“Infant Industries,” Industrial Policy, and Development in a Model of Productive Variety

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The Issues:

How much does it benefit a country to develop an “infant industry”—to subsidize an expansion of the scope of products that it can produce? Developments have wrestled with this question ever since John Stuart Mill coined the phrase “infant industry.” The question has taken on more salience as we wonder whether the proper guide to the twenty-first century might be not Adam Smith but Joseph Schumpeter: that we should stop thinking of the good firm as a competitive price taker and instead think of the good firm as a dynamic and innovative monopolist.

Robert Barro (2007a) has argued that innovation is of immense value—hence implicitly that “infant industries” are well-deserving of subsidy. In his view it is not just the *profits* but the *revenues* of an innovating company that brings new technology to the world (his example is Microsoft) or to the country that serve as a likely rough lower bound to the social value of its innovations and contributions to economic growth. If firm revenues are a rough match to contributions to economic growth, than the profits of innovators are almost surely not too large but too small: they are insufficient to provide the efficient spur to research and development, and governments should be thinking of industrial policy subsidies to dynamic innovators rather than of antitrust policy to curb their profits.

Let's try to think about the simple analytics here by following Barro (2007b), who follows a line of authors back to at least Romer (1994), in building our model.

The Framework:

Start with the standard assumption that final output Y are is a function of labor (and other factor inputs) L and of intermediate industrial goods produced by technological capability (“ideas”) I according to the production function:[1]

$$Y = L^{1-\alpha} I^{\alpha}$$

Where I is a Dixit-Stiglitz aggregation of N varieties of monopoly-produced intermediate goods:

$$I = \left[\sum_{j=1}^{N} \left(x_j \right)^{\sigma} \right]^{(1/\sigma)}$$

x(j) is the amount of final goods purchased to produce the jth variety of the intermediate good, σ is a parameter between 0 and 1, and where each of the N intermediate industrial goods is produced by a different monopolist, each of which has acquired expertise in the "idea" of producing its particular variety. The acquisition of technological capability in this model takes the form of investment to increase the number N of ideas.

The greater the economy’s technological capability—the greater the number N of varieties of intermediate industrial goods that the economy can produce—the better. And the more distinct are the varieties--the less they are substitutes—the smaller is the parameter σ—the better. If X are the total inputs devoted to producing intermediate goods, then we can solve for the aggregate quantity of technologically-sophisticated intermediate goods in the case in which the X are evenly divided among all the N varieties:

The aggregate quantity of intermediate industrial goods is:

$$I = \left[\sum_{j=1}^{N} \left(x_j \right)^{\sigma} \right]^{1/\sigma}$$

$$I = \left[\sum_{j=1}^{N} \left(\frac{X}{N} \right)^{\sigma} \right]^{1/\sigma}$$

$$I = \left[N \left(\frac{X}{N} \right)^{\sigma} \right]^{1/\sigma}$$

$$I = \left[\left(X \right)^{\sigma} \right]^{1/\sigma} \left[\left(\frac{N}{N^{\sigma}} \right) \right]^{1/\sigma}$$

$$I = XN^{1/\sigma - 1}$$

When σ is near zero, the number of varieties and thus the technological capability matters a lot. When σ is one, the number of varieties doesn't matter for society's ultimate welfare at all.

Set the price of the final good Y to be equal to one, to be numeraire. The monopolist intermediate goods producers purchase the final good and sell it, transformed using their intellectual property, at a price P(j) so that the operating profits of the jth monopolist are:

$$\pi_j = x_j (P_j - 1)$$

Demand x(j) for the jth intermediate good by the competitive industry of final goods producers will be determined by:

$$P_j = \frac{\partial Y}{\partial x_j} = \alpha\left(\frac{Y}{I}\right)\left(\frac{\partial I}{\partial x_j}\right) = \alpha\left(\frac{Y}{I}\right)\frac{\partial}{\partial x_j}\left[\sum_{j=1}^{N}\left(x_j\right)^{\sigma}\right]^{1/\sigma}$$

$$P_j = \frac{\partial Y}{\partial x_j} = \alpha\left(\frac{Y}{I}\right)\left(\frac{1}{\sigma}\right)\left[\sum_{j=1}^{N}\left(x_j\right)^{\sigma}\right]^{(1/\sigma)-1}\sigma\left(x_j\right)^{\sigma-1}$$

$$P_j = \alpha Y \frac{\left(x_j\right)^{\sigma-1}}{\left[\sum_{j=1}^{N}\left(x_j\right)^{\sigma}\right]}$$

$$\left(x_j\right)^{1-\sigma} = \frac{\alpha Y}{I^{\sigma} P_j}$$

$$x_j = \left(\frac{\alpha Y}{I^{\sigma} P_j}\right)^{1/(1-\sigma)}$$

Which implies that the profit-maximizing price for the jth monopolist is determined by:

$$\pi_j = x_j(P_j - 1) = \left(\frac{\alpha Y}{I^{\sigma}}\right)^{1/(1-\sigma)}\left(P_j^{\sigma/(\sigma-1)} - P_j^{1/(\sigma-1)}\right)$$

$$0 = \frac{\partial \pi_j}{\partial P_j} = \left(\frac{\alpha Y}{I^{\sigma}}\right)^{1/(1-\sigma)}\left[\frac{\sigma}{(\sigma-1)}P_j^{1/(\sigma-1)} - \frac{1}{(\sigma-1)}P_j^{-\sigma/(\sigma-1)}\right]$$

$$0 = \frac{\sigma}{(\sigma-1)} - \frac{1}{(\sigma-1)}P_j$$

And is:

$$P_j = \frac{1}{\sigma}$$

But (following Barro (2007b)) the monopolist’s control over its ability to produce that particular variety is imperfect. If its profits are too high, other competitors might enter the market and compete. Thus limit-pricing industrial-goods producers charge only a fraction λ of the profit-maximizing price, with λ greater than σ, so that in fact:

$$P_j = \frac{\lambda}{\sigma}$$

In order to induce efficient production at any one point in time, we want to set λ to maximize C right now: λ = σ, so that the intermediate industiral inputs are priced at their short-run social marginal cost. But that would eliminate profits—and in this institutional setup it is the expectation of future monopoly profits that induces the research and development and innovation that expands the country's technological capability and thus the number of varieties N.

The Cobb-Douglas form of the final output function means that the amount final goods producers spend on purchasing intermediate goods is equal to α times final output Y, which means that the quantity of intermediate goods is:

$$X = \frac{\alpha\sigma Y}{\lambda}$$

Which means that Y is:

$$Y = L^{1-\alpha} I^{\alpha}$$

$$Y = L^{1-\alpha} X^{\alpha} N^{\alpha/\sigma-\alpha}$$

$$Y = L^{1-\alpha} N^{\alpha/\sigma-\alpha}\left(\frac{\alpha\sigma Y}{\lambda}\right)^{\alpha}$$

$$Y^{1-\alpha} = (\alpha\sigma/\lambda)^{\alpha} L^{1-\alpha} N^{\alpha/\sigma-\alpha}$$

$$Y = (\alpha\sigma/\lambda)^{\alpha/(1-\alpha)} L N^{(\alpha(1-\sigma))/(\sigma(1-\alpha))}$$

And so net consumable output C is:

$$C = (1 - \alpha\sigma / \lambda)Y$$

$$C = (1 - \alpha\sigma / \lambda)(\alpha\sigma / \lambda)^{\alpha/(1-\alpha)} L N^{(\alpha(1-\sigma))/(\sigma(1-\alpha))}$$

The Value of Innovation:

In this framework, the value of innovation—of acquiring the technological capability to make a marginal additional variety dN—is simply the derivative of C with respect to N:

$$dC = \frac{((\sigma(1-\alpha))/(\alpha(1-\sigma))C}{N} dN$$

Barro (2007a) argued that the social value dC of inventing the marginal Nth variety is likely to be bounded below by the total spending dS on that marginal Nth variety. With the monopolist charging a price $P = \lambda/\sigma$ for that marginal variety, total spending on that newly-invented marginal intermediate good is:

$$dS = \frac{\alpha C}{N(1 - \alpha\sigma / \lambda)} dN$$

(Note: dS is *not* the increase in intermediate goods spending. dS is spending on the additional possible intermediate good.) And the ratio of social benefit to total sales of the intermediate good is:

$$\frac{dC}{dS} = \frac{(1-\sigma)(1 - \alpha\sigma / \lambda)}{\sigma(1-\alpha)}$$

When prices are equal to marginal cost ($\lambda = \sigma$), then:

$$\frac{dC}{dS} = \frac{(1-\sigma)}{\sigma}$$

which will be greater than or less than zero depending on whether σ is less than or greater than 1/2. The closer is σ to one, the smaller the relative benefit.

When prices are above marginal cost ($\lambda > \sigma$), the ratio of social benefit to sales is lower, as it should be.

When there is no threat of entry and so $\lambda = 1$, then the ratio of social benefit to sales increases with α:

$$\frac{dC}{dS} = \frac{(1-\sigma)(1-\alpha\sigma)}{\sigma(1-\alpha)}$$

If α is near one, then the ratio of the social benefit from the marginal intermediate good to its sales becomes very large; for small α the ratio depends on σ. As σ approaches zero the ratio of the social benefit from to the sales of the marginal intermediate good variety becomes arbitrarily large: for σ near zero, an industrial firm's sales vastly understate its social value. As σ approaches one, the ratio of the social benefit from to the sales of the marginal intermediate goods variety approaches zero: an industrial firm's sales vastly overstate its social value. This is how it should be: an invention that does something completely new and valuable (σ near zero) should have a much bigger impact than an invention that is a close substitute for already existing technologies (σ near one).

In the limit in which σ=1, there is--in conventional models--no benefit at all to learning how to produce a new variety. When σ=1:

$$C = (1-\alpha\sigma/\lambda)(\alpha\sigma/\lambda)^{\alpha/(1-\alpha)}L$$

And net final output does not depend on N, so dC/dS = 0.

The Utility of Industrial Policy:

Of particular interest from the standpoint of industrial policy is the ratio of social value to new firm profits. New firm profits are:

$$\pi_j = x_j\left(\frac{1-\sigma}{\sigma}\right)$$

$$\pi_j = \left(\frac{Y}{N}\right)\left(\frac{\lambda-\sigma}{\sigma}\right)$$

$$\pi_j = \left(\frac{(1-\alpha\sigma/\lambda)Y}{N}\right)\left(\frac{\lambda-\sigma}{\sigma}\right)$$

and so the ratio of social value created to private profit is:

$$\frac{dC}{\pi_j dN} = \frac{(1-\sigma)(1-\alpha\sigma/\lambda)}{\sigma(1-\alpha)}\left(\frac{\lambda}{(\lambda-\sigma)}\right)$$

If λ is equal to one:

$$\frac{dC}{\pi_j dN} = \frac{(1-\alpha\sigma)}{\sigma(1-\alpha)}$$

Since dC/(π(j)dN > 1, incentives for innovation are always "too small" in economists' standard sense.

The desire to induce efficiency in static production—to get final-goods producers using the right amount of intermediate inputs—would lead us to wish to push λ down below one, toward the value λ = σ at which intermediate goods' prices are equal to short-run marginal social cost. But the value of an innovative variety is already greater than the profits when λ = 1—and pushing λ down will only worsen the incentives for innovation. Whether industrial subsidy policy is desirable (and how much is desirable) then turns on three things:

- The rate of discount
- How much each marginal diminution of monopoly profits reduces the pace of innovation.

- The size of the static Harberger triangle produced by the elevation of price over marginal cost made possible by the absence of antirust policy.

What kind of industrial policy is desirable also depends on a great many unmodeled considerations. There are a number of possibilities: government investment in new technologies, non-profit (i.e., university) investment, raising λ by shoring up intellectual property rights, raising λ by imposing tariffs on imports, direct payments to firms—either beforehand or prizes upon delivery—bounties for manufacturing exports (in the case of developing countries seeking to encourage technology transfer), or manipulating the exchange rate in order to provide a subsidy to successful exporters. Different countries have tried all these policies—but perhaps the most common one for a developing country is the relatively indirect but even-handed and hard-to-corrupt policy of exchange-rate manipulation. Why this is so is an open question.

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