439-449.

Cooper, Russell W., and **John C. Haltiwanger.** "On the Nature of Capital Adjustment Costs." *The Review of Economic Studies* 73, no. 3 (2006): 611-633.

Daley, Brendan, and **Brett Green.** "Waiting for News in the Market for Lemons." *Econometrica* 80, no. 4 (2012): 1433-1504.

Dong, Feng, Pengfei Wang and **Yi Wen,** "Credit Search and the Credit Cycles." Working Paper, Shanghai Jiao Tong University, Hong Kong University of Science and Technology, Federal Reserve Bank of St. Louis, and Tsinghua University (2014).

Eisfeldt, Andrea L. "Endogenous Liquidity in Asset Markets." *The Journal of Finance* 59, no. 1 (2004): 1-30.

Easterly, William, Roumeen Islam, and **Joseph E. Stiglitz.** "Shaken and Stirred: Explaining Growth Volatility." In Annual World Bank Conference on Development Economics, vol. 191, p. 211. 2001.

Gali, Jordi. "Monopolistic Competition, Business Cycles, and The Composition of Aggregate Demand." *Journal of Economic Theory* 63, no. 1 (1994): 73-96.

Gilchrist, Simon, and **Egon Zakrajšek.** "Credit Spreads and Business Cycle Fluctuations." *The American Economic Review* 102, no. 4 (2012): 1692-1720.

Guerrieri, Veronica, Robert Shimer, and **Randall Wright.** "Adverse Selection in Competitive Search Equilibrium." *Econometrica* 78, no. 6 (2010): 1823-1862.

Guerrieri, Veronica, and **Robert Shimer.** 2014. "Dynamic Adverse Selection: A Theory of Illiquidity, Fire Sales, and Flight to Quality." *The American Economic Review*, 104(7): 1875-1908.

House, Christopher L. "Adverse Selection and the Financial Accelerator." *Journal of Monetary Economics* 53, no. 6 (2006): 1117-1134.

Kiyotaki, Nobuhiro, and **John Moore.** "Credit Cycles." *The Journal of Political Economy* 105, no. 2 (1997): 211-248.

Klein, Benjamin, and **Keith B. Leffler.** "The Role of Market Forces in Assuring Contractual Performance." *The Journal of Political Economy* (1981): 615-641.

Kurlat, Pablo. "Lemons Markets and the Transmission of Aggregate Shocks." *The American Economic Review* 103, no. 4 (2013): 1463-1489.

Liu, Zheng, and **Pengfei Wang.** "Credit Constraints and Self-Fulfilling Business Cycles." *American Economic Journal: Macroeconomics* 6, no. 1 (2014): 32-69.

Ohanian, Lee E. "The Economic Crisis from A Neoclassical Perspective." *The Journal of Economic Perspectives* 24, no. 4 (2010): 45-66.

Priest, George L. "A Theory of the Consumer Product Warranty." *Yale Law Journal* (1981): 1297-1352.

Rotemberg, Julio J., and **Michael Woodford.** "The Cyclical Behavior of Prices and Costs." *Handbook of Macroeconomics* 1 (1999): 1051-1135.

Shapiro, Carl. "Consumer Information, Product Quality, and Seller Reputation." *The Bell Journal of Economics* (1982): 20-35.

Spence, Michael. "Job Market Signaling." *The Quarterly Journal of Economics* (1973): 355-374.

Stiglitz, Joseph E., and **Andrew Weiss.** "Credit Rationing in Markets with Imperfect Information." *The American Economic Review* (1981): 393-410.

Wang, Pengfei, and **Yi Wen.** "Imperfect Competition and Indeterminacy of Aggregate Output." *Journal of Economic Theory* 143, no. 1 (2008): 519-540.

Wen, Yi. "Capacity Utilization under Increasing Returns to Scale." *Journal of Economic Theory* 81, no. 1 (1998): 7-36.

Wilson, Charles. "The Nature of Equilibrium in Markets with Adverse Selection." *The Bell Journal of Economics* (1980): 108-130.