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Technical Annex

The Effects of Biotechnology Policy on Trade and Growth

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This document is the technical annex to the full paper "The Effects of Biotechnology Policy on Trade and Growth," which is available separately.

Introduction

The model uses three trading blocks differentiated by their relative R&D capabilities, capital-labour ratios, and regulatory policies relevant to biotech production and consumption. North America (N) and Europe (E) constitute the two "North" trading blocs; the "South" trading block (S) represents developing countries. Each block is characterized by three sectors: an outside-goods sector, a biotech sector, and an R&D sector. The outside-goods sector includes traditional (non-biotech) agricultural

products that we assume do not experience innovation. The biotech sector is represented by those goods that can be replaced by new goods of higher quality through innovation resulting from research and development. The R&D sector, therefore, affects innovation in the biotech sector. The underlying assumptions of the neo-Schumpeterian model used are that:

1. R&D is inherently a risky investment;
2. biotech products are made obsolete and replaced by the next generation of higher quality products;
3. successful researchers obtain some degree of monopoly power and rents from their discovery of the next generation of products; and
4. the lure of monopoly profits draws firms into the R&D process.

The assumptions concerning initial endowments for each trading block are as follows: capital/labour (K/L) ratios are given as $(K/L)^N > (K/L)^E > (K/L)^S$; agricultural research and development expenditures are $R\&D^N > R\&D^E > R\&D^S$; and the gross domestic incomes (GDP) are $GDP^N > GDP^E > GDP^S$. N and E have the technical capacity to undertake biotechnology R&D, but S does not. The difference between N and E is that N produces and consumes biotechnology products, but E has regulations that effectively prohibit either production or consumption of these products. Intellectual property rights (IPRs) and protection are assumed equivalent in N and E but lower in S.

The Hecksher-Ohlin-Samuelson diagram in figure 1 illustrates the initial model assumptions. The bottom left corner (O) is the origin for E, while N and S make up the balance of the world with their origin at the top right (O_1). E is separated to

highlight its prohibitive biotech policies. The endowment points (e^i , I=E, S, N) reflect the capital-labour endowments of the countries. The polygon in the interior of the box represents the factor-price equalization set. For endowments lying within this box, trade in final products results in factor-price equalization across trading blocks. Each line segment ($\overline{OR_W}, \overline{R_W B_W}, and \overline{B_W O_1}$) represents the equilibrium world allocation of capital and labour to produce R&D, biotech goods, or outside goods, respectively. The relative slopes of the production vectors reveal that R&D is the most capital intensive while outside goods are the most labour intensive.

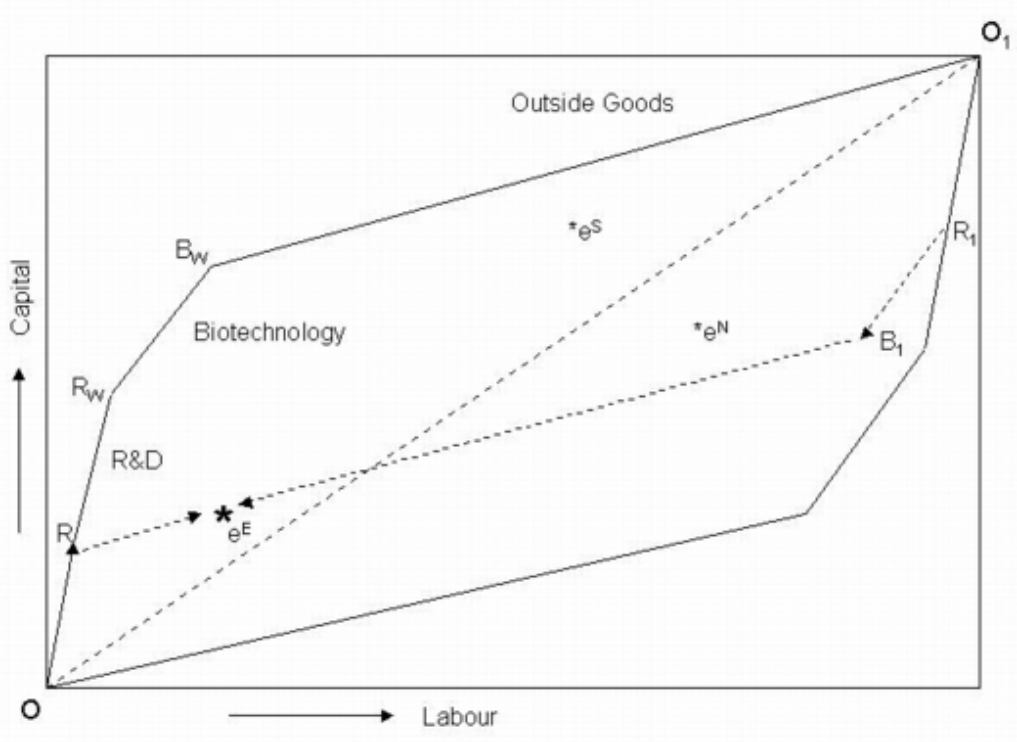

Figure 1 Factor content of production with no EU biotech production

Each vector in figure 1 represents the allocation of a trading block's capital and labour utilized in the production of a specific product. The moratorium on biotech production means that E produces only R&D ($\overrightarrow{OR}$) and outside goods ($\overrightarrow{\mathrm{Re}^{E}}$). The N and S trading blocks produce all biotech goods ($\overrightarrow{O_1 R_1}$) as well as the balance of R&D ($\overrightarrow{R_1 B_1}$) and outside goods ($\overrightarrow{B_1 e^{E}}$). Note that E still engages in R&D, which results in biotechnology product or process innovations, which are then transferred to the biotech producers in N & S.

Effects of Consumption Restrictions

As a point of departure, consider the standard Hecksher-Ohlin-Samuleson analysis assuming homothetic preferences (no consumption restrictions in E of biotechnology

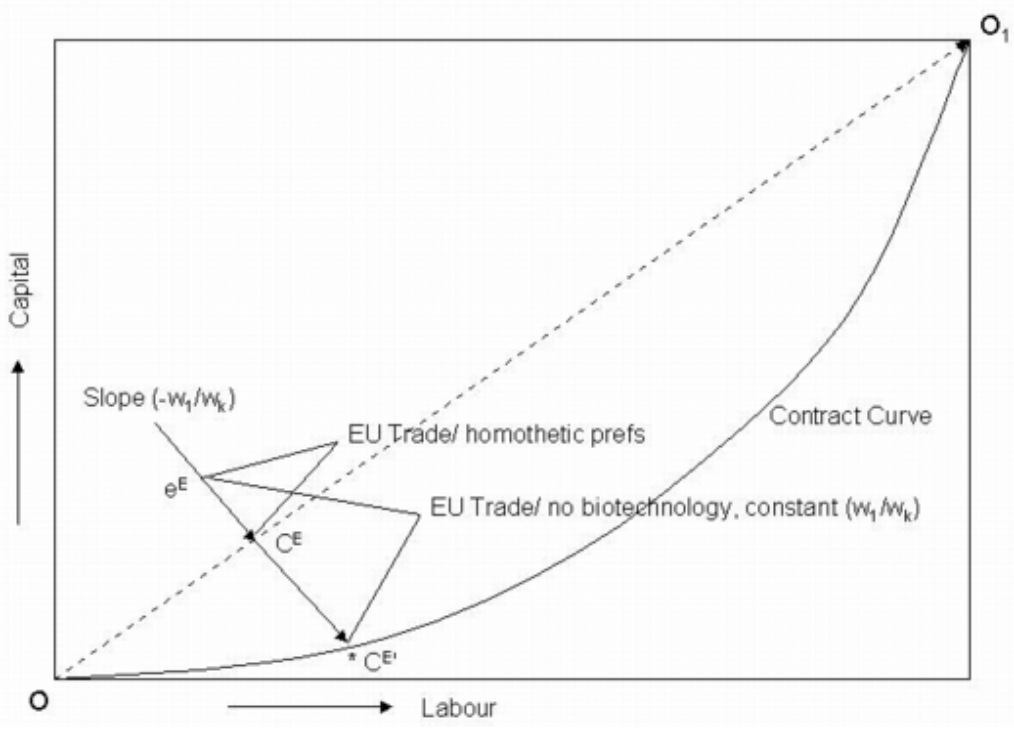

Figure 2 Factor content of consumption and trade with EU biotech consumption

products). In this case the E consumption point C^E, lies on the diagonal (figure 2). Trading takes place along the factor price ratio line ($-w_l/w_k$), which is determined by world equilibrium. The vector from the endowment point to the consumption point represents the factor content of trade. The result is that E consumes more labour-intensive outside goods than it produces, therefore E will import the balance of its outside goods from N & S (vector from E^E to C^E). N, like E, will import labour-intensive outside goods and export capital-intensive goods to S. S's trade mix is the opposite of N's. These short-run results are standard Hecksher-Ohlin-Samuelson outcomes.

The problem with the Hecksher-Ohlin-Samuelson model is that preferences are not homothetic. When the biotech consumption restrictions are enforced (non-homothetic preferences), the results become more interesting. Figure 2 illustrates heuristically what happens to E trade when the policy restrictions on biotech products are enforced. They now consume on the contract curve (a locus of points representing the optimal allocation of production factors), which lies below the diagonal because E consumers will not consume biotech goods. E consumers prefer outside goods, which are labour-intensive goods, which means that E imports more labour-intensive goods in the short run than it would have without consumption restrictions.

The overall trade effects up to this point are as follows: N produces all three products, but has a comparative advantage in R&D and biotechnology production sectors, hence it is a net exporter of biotechnology R&D and products and a net importer of outside goods; E exports biotechnology R&D and imports labour-

intensive goods; and S imports biotechnology R&D and exports outside goods. Depending on how labour intensive the S endowment is, S may import or export biotechnology products, with greater labour intensity associated with greater imports.

Biotech R&D and Growth

World production and consumption are not constant over time. Indeed, one of the primary effects of R&D is to expand production, and thus consumption, through productivity increases. To represent growth in a Hecksher-Ohlin-Samuelson framework, we follow Dinopoulos, Oehmke and Segerstrom (1993) and interpret production factors as measured in efficiency units. An increase in factor productivity is assumed to be equivalent to an increase in the efficiency of the factors employed in production (as is the case in any constant-returns-to-scale production function). In this context, the Hecksher-Ohlin-Samuelson framework allows exploration of the efficiency-adjusted factor content of international trade.

R&D increases factor productivity, and thus increases the effective amount of factors available to the world economy. We assume that technologies are owned by the inventor until the next-generation innovation is discovered. Upon this discovery, the previous-generation innovation becomes public knowledge – that is, the firm owning the previous generation ceases to spend money protecting its now obsolete invention (this is also consistent with Bertrand competition between the owners of the previous and current generations of technology).

The initial R&D race to discover the first biotech innovation increases the world's efficiency-adjusted factor endowment (figure 3). This increase is in proportion to the

capital/labour ratio employed in the R&D sector, which created the first biotech innovation. The world increase in efficiency-adjusted factors is represented by the movement of the second origin from O_1 to ON_1 in figure 3. The points e^N and e^S have been re-scaled so that the vectors $\overrightarrow{O_1' e^N}$ (not pictured) and $\overrightarrow{O_1' e^S}$ (not pictured) in figure 3 are equal to $\overrightarrow{O_1 e^N}$ and $\overrightarrow{O_1 e^S}$ in figure 1. The discovering firm owns the first biotech innovation, and consequently the increase in efficiency-adjusted factors. This firm is located in N with probability $R\&D^N/R\&D$, and in E with probability $R\&D^E/R\&D$. This expected increase in efficiency-adjusted factors is multiplied by the probability that the firm is located in N or E. The vector $\overrightarrow{e^N e^{N'}}$ (not pictured) represents the expected increase in the N efficiency-adjusted factor endowment. The vector $\overrightarrow{e^E e^{E'}}$ represents the expected increase in the E efficiency-adjusted factor endowment. S, owning none of the R&D firms, receives no increase in efficiency-adjusted factors after the initial R&D discovery.

The effects of the discoveries of later innovations are somewhat more complicated. Upon the discovery of innovation 2, the discovering firm gains monopoly rents, and the owners of innovation 1 lose their monopoly rents. The net effect will depend on the relative magnitude of the rents. In the steady-state in which R&D expenditures and monopoly rents are constant for each R&D race, the net effect of the discovery of innovation 2 on industry monopoly rents is nil. That is, the asset increases to ON_1 in figure 3 are "a one-time shift only". Further details on this asset adjustment are found in Dinopoulos, Oehmke and Segerstrom (1993).

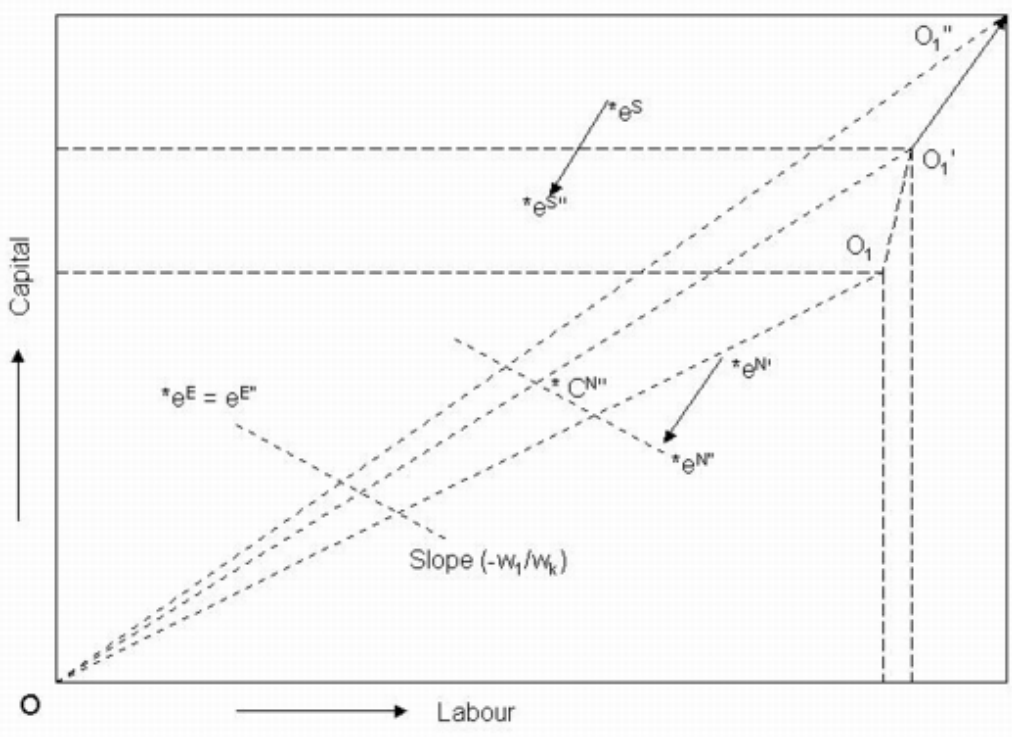

Figure 3 Asset expansion and expected asset-adjusted endowments, effective factor content of production, consumption and trade.

However, upon discovery of innovation 2, the initial innovation becomes publicly accessible. That is, the economic value of the increased efficiency from innovation 1 (compared to the no-innovation scenario) is now captured by producers rather than by a monopolist supplier of the biotechnology. With a competitive production sector this value is passed on to consumers in the form of increased production.

The value to consumers of this increased production can be measured in terms of the factor content of the production (figure 3). The increased efficiency of biotechnology production is represented by the shift in the second origin from O_1' to

O_1". The vector $\overrightarrow{O_1' O_1''}$ is drawn with the same capital/labour ratio employed in biotechnology production. The length from O_1' to O_1" is determined by the increase in efficiency attributable to the innovation. The vector from O_1' to O_1" represents the increase in factors employed with initial technology that would be necessary to produce output equal to the amount produced using factors represented by the vector $\overrightarrow{R_1 B_1}$ (figure 1) at the new technology level. Assume the effect of the innovation is to increase productivity by a factor of α. The same level of production can be achieved by increasing the quantity of capital and labour by α with no increase in productivity (under constant returns to scale). Consequently, we represent the effect of the productivity increase as an increase in the effective factor endowments. A similar efficiency adjustment is made after each successive innovation becomes publicly accessible, leading to a series of expansions from O_1' to O_1".

Because biotechnology production is more capital intensive than is the initial world endowment the world becomes more abundantly endowed in effective capital relative to effective labour. Since E produces no biotech, there is no increase in the effective factors of production employed in E (after the initial, R&D-driven asset effect). Thus $e^{E'} = e^{E''}$. Thus, as the world becomes more capital abundant, E becomes relatively less capital abundant and more labour abundant. Because E consumes relatively more of the labour-intensive outside goods, the overall effect is to diminish E's trade.

Biotechnology producers – N and S – capture the increased effective factor endowments. Similar increases in the effective endowments for N and S occur as each

successive generation of biotechnology becomes publicly accessible. The effect on N is ambiguous. If the initial endowment e^N is more (less) capital abundant than is the use of capital in biotech production, then increases in effective endowments along the capital/labour ratio determined by biotech production will make N relatively less (more) capital intensive.

Since S is initially relatively labour abundant, it too becomes more abundant in effective capital. This means that S's production will shift to more capital-intensive goods, namely biotechnology production, and possibly biotechnology R&D. In terms of economic growth, capital expansion as modeled here largely benefits S. In the long run, it is conceivable that S will become sufficiently capital intensive to become a major exporter of biotechnology products.