Collateral and Innovation*

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Abstract

This paper incorporates one of the characteristic on collateral of Uniform Commercial Code, where the future assets can be collateralized, into a corporate finance model and considers the effect of the securitization on the incentive of innovation. We show the importance of the collateral institution for innovation through the corporate finance. The entrepreneur's effort to develop new technology or product with high value tends to smaller than that for not high value product. The incentive for high value product under the institution that allows to register the future assets is higher than that under the benchmark institution that can register the existing assets through the complementary effect. The marginal effect of high value product on the effort of the entrepreneurs under the concerned institution is also higher than that under the benchmark institution. Collateral institution matters for innovation not only for access to external finance easily but also for providing more incentive to the parties.

1 Introduction

Innovation is an important driving force to promote economic growth and development. The entrepreneurs who have an innovative idea develop new

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products or technology. External finance helps to promote innovation through entrepreneurship. Institutions regarding collateral are one of the fundamental property rights to support corporate finance. Needless to say, intellectual property law is important to promote innovation. This paper shows that the legal institution on inside collateral can encourage innovation through corporate finance.

What assets can be collateralized is decided by the law outside the private contract, that is, it is determined as property rights, and the parties cannot decide it. The contents of legal institutions regarding collateral have a great influence on the parties' activities through the credit contract.

Some authors study inside collateral (Niinimaki (2009) and Wang (2010)), but most of the research on collateral are related to the analysis of outside collateral (Besley, Burchardi and Ghatak (2012), Manove, Padilla and Pagano (2001) and Niinimaki (2009)). We are considering the effect of inside collateral on incentives of the entrepreneurs and investors. As far as we know, there is little studies where explicitly analyze collateralizing of the future assets, although the US institution, Uniform Commercial Code (UCC), permits to collateralize the future assets.

In reality, there is legal difference on (inside) collateral among the countries. One is the institution that not to permit securitization of the future assets, and the other is to permit. We examine the effects of legal difference with regard to collateral on R&D or development of intellectual property.

Firstly, we analyze the model under the institution which permits to collateralize only the existing assets as a benchmark model. We refer this institution to the specific registration. Then we consider the institution, such as UCC, which allows to register the future assets as well as the existing assets. We refer this institution to the generic registration. Finally, we

compare the two equilibrium outcomes.

The remainder of the paper is organized as follows. The next section briefly discuss the legal background of the difference of secured asset registrations. Section 3 introduces a basic corporate finance model and analyzes the credit contract under the specific registration of collateral as a benchmark model. Section 4 examines the contract under the generic registration. Section 5 explores comparative analysis on the above registrations. Section 6 concludes briefly.

2 A brief introduction to the legal difference of secured asset registrations

Insert Sato's argument

- Discuss Article 9 of the UCC
- Discuss characteristics of collateral institution in the most civil countries

3 The basic model

We study contracting between borrowers (entrepreneurs) and lenders (investors), and use a standard agency model that is often used to analyze corporate finance, where the borrower's effort is not verifiable and is a source of moral hazard. In order to focus on inside collateral, it is assumed that the borrower has no wealth for simplicity and cannot pledge his own assets as outside collateral. The borrower has a unique idea for the business and takes R&D to achieve the idea. He needs external (fixed) credit from a lender because of no wealth. The lender has money but no idea for business. We assume that when the lender provides credits for the business,

she needs to secure the business assets as (inside) collateral, otherwise, the credit rationing occurs.

The borrower tries to develop a new product or intellectual property z and need investment to z. He has no her own wealth and his company has no cash to invest, thus he needs lenders. The borrower makes an effort e, where $0 \leq e \leq \bar{e}$, and at probability e a new intellectual property z is developed. The effort e is unobservable for the lender and unverifiable, therefore is not contractable on e. The effort e needs the cost $d(e)$ for her, where $d(e)$ is increasing and convex function of e.

The borrower has asset x as his company asset, which exists at the time of the contract. This is used as (inside) collateral. If the borrower develops a new intellectual property or new product z successfully and the business is in success, and then he can receive y_z as the cash flow of the successful business. This cash flow includes business sales by using x and z. If he fails to develop z but the business is still successful, he gets y_x as the cash flow by using x, where $y_z > y_x$. That is, there can be in failure of the business even when the R&D is successful, and there can be in success of the business even when the R&D fails.

The lender provides a fixed investment L to the borrower. The value of the asset x and z as collateral for the lender denotes v_x and v_z, respectively. v_x and v_z indicates the cash flow or resale value when the lender acquires x or z as collateral. The lender does not find theses collateral values ex ante, and she makes effort q to evaluate the asset. The evaluation is stochastic and takes the value v_i, $i = x$ or z with the probability q. The lender tries to understand the content of the business through the effort q. The cost of effort q is $c(q)$, and $c(q)$ is increasing and convex function of q. Note that the effort q by the lender increases the expected collateral value for the lender,

but it does not directly increase the value of the R&D. On the other hand, the effort e by the borrower increases the expected business value directly through the change from y_x to y_z.

The timeline of the model is the following.

1. The borrower and lender sign up a credit contract (R_z, R_x, V), where R_z and R_x are the repayments in z or x, respectively. V is the secured assets for the investor in case of default. The lender makes effort q to evaluate the assets as collateral.

2. The borrower makes effort e to develop a new product.

3. The borrower acquires a new product z if the R&D is successful or do business by using the existing assets x if the R&D is failed.

4. It is verifiable whether the business is successful (the borrower obtains the cash flow) or failed (the borrower obtains no cash flow). The borrower repays R_z or R_x, which depends on the state, in the case of success of the business. In case of failure of the business, The lender collects assets V as collateral.

Given the contract (R_z, R_x), the payoff of the borrower from the project is

$$p \times [e \times (y_z - R_z) + (1 - e) \times (y_x - R_x)] - d(e), \tag{1}$$

where p is the probability of success of the business, R_z is the repayment in the case of successful development of a new product z, and R_x is the repayment in the case of failure of new product. We assume that the development of new product z is verifiable, and the state whether z is developed is contractable. The form of this payoff of the borrower is the same both

under specific and generic registrations. We analyze inside collateral and see that the payoff of the borrower is independent from the value of inside collateral.

In order to guarantee that the borrower entries into the business, the contract is satisfied to the following condition:

$$p \times [e \times (y_z - R_z) + (1 - e) \times (y_x - R_x)] - d(e) \geq u, \tag{2}$$

where $u \geq 0$ is the payoff from the outside option. This indicates the payoff of the borrower from the business should be larger than that of the outside option. We refer to this condition as the participation constraint (PC) of the borrower.

The borrower decides the effort e to maximize his payoff of the business, and the level of effort e is satisfied to the following condition:

$$p[\Delta y + (R_x - R_z)] = d'(e), \tag{3}$$

where $\Delta y = y_z - y_x$. This condition comes from the first order condition of the payoff (the left hand of the (2)) with regard to the effort e. The lender has to take into account this condition to prevent the borrower from the moral hazard. We refer to this condition as incentive compatibility condition (ICC) of the borrower.

Before proceeding the analysis, we make the three assumptions; assumptions about other institutions, inside collateral, and legal difference on collateral registration. We focus on the difference in the ways of registration of collateral. It is assumed firstly that other legal institutions, such as foreclosure, reorganization, or liquidation, and the level of enforcement are given, though theses institutions also influence on corporate finance. Therefore,

other (institutional) things being equal, we provide comparative analysis on institution of collateral registration.

Secondly, to make the analysis of inside collateral meaningful, we assume that a creditor shares the claim with "other creditors" related for the business in default when there are not enough assets to satisfy all of the debt, and then the creditor can fully collect debt if she registers the firm assets as collateral, although any business-related creditors have the right to acquire the firm's remaining assets to collect the debt in the case of default.

Finally, we mention two types of legal registration on collateral; "generic" approach and "specific" one. Although there are other different characteristics between the generic and specific approaches[1], this paper focuses on whether the future assets can be collateralized or not. On the one hand, a legal institution requires that the corporate assets must be registered "specifically." This kind of rule is closely related to the civil law countries such as Germany and Japan.[2] In such countries, they can register only "specified" asset as collateral. Specific registration in this paper indicates that the assets must be specified to be registered as collateral. That is, it is impossible to collateralize the future corporate assets, which are not specified at the time of contract, as collateral under the specific approach. On the other hand, in the generic registration, we keep Article 9 of UCC in mind. We can "generically" register the corporate assets under this institution. Generic registration in this paper means that it is possible to registrar the future assets as collateral as well as the existing asset.

In addition, we assume the following technical assumptions as the second

[1] See Armour (2008).

[2] In the specific registration, we keep civil law countries such as Germany and Japan in mind. In such countries, they employs the following as fundamental principles: the principles of Specificity, certainty and public disclosure. See Reimann and Zekoll (2005) and Foster and Sule (2010) in German law, and .... in Japanese law.

order condition in the second best:

$$2d''(e) + ed'''(e) > 0, \text{ and} \quad (4)$$

$$c''(q)[d''(e) + (1-\alpha)(d''(e) + ed'''(e)] - [(1-p)(v_z - v_x)]^2 > 0, \quad (5)$$

where $\alpha = \lambda_1$ or μ_1. λ_1 and μ_1 are Lagrange multipliers for the participation condition under the specific and generic registrations, respectively.

Based on the above setting, we consider the optimal contract problem under each registration of collateral; the specific and generic registrations. Assume that the lender makes a take-it-or-leave-it offer to the borrower. In order to make the contract to guarantee the participation of the borrower and to prevent the borrower from the moral hazard, the contract must satisfy the PC and ICC.

3.1 Credit contract under the specific registration

Let us consider the optimal contract under the specific registration, where the asset that the lender can collateralize is the existing asset x at the time of the contract. This legal environment on collateral has been (implicitly) assumed and examined in the past studies. Inside collateral is directly independent from the payoff of the borrower, and the borrower prefers pledging all of the business collateral because pledging collateral improves his payoff through an decrease in the repayments. In order to consider the optimal contract, in addition to the constraints PC and ICC, the feasible conditions on the repayments ($R_z \leq y_z$ and $R_x \leq y_x$) are included in the contract. From the ICC and two feasible conditions, however, we find that one of the feasible condition ($R_z \leq y_z$) is redundant, and we remove this condition as a constraint. Thus, the lender solves the following problem under the specific

registration:

$$\max_{R_z,R_x,q} p[e \times R_z + (1-e) \times R_x] + (1-p)qv_x - c(q) - L$$

$$\text{subject to} \quad \text{PC, ICC, and } R_x \leq y_x.$$

The solutions depend on whether the PC and/or the feasible condition is binding or not. The optimal contract is classified into three cases.

Proposition 1. *Assume that the borrower needs to pledge some collateral to acquire external finance. Then under the specific registration collateral* V^S *is set to the existing assets* v_x *in the business. The optimal contract* (R_z, R_x) *and the efforts* (e, q) *are given by the following:*

Case 1 (the PC is binding and the feasible condition is not binding):

For $u > \bar{u}$,

$$R_z = R_x = y_x + \frac{ed'(d) - d(e) - u}{p} < y_x$$

e^{S1} *satisfies that* $p\Delta y - d'(e) = 0$.

Case 2 (the PC is binding and the feasible condition is binding):

For $\underline{u} \leq u \leq \bar{u}$,

$$R_z = y_z - \frac{d'(e)}{p}, \; R_x = y_x.$$

e^{S2} *satisfies that* $ed'(e) - d(e) = u$.

Case 3 (the PC is not binding and the feasible condition is binding):

For $u < \underline{u}$,

$$R_z = y_z - \frac{d'(e)}{p}, \; R_x = y_x.$$

e^{S3} *satisfies that* $p\Delta y - d'(e) - ed''(e) = 0$.

$e^{S3} < e^{S1}$ *and* $e^{S2} < e^{S1}$.

Irrespective of the above cases, q^S *is determined by* $(1-p)v_x = c'(q^S)$.

Case 1 is when the outside option is enough high, where the participation condition is binding and the feasible condition is not binding. In this case, the borrower chooses the best effort under the specific registration. Two type of repayments set equally, $R_z = R_x$, that is, the borrower can make a fixed repayment in the case of both success and failure in R&D. The borrower receives the same level of payoff as the outside option and is the full residual claimant of the return of his effort under the specific registration.

Second is the case when the outside option is in the middle range, but a feasible condition is still binding. In this case, the participation condition of the borrower is binding and the borrower receives the same level of payoff as the outside option. The form of the repayments (R_z, R_x) is the same as Case 1 and the repayment in the case of successful R&D still exceed that in the case of failure, but the difference between the repayments is smaller than that in Case 3. The effort of the borrower depends on the level of outside option, and is higher than that in Case 1.

When the outside option is small enough ($u < \bar{u}$), the effort of the borrower is the smallest among the three cases. In this case, the participation condition of the borrower is not binding and the borrower can receive a larger payoff than the outside option. Since the cash flow without new product, y_x, is not large enough, the repayment in the case of failure of development sets to all of the cash flow from the business, i.e., a feasible condition is binding $R_x = y_x$. The repayment in the case of successful business exceed that in the case of failure ($R_z > R_x$).

The efforts of the lender are the same level, regardless of the environment

of the borrower. Since the lender under the specific registration takes notice of her secured asset which exists at the time of the contract, the effort chosen by the lender is independent of that by the borrower

In the context of R&D, it is important to consider the difference in the above three cases. The outside option in this context can be interpreted as an alternative R&D project. In such an interpretation on the outside option, in Cases 1 and 2 where the participation condition is binding, the value of the concerned project for the borrower is the same as that of an alternative project. Therefore, we can say that Case 3 is the most important environment to consider the promotion of innovation because the concerned project value is larger than an alternative one. Following this interpretation, we find that the borrower makes less effort in more valuable project.

4 Contract under the generic registration

Now let us consider the optimal contract under the generic registration, where the lender can register the future asset as collateral as well as the existing asset. The effect of the securitization of the future assets has not analyzed in the past studies. In this regime, given evaluation effort q, the expected value of inside collateral V for the lender is $(1-p)q[ev_z+(1-e)v_x]$. This is only difference to the optimal contract problem under the specific registration. The problem of the optimal contract for the lender is as follows:

$$\max_{R_z,R_x,q} p[e \times R_z + (1-e) \times R_x] + (1-p)q[e \times v_z + (1-e) \times v_x] - c(q) - L$$

$$\text{subject to} \quad \text{PC, ICC, and } R_x \leq y_x.$$

The effort q chosen by the lender meets the following condition:

$$(1-p)[ev_z + (1-e)v_x] = c'(q). \tag{6}$$

This means that the marginal benefit of the effort (the left) equals the marginal cost of the effort (the right).

Our result is given by:

Proposition 2. *Assume that the borrower needs to pledge some collateral to acquire external finance. Then under the generic registration collateral* V^G *is set to* $(1-p)q[ev_z + (1-e)v_x]$. *The optimal contract* (R_z, R_x) *and the efforts* (e, q) *are given by the following:*

Case 1 (the PC is binding and the feasible condition is not binding):

For $> \bar{u}$,

$$R_z = y_x + \frac{ed'(d) - d(e) - u}{p} - (1-p)q(v_z - v_x)$$
$$R_x = y_x + \frac{ed'(d) - d(e) - u}{p}$$

(e^{G1}, q^{G1}) *satisfies the equation (6) and the following equation:*

$$p\Delta y - d'(e) + (1-p)q(v_z - v_x) = 0. \tag{7}$$

Case 2(the PC is binding and the feasible condition is binding):

For $\underline{u} \leq u \leq \bar{u}$,

$$R_z = y_z - \frac{d'(e)}{p},\ R_x = y_x.$$

(e^{G2}, q^{G2}) *satisfies the equation (6) and the following equation:*

$$ed'(e) - d(e) = u. \tag{8}$$

Case 3 (the PC is not binding and the feasible condition is binding):
For $u < \underline{u}$*,*

$$R_z = y_z - \frac{d'(e)}{p},\ R_x = y_x.$$

(e^{G3}, q^{G3}) *satisfies the equation (6) and the following equation:*

$$p\Delta y - d'(e) - ed''(e) + (1-p)q(v_z - v_x) = 0. \tag{9}$$

Interpretation on the above three cases is similar with that under the specific registration, but there are some differences. Efforts by the borrower and lender become complementary inputs now in Case 1 and 3 under the generic registration. On the other hand, the efforts under the specific registration are independent inputs. Efforts of the borrower in Case 2 under both registration depend on the outside option value u and is the same level. In comparing with the first order condition on the efforts under the specific registration, the marginal benefit of each effort by the borrower and lender is larger by an increase in the expected value of collateral in all of the cases under the generic registration.

The form of the repayment in Cases 1 and 2 under the generic registration is the same as that under the specific registration, but it is interesting to note that the repayment in case of failure of development can exceed that in case of success, i.e., $R_x > R_z$ when the expected value of collateral is large enough. This is because the lender has to leave the borrower more cash flow

in case of success since the return of the effort by the borrower for the lender is higher.

In Case 1, the repayment in case of failure of development is smaller by the expected value of collateral than that in case of success. This is again because the lender gives the borrower the incentive to make effort more. Efforts (e^{G1}, q^{G1}) are now the first best in this framework. In fact, the social welfare, which consists of the expected of the business value that the efforts' cost are subtracted from, is

$$\begin{aligned} & p\times[e \times y_z + (1-e) \times y_x] \\ & \quad + (1-p)q[e \times v_z + (1-e) \times v_x] - L - d(e) - c(q). \end{aligned}$$

The first best efforts (e^{FB}, q^{FB}) are determined by the following first order conditions.

$$p\Delta y + (1-p)q^{FB}(v_z - v_x) = d'(e^{FB}) \tag{10}$$

$$(1-p)[e^{FB}v_z + (1-e^{FB})v_x] = c'(q^{FB}) \tag{11}$$

These equations are the same conditions as that of (e^{G1}, q^{G1}). Note that the best efforts (e^{S1}, q^S) of Case 1 under the specific registration is smaller than the first best because the lender will not able to secure the future asset, which the borrower might develop, as collateral, and this possible future value will be shared by the other business creditors. In this framework, the first best efforts are achieved when the outside option of the borrower is high enough and when the borrower and lender are under the generic registration. In other words, the parties under the specific registration cannot achieve the first best outcome even when the outside option is high enough.

5 Comparative analysis

Now let us examine the effect of the difference in the legal registrations. We firstly summarize the value of collateral under both registrations. The collateral value V^S for the lender under the specific registration is v_x because the lender under the specific registration can register only the existing assets x as collateral. On the other hand, the collateral value V^G for the lender under the generic registration is $e \times v_z + (1 - e) \times v_x$ because the lender under the generic registration can register not only the existing assets x but also the asset z that might exist in the future. Obviously, we have $V^S < V^G$ by the assumption. By higher effective collateral value, we can expect that the borrower under the generic registration can acquire the external finance much easily. In addition, this difference makes effects in the level of the efforts.

Secondly, we summarize the comparison of the effort by the borrower between under the specific and generic registrations:

Proposition 3. *The effort by the borrower under the generic registration is larger than that under the specific registration in Case 1 and 3, the effort is the same level in Case 2:*

$$e^{S1} < e^{G1} \text{ in Case 1,}$$
$$e^{S2} = e^{G2} \text{ in Case 2, and}$$
$$e^{S3} < e^{G3} \text{ in Case 3.}$$

The results say that the borrowers under the generic registration have more incentive for R&D than that under the specific registration in Case 1 and 3. This means that the generic registration provides much powerful incentive for the innovators. There is no difference on efforts of the borrower

in Case 2 under both registrations. In Case 2, where the relative value of outside option is higher than Case 3 but is not high enough to induce the effort. When the concerned project value is not high such as Case 2, there is no difference on the efforts, which depend only on the outside option, between both registrations.

From the discussion of Section 3.1, Case 3 under each registration is a more important environment for consideration of R&D, where the value of the concerned project is much higher than that of alternative one. In such important Case 3, the generic registration gives the entrepreneurs stronger incentive than the specific registration.

From the above argument we find the comparison of the efforts of the lender's evaluation:

Proposition 4. *The efforts by the lender under the generic registration exceed that under the specific registration:*

$$q^S < q^{Gi}, \text{ where } i = \{1, 2, 3\}.$$

One reason why the effort under the generic registration is better is because the scope to collateralize assets under the generic registration is larger than that under the specific registration, i.e., $ev_z + (1-e)v_x > v_x$. Another reason is because the efforts of the borrower and lender are complementary relation under the generic registration but the efforts under the specific registration are independent relation. The relationship between the efforts of the borrower and lender is complement is important because the relationship influences not only the magnitude of the efforts but also the reaction of the efforts to exogenous variables that we will see next.

Finally, let us consider the difference on the comparative statistics of the

efforts between the registrations. This is the comparative statistics on (e, q) with respect to the value of new product y_z .

Proposition 5.

$$\frac{\partial e^{G1}}{\partial y_z} > \frac{\partial e^{S1}}{\partial y_z} > 0,\ \frac{\partial e^{G2}}{\partial y_z} = \frac{\partial e^{S2}}{\partial y_z} = 0,\ \frac{\partial e^{G3}}{\partial y_z} > \frac{\partial e^{S3}}{\partial y_z} > 0,$$
$$\frac{\partial q^{S}}{\partial y_z} = 0,\ \frac{\partial q^{G1}}{\partial y_z} > 0,\ \frac{\partial q^{G2}}{\partial y_z} = 0,\ \ and\ \frac{\partial q^{G3}}{\partial y_z} > 0.$$

From $\frac{\partial e^{G}}{\partial y_z} > \frac{\partial e^{S}}{\partial y_z}$ in Case 1 and 3, the marginal effect of new development on the effort by the borrower under the generic registration is higher than that under the specific registration. That is, the difference in the efforts increases as the value of the R&D product increases. This is because that an increase in y_z affects not only directly the borrower's effort but also indirectly the effort through an increase in the lender's effort under the generic registration. This is the complementary effect. On the other hand, an increase in y_z affects directly the borrower's effort but there is no complementary effect through the lender's effort under the specific registration. Case 3 is the important environment for R&D, where the concerned project value is much higher than alternative one, and the generic registration provides again much incentive from the viewpoint of the marginal effect on the R&D.

Potentially higher value project, which is much valuable than alternative project (such as in Case 3 of our model), leads to little incentive for the parties, and it is important to improve the situation. We find from the Propositions 3 and 5 that the generic registration gives the borrower much powerful incentive for R&D with regard to not only the magnitude of the effort but also the marginal effect through the complementary effect in comparison with the specific registration. This is the important implication for

the promotion of the R&D. The relationship between the R&D effort of the borrower and the evaluation effort of the lender is independent under the specific registration. On the other hand, the relationship under the generic registration is complementary, and this can help to improve both efforts. We can say that the generic approach on registration of inside collateral contributes to create the true partnership through the credit contract and to promote innovation.

6 Concluding remarks

We compare the inside collateral institutions between the specific and generic registrations, and examine the effect of the legal difference on incentives through the credit contract. The specific registration, which allows the lenders to secure only the existing asset of the business, provides relatively little incentive to develop new product, and this problem deteriorates especially in the potential high value project. The generic registration, which allows the lenders to secure the future assets as well as the existing asset, gives the entrepreneurs relatively high incentive for R&D through the complementary effect. In other words, the generic registration makes the entrepreneurs and lenders complementary relationship.

Appendix

Proof of Proposition 1

The Lagrangian under the specific registration by using the ICC is

$$\mathcal{L}^S = p[e(\Delta y - \frac{d'(e)}{p}) + R_x] + (1-p)qv_x - c(q) \\ + \lambda_1[ed'(e) - d(e) + p(y_z - R_x) - u] + \lambda_2[y_x - R_x],$$

where $\Delta y = y_z - y_x$.

The Kuhn-Tucker conditions for $(e^* > 0, q^* > 0, R_x^* > 0)$ are as follows:

$$\frac{\partial \mathcal{L}^S}{\partial e} = p\Delta y - d'(e) - ed''(e) + \lambda_1 ed''(e) = 0 \tag{12}$$

$$\frac{\partial \mathcal{L}^S}{\partial q} = (1-p)v_z - c'(q) = 0 \tag{13}$$

$$\frac{\partial \mathcal{L}^S}{\partial R_x} = p - \lambda_1 p - \lambda_2 = 0 \tag{14}$$

Given $\lambda_1 = 0$, then we get $p = \lambda_2$ from (14), which means that $y_x > R_x$. Similarly, given $\lambda_1 = 1$, then we get $\lambda_2 = 0$. Given $0 < \lambda_1 < 1$, then $\lambda_2 > 0$ from $p(1-\lambda_1) = \lambda_2$. Therefore, we can classify this problem into three cases: Case 1 $(\lambda_1 = 1, \lambda_2 = 0)$, Case 2 $(0 < \lambda_1 < 1, \lambda_2 > 0)$ and Case 3 $(\lambda_1 = 0, \lambda_2 > 0)$.

Apparently, for all cases, q^S is determined by $(1-p)v_z = c'(q)$, which mean that for q marginal benefit equals to marginal cost.

Case 1 is the case when the PC is binding and the FC is not binding. From (12), e^{S1} is determined by $p\Delta y = d'(e)$. The ICC is $p[\Delta y - (R_z - R_x)] = d'(e)$. These two equations must have the same value of e, and we require that $R_z = R_x$. Since the PC is binding, by using the ICC we have

$$R_z = y_z + \frac{ed'(e) - d(e) - u}{p}. \tag{15}$$

Case 2 is the case when the PC is binding and the FC is binding. From $R_x = y_x$ and the ICC, we have $R_z = y_z - \frac{d'(e)}{p}$. In addition, from the ICC $R_z = \Delta y - \frac{d'(e)}{p} + R_x$. Since by (12) $p\Delta y - d'(e) = ed''(e) > 0$, we have $R_z > R_x$. Since the PC is binding, e^{S2} is determined by $ed'(e) - d(e) = u$.

Case 3 is the case when the PC is not binding and the FC is binding. Similarly to Case 2, we have $R_x = y_x - \frac{d'(e)}{p}$ and $R_z > R_x$. From (12), e^{S3}

is determined by $p\Delta y - d'(e) - ed''(e) = 0$.

Proof of Proposition 2

The Lagrangian under the generic registration by using the ICC is

$$\mathcal{L}^G = p[e(\Delta y - \frac{d'(e)}{p}) + R_x] + (1-p)q[ev_z + (1-e)v_x] - c(q) \\ + \mu_1[ed'(e) - d(e) + p(y_z - R_x) - u] + \mu_2[y_x - R_x].$$

The Kuhn-Tucker conditions for $(e^* > 0, q^* > 0, R_x^* > 0)$ are as follows:

$$\frac{\partial \mathcal{L}^G}{\partial e} = p\Delta y - d'(e) - ed''(e) + (1-p)q(v_z - v_x) + \mu_1 ed''(e) = 0 \quad (16)$$

$$\frac{\partial \mathcal{L}^G}{\partial q} = (1-p)[ev_z + (1-e)v_x] - c'(q) = 0 \quad (17)$$

$$\frac{\partial \mathcal{L}^G}{\partial R_x} = p - \mu_1 p - \mu_2 = 0 \quad (18)$$

From (18), similarly to Proposition 1, we can classify this problem into three cases: Case 1 ($\mu_1 = 1, \mu_2 = 0$), Case 2 ($0 < \mu_1 < 1, \mu_2 > 0$) and Case 3 ($\mu_1 = 0, \mu_2 > 0$).

Case 1 is the case when the PC is binding and the FC is not binding. The efforts (e^{G1}, q^{G1}) satisfy the following equations:

$$p\Delta y + (1-p)q(v_z - v_x) = d'(e) \quad (19)$$

$$(1-p)[ev_z + (1-e)v_x] = c'(q) \quad (20)$$

The ICC is

$$\Delta y - (R_z - R_x) = d'(e) \quad (21)$$

The equations (19) and (21) have the same value of e, and we have

$$(1-p)q(v_z - v_x) = R_x - R_z > 0 \tag{22}$$

and $R_x > R_z$.

From the PC and ICC, we have

$$R_x = y_x + \frac{ed'(e) - d(e) - u}{p} \quad \text{and} \tag{23}$$

$$R_z = y_x + \frac{ed'(e) - d(e) - u}{p} - (1-p)q(v_z - v_x). \tag{24}$$

Case 2 is the case when the PC is binding and the FC is binding. Since the PC is binding, e^{G2} is determined by $ed'(e) - d(e) = u$. q^{G2} is determined by $(1-p)[e^{G2}v_z + (1-e^{G2})v_x] = c'(q)$. Since $R_x = y_x$, $R_z = y_z - d'(e)/p$.

Case 3 is the case when the PC is not binding and the FC is binding. The efforts (e^{G3}, q^{G3}) satisfy the following equations:

$$p\Delta y + (1-p)q(v_z - v_x) = d'(e) + (1-\mu_1)ed''(e) \tag{25}$$

$$(1-p)[ev_z + (1-e)v_x] = c'(q) \tag{26}$$

Since $R_x = y_x$, $R_z = y_z - d'(e)/p$.

Proof of Proposition 5

Let us consider the difference on the comparative statistics of the efforts between the registrations. This is the comparative statistics in Case 1 and 3.

$$\frac{\partial e^S}{\partial y_z} = \frac{p}{d'' + (1-\lambda_1)(d'' + ed''')} > 0, \tag{27}$$

$$\frac{\partial e^G}{\partial y_z} = \frac{p}{d'' + (1-\mu_1)(d'' + ed''') - \frac{1}{c''}\{(1-p)\Delta v\}^2} > 0, \tag{28}$$

$$\frac{\partial q^S}{\partial y_z} = 0, \text{ and} \tag{29}$$

$$\frac{\partial q^G}{\partial y_z} = \frac{p(1-p)\Delta v/c''}{d'' + (1-\mu_1)(d'' + ed''') - \frac{1}{c''}\{(1-p)\Delta v\}^2} > 0. \tag{30}$$

where $\Delta v = v_z - v_x$, and λ_1 and μ_1 are Lagrange multipliers. Case 1 applies when $\lambda_1, \mu_1 = 1$, and Case 3 applies when $\lambda_1, \mu_1 = 0$.

From $\frac{\partial e^G}{\partial y_z} > \frac{\partial e^S}{\partial y_z}$ for the same level of Lagrange multipliers ($\lambda_1 = \mu_1$), we can see that in a similar environment, the marginal effect of new development on the effort by the borrower under the generic registration is higher than that under the specific registration.

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