1 A Model of Coordination and Asymmetric Information

- One base technology and one follow-on innovation
- follow-on technology can be of high or low value, $\lambda \in \left\{\underline{\lambda}, \overline{\lambda}\right\}$ with $\underline{\lambda} < \overline{\lambda}$
- two identical potential follow-on inventors, each knows λ
- owner of the base technology only knows that with probability α the follow-on technology is worth $\overline{\lambda}$
- follow-on technology an innovator needs to sustain a cost equal to S with $\overline{\lambda}/2 - S < 0$ and $\underline{\lambda} - S > 0$.

1.0.1 No patent on the base technology

		Innovator 2	
		Invest	Not-Investing
Innovator 1	Invest	$\lambda/2 - S, \lambda/2 - S$	$\lambda - S, 0$
	Not Invest	$0, \lambda - S$	$0, 0$

- two asymmetric pure strategies Nash equilibria in which one of the two follow-on innovators invests and the other does not
- literature on economic coordination suggests asymmetric pure-strategy equilibria are unconvincing in a symmetric setting like ours. Bolton and Farrell (1990) argue that it is inappropriate to focus on asymmetric pure-strategy equilibria because it is not clear how firms "find" one of those equilibria.
- we therefore focus on the symmetric mixed strategy equilibrium in which each innovator invests with probability

$$p(\lambda) = \frac{2(\lambda - S)}{\lambda}$$

with $\lambda \in \left\{\underline{\lambda}, \overline{\lambda}\right\}$.

- follow-on innovation with probability $1 - (1 - p(\overline{\lambda}))^2$ if the second generation technology has high value and with probability $1 - (1 - p(\underline{\lambda}))^2$ if the follow-on technology has low value.
- expected level of follow-on innovation

$$\begin{aligned} I_{NOP} &= \alpha \left(1 - (1 - \frac{2(\overline{\lambda} - S)}{\overline{\lambda}})^2\right) + (1 - \alpha) \left(1 - (1 - \frac{2(\underline{\lambda} - S)}{\underline{\lambda}})^2\right) \\ &= \alpha \left(1 - (\frac{2S - \overline{\lambda}}{\overline{\lambda}})^2\right) + (1 - \alpha) \left(1 - (\frac{2S - \underline{\lambda}}{\underline{\lambda}})^2\right) \end{aligned}$$

Patent on the base technology

- Patentability of the follow-on technology induces the owner of the base technology to license it to only one of the two follow-on innovators. We assume that the patentee makes a take-it-or-leave it offer to the follow-on innovator.
- licensing fee $= \underline{\lambda} - S$ will be accepted both when the value of the follow-on innovation is high as well as when the value is low. Fee $= \overline{\lambda} - S$ will be accepted only when the second generation technology has high value.
- in expectation it is more profitable to offer $\overline{\lambda} - S$ if $\alpha(\overline{\lambda} - S) \geq \underline{\lambda} - S$ or

$$\alpha \geq \widetilde{\alpha} \equiv \frac{\underline{\lambda} - S}{\overline{\lambda} - S}$$

- Thus patent protection on a base technology the expected level of follow-on innovation will be:

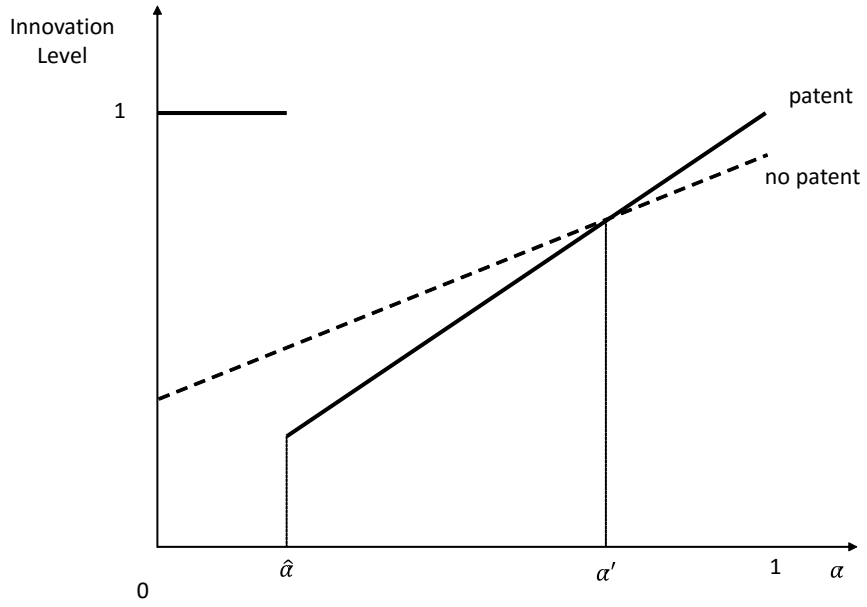
$$I_P = \begin{array}{c} 1 \text{ if } \alpha \leq \widetilde{\alpha} \\ \alpha \text{ if } \alpha > \widetilde{\alpha} \end{array}$$

Comparison of the two regimes

Comparing the follow-on innovation activity with and without patent on the base technology we obtain the following result.

Proposition 1 *For $\overline{\lambda}$ large enough there exists $\alpha' > \widetilde{\alpha}$ such that $I_{NOP} > I_P$ if $\alpha \in [\widetilde{\alpha}, \alpha']$ and $I_P < I_{NOP}$ if $\alpha > \alpha'$ or $\alpha < \widetilde{\alpha}$.*

The proposition shows that whether patent protection on the base technology is associated with higher or lower follow-on innovation depends on a trade-off between *coordination failure* and *bargaining breakdown.* The following figure illustrates the result.



Patents and follow-on innovation

2 Relation with previous literature

There are two main assumptions in the model:

Assumption 1: $\lambda/2 - S < 0$ for $\lambda \in \left\{\underline{\lambda}, \overline{\lambda}\right\}$

Assumption 2: *Follow-on innovators know the value of the follow-on technology. The patentee only knows that with probability α the follow-on technology is worth $\overline{\lambda}$ and that with probability $1-\alpha$ is worth $\underline{\lambda}$*

- coordination problem is driven by assumption 1. If we drop it, so $\lambda/2 - S > 0$ for $\lambda \in \left\{\underline{\lambda}, \overline{\lambda}\right\}$ follow-on innovators invest with probability 1 in the symmetric equilibrium without patent.
- asymmetric information problem is driven by assumption 2. Dropping it, there is always follow-on innovation with a patent on the base technology
- dropping both assumptions, follow-on innovation takes place with and without patent rights on base technology, as in Green and Scotchmer (1995)
- imposing assumption 1 only, follow-on innovation when there is a patent on the base technology, as in Kitch (1977)
- imposing only assumption 2, innovation is higher without patent protection, as in Bessen and Maskin (2009)
- If both assumption 1 and assumption 2 hold, the prediction of the model is ambiguous and a valid patent on a base technology may be associated with greater or lower downstream innovation depending on the relative strength of the coordination failure and asymmetric information forces.