Staff Paper

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Abstract

The emergence of agricultural biotechnology and policy responses to is altering global agricultural trade patterns. This paper models the effects of restrictive policies concerning the production and consumption of genetically modified agricultural products. The model relies on a Hecksher-Ohlin-Samuelson framework, adapted to include neo-Schumpeterian research and innovation. The model includes two 'North' countries, the United States (US) and the European Union (EU), and the 'South'. The EU is represented as prohibiting the production and consumption of biotech products, but not restricting biotech research relative to NA. Model results include implications for economic growth, welfare, and trade patterns for the EU, US and S, given the restrictive biotech policies of the EU.

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[1]Paper prepared for the ICABR conference on "The Shape of the Coming Agricultural Biotechnology Transformation: Strategic Investment and Policy Approaches from an Economic Perspective". University of Rome "Tor Vergata", June 17-18-19, 1999.

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The next millennium will witness tremendous change in the agricultural system. Biotech is allowing us to study, design, and build new products that may not resemble agricultural products of the past. This new science is forcing the world's largest companies to reinvent themselves into what has become known as 'life-science' companies which combine and synthesize knowledge from the agricultural, biotech, chemical, food, energy environmental, pharmaceutical, and computer technology industries. The introduction of biotechnologies into the market place has caused dramatic shifts in industry structure in agriculture and related industries. The trends of mega-mergers and strategic alliances are fairly clear in the corporate world. However, where these firms decide to locate in the future and the impact on the respective countries and trade flows are not pellucid.

Contemporary agricultural economics theory focuses on the impacts of innovations on markets and market participants. Taking market structure and innovation as given, these models were designed to calculate the effects of existing innovations on social welfare (*e.g.*, Huang and

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Sexton; Alston , Sexton and Zhang; Moschini and Lapan). Regrettably, these models neglect the process of research and inventive activity that precedes innovation. Some important insights into dynamic research and competition among private-sector firms to discover next-generation innovations are found in the economics literature (*e.g.*, Segerstrom; Dinopoulos; and Barro and Sala-i-Martin). Endogenous growth resulting from research and development has been shown by Grossman and Helpman. Segerstrom, Anant and Dinopoulos applied the North-South model to economic growth and found that sequential innovation races resulted in economic growth. This paper builds on and extends the Segerstrom, Anant, and Dinopolous North-South model and the North-North model by Dinopoulos, Oehmke, and Segerstrom and examines the evolution of trade patterns, innovation, and competitive advantage in biotech products.

In this paper, the effects of restrictive policies concerning the production and consumption of genetically modified agricultural products are analyzed utilizing a Heckscher-Ohlin-Samuelson trade model. This paper utilizes a unique neo-Schumpeterian approach to investigate biotech research and development (R&D) and innovation. The defining characteristics of this approach are that: R&D is inherently a risky investment; products are made obsolete and replaced by the next generation of higher-quality products; successful researchers obtain some degree of monopoly power and rents from their discovery of the next generation of products; and that the lure of monopoly profits draws firms into the R&D process (Dinopoulos). Each of these assumptions accurately represents a part of the biotech industry. The paper concludes with a discussion of the implications for economic growth, welfare and the trade patterns for the

European Union (EU), the United States (US) and the South (S), given the restrictive biotech policies of the European Union.

The Model

In our model there are three trading blocks in the world, two are in the North, the United States (N^{US}) and the European Union (N^{EU}), and one in the South (S). Each block is characterized by three sectors: the outside good sector (which includes traditional agricultural products), the biotech sector, and the R&D sector. The outside good sector is large and determines aggregate expenditures and factor prices. Because the outside good sector does not experience innovation, aggregate sector expenditures and factor prices are treated as fixed. The biotech sector is represented by those goods that can be replaced by new goods of higher quality through research and development (Dinopoulos, Oehmke and Segerstrom). R&D takes the form of a sequence of R&D races. Each participant attempts to be the first to discover the next-generation biotech innovation. The winning firm is the first to develop the innovation and obtain a patent which protects the innovation. This firm's innovation becomes the current generation of technology, and the firm enjoys limited monopoly power. The monopoly power vanishes when a firm wins the next R&D race, which starts immediately upon completion of the previous race, and discovers the next-generation product. The new R&D winner obtains monopoly power until the next R&D race is complete.

The assumptions concerning initial endowments for each trading block are as follows: capital/labor (K/L) ratios are given as $(K/L)^{US} > (K/L)^{EU} > (K/L)^{S}$, agricultural research and development endowments are $R\&D^{US} > R\&D^{EU} > R\&D^{S}$, and the gross domestic incomes (GDP) are $GDP^{US} > GDP^{EU} > GDP^{S}$. Intellectual property rights (IPRs) and protection are assumed equivalent in the US and EU but lower in the South, and the restriction on biotech research, production and consumption are the most restrictive in the EU, US, and South, respectively.

We assume there are two types of consumers in the world, those that are willing to consume biotech products and those that are not. US and South consumers are willing to consume biotech products while EU consumers are not. The world consists of two types of governmental policies, those that allow the production of genetically modified organisms (GMOs) and those that do not. The EU does not allow production of biotech products while the US and South have no restriction on production.

The Heckscher-Ohlin-Samuelson diagram in figure 1 illustrates the model. The bottom left corner is the origin for the EU while the US and South make up the balance of the world with their origin at the top right. The EU was separated to highlight EU consumption preferences and production policies while the US and South were combined due to their similar governmental, consumption, and production policies. The endowment (E) points reflect the capital/labor ratios. The equilibrium world production of R&D, biotech goods, which are themselves the result of R&D, and outside goods are represented by the line segments in Figure 1. The relative slopes of the production vectors reveals that R&D is the most capital intensive while outside goods are the most labor intensive.

Each vector, represented by a dotted arrow, in figure 2 represents the allocation of a trading block's capital and labor utilized in the production of a specific product. The EU's moratorium on biotech production means that the EU can only produce R&D (graphically represented by the vector from the EU origin to point A) and outside goods (points A to B). The US and South produce all biotech goods (US & S origin to point G) as well as the balance of R&D (points G to D) and outside goods (points D to B). Note that the EU still engages in R&D, which results in biotech products, even though they are not allowed to produce biotech products.

Figure 3 separates out the US and the South production from EU activities. Therefore, the US origin is at the endowment point for the EU (point B in figure 2). The US and South's endowments are represented at point E and the production of goods lie on the dotted line in figure 3. Assuming that the South initially produces no R&D, due to the capital intensity of R&D, the mapping of the outside goods and biotech sector determines the production levels. The US produces all of the R&D between the US and the South (US origin to point H). Both the US and the South produce the outside goods (points I to J for the US and L to the South's origin for the S) and biotech products (points H to I for the US and J to L for the South). With the further restriction of no biotech goods produced by the EU, the result is that the South is the 'dominant' producer of biotech outputs (points L to J) in that the South devotes the greatest amount of resources to biotech production as seen by the length of the vector $| LJ | > | HI |$. This result differs from other N-S and N-N-S models as, given the technology policy restriction, the typical product life cycle of US to EU to South with corresponding evolution from monopoly to competition no longer exists. The latest biotech output will be produced in the US and the South.

With aggressive IPR laws, the South may even be the first producer of certain biotech products from R&D races.

Consumption Restrictions versus No Consumption Restrictions

To this point we have focused on production decisions. Now we consider the consumption decisions and resulting trade effects. Assuming homothetic EU preferences, it trades from its endowment, E^{EU}, to its consumption point, C^{EU}, which is on the diagonal in figure 4. Trading takes place along the factor price ratio line ($-w_l/w_k$). The result is that the EU consumes more labor intensive outside goods than it produces in the short run, therefore it imports the balance of needed outside goods.

Figure 5 is similar to figure 3 in terms representing the US and South. The endowment $E^{US\&S}$ represents the factor endowments for the US and South and $C^{US\&S}$ is the consumption point (diagonal of the trade adjusted US&S consumption point). The US, like the EU imports labor intensive outside goods and export capital intensive goods to the South. The South's trade mix is just the opposite. These short-run results from figures 4 and 5 are standard Heckscher-Ohlin-Samuelson outcomes.

When the biotech consumption restrictions are enforced, the results become more interesting. Figure 6 illustrates what happens to EU trade when the consumption policy restriction on biotech products are enforced. The contract curve, a locus of points representing the optimal allocation of production factors, lies below the diagonal because the EU consumers will not consume biotech goods. Instead, EU consumers prefer outside goods which are labor intensive goods in this model. The trade vector from the EU endowment to the diagonal reflects the trade under homothetic preferences as discussed in figure 4. When the policy is implemented, the EU's trade preferences extend to the contract curve which means that they import more labor-intensive goods in the short run than they would have without consumption restrictions.

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. In figures 7 and 8, growth stimulated by biotech R&D is explored. In order to obtain results, we make assumptions related to asset ownership including:

1. Technologies owned by the successful inventor are private until the patent expires or an imitator copies it. After that, the technology becomes public knowledge (this follows Dinopolous, Oehmke, and Segerstrom).
2. The EU owns some proportion of the current-generation technology assets. However, past assets, technologies which are in the public domain knowledge set, are owned by producers.

The first assumption means that as a technology moves from the private sector to the public sector it generates an increase in public welfare. In addition, the spillover effects are positive when considering the South's initial capital level. Figure 7 illustrates an asset expansion generated by the biotech sector. The asset expansion due to successful R&D makes the world relatively more capital abundant. The EU effective endowment expands along the biotech vector proportionately by the amount of (EU R&D)/(World R&D). The slope of the diagonal for the world is increasingly steeper, more capital intensive, as shown in figure 8. More important, the slope of the diagonal is increasing at a faster rate than the effective endowment expansion path for the EU. If this type of expansion were to continue for a long period of time, the EU becomes a labor intensive country with respect to the rest of the world.

In terms of economic growth, capital expansion as modeled here largely benefits the South. Over time it is conceivable that the South will become capital-intensive and be a major player in the biotech R&D race. As the successful biotech research augments the effective capital and labor devoted to biotech production, we expect the South's economy to expand at the expense of the European economy. This is a direct result of the restrictive biotech policies. As the EU becomes more labor intensive and consumes more labor intensive goods, the amount of trade with the rest of the world is expected to decrease, hence, the EU will lower its agricultural related GDP. The US is expected to continue producing all three goods and continue with its present growth rate.

Conclusions

The major results of this paper may be summarized briefly as follows: under the restrictive EU policies on biotech production and consumption the US will be the dominant producer of R&D; the South may be the dominant producer of biotech products; and the EU will be the dominant producer of outside goods (traditional agricultural products). These results are interesting because they imply that over time the EU will produce products that are more labor intensive and the South will produce goods that are more capital intensive. The South might experience positive spillover effects from the biotech production process and evolve into a R&D competitor in the long run.

In this analysis the trade flows are different from the usual North-South models. Given the restriction on consumption and production of biotech products in the EU, the product life cycle for biotech R&D will go from the US directly to the South versus in the North-South models where it would have gone from the US to the EU and then to the South. The South is expected to become the dominant producer of biotech outputs and some preliminary data about world production of GMOs support this result. It is conceivable that the South will not only produce the raw biotech products but will also add value to those products for export to the rest of the world (*i.e.*, Europe will most likely import refined products such as cotton shirts that originate from Bt cotton grown in the South). These results give hope for economic growth in the South. Second, the EU will produce more labor intensive outputs which are the outside good products. Due to their high production and consumption of labor intensive goods, agriculturally related trade from the EU is expected to decrease. The EU firms will have to conduct their R&D somewhere, hence, they will choose to invest in the US or the South depending on the IPR, biosafety regulations, and the risk of producing that particular product.

The overall effect of the EU's restrictive biotech policies results in an effective export subsidy of capital to the South. The South will become more capital intensive with respect to both production and consumption, increase the value of its traded goods, benefit from the spillover effects, and will become a player in the R&D market.

Figure 1. Factor Endowments and World Production

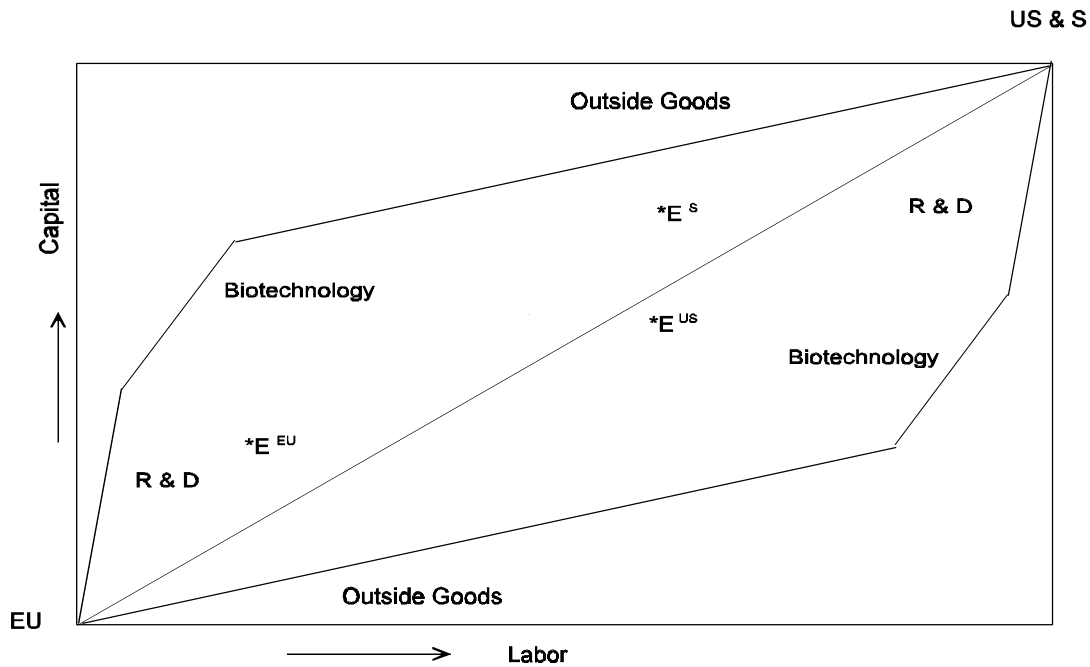


Figure 2. Factor Content of Production with no EU Biotech Production

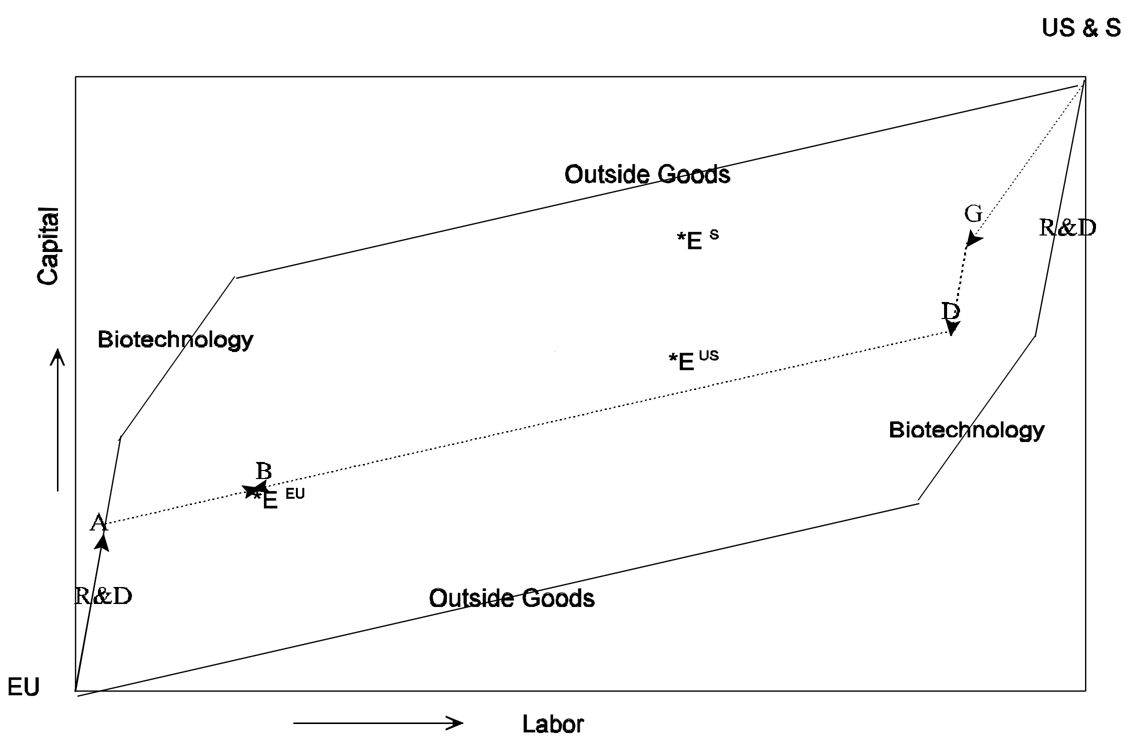


Figure 3. US and South Endowments and Production

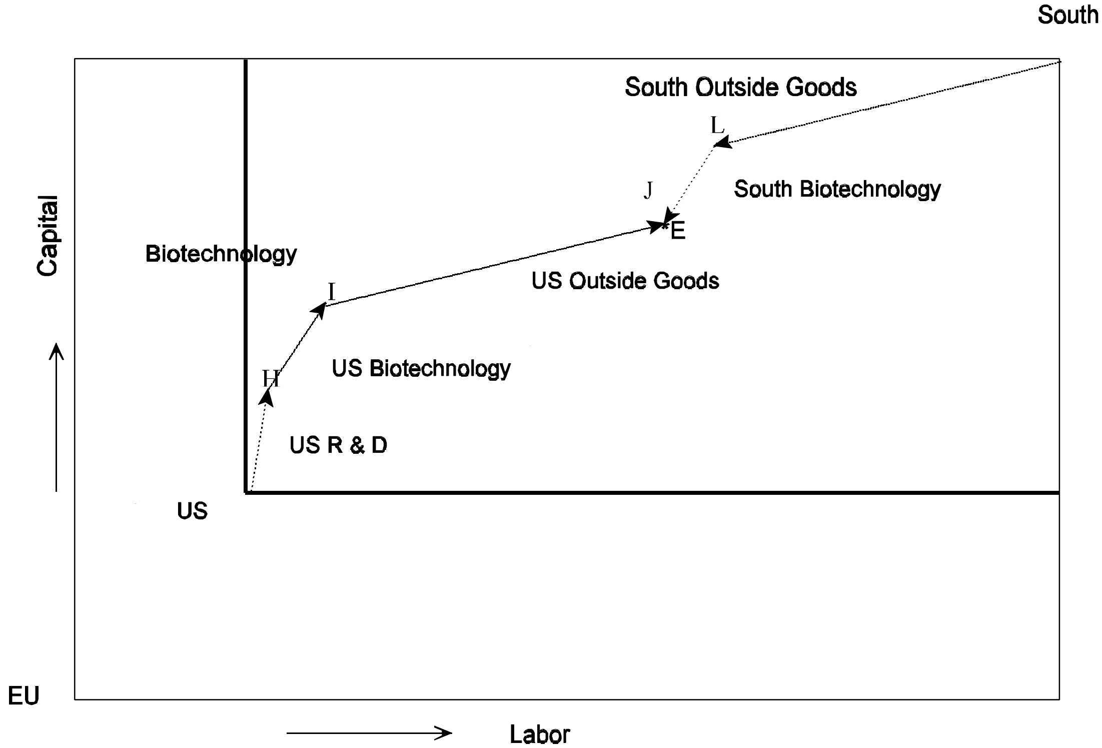


Figure 4. Factor Content of Consumption and Trade with No Consumption Restrictions

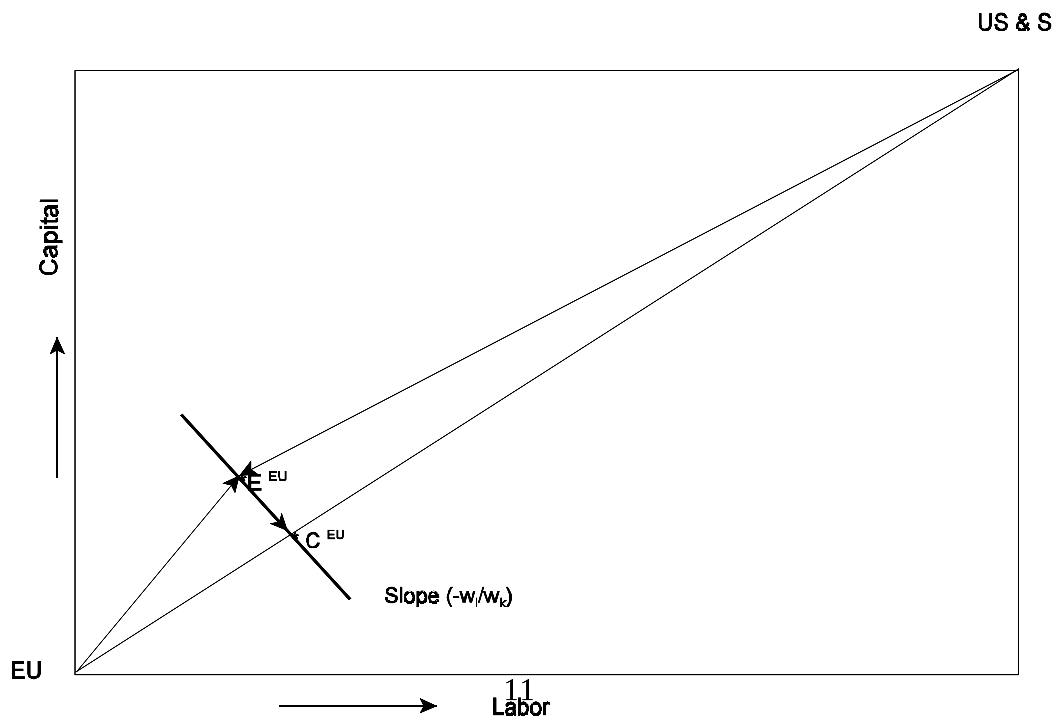


Figure 5. Factor Content of US-South Trade

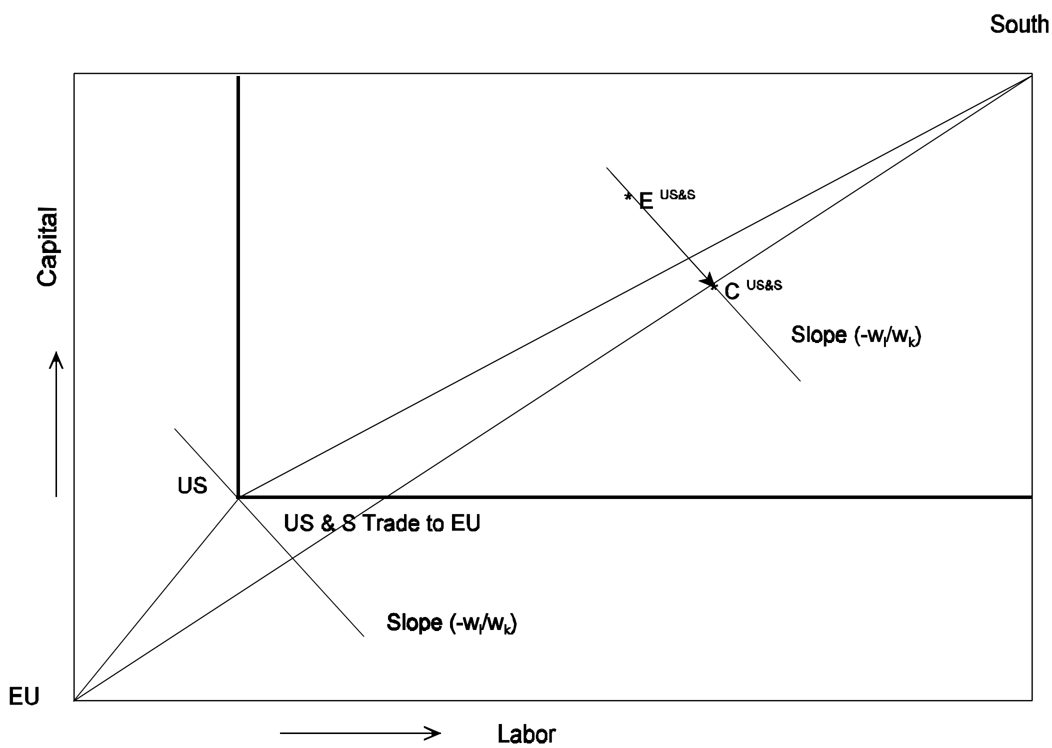


Figure 6. Factor Content of Consumption and trade with Biotech Consumption Restriction

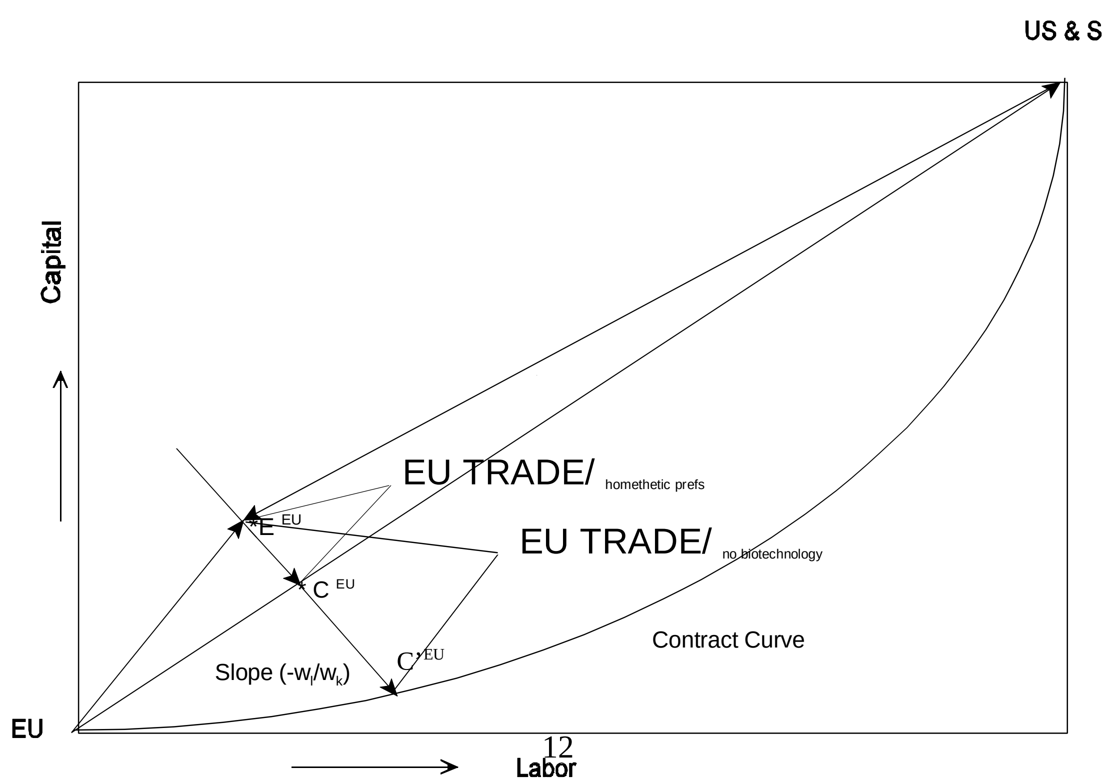


Figure 7. Asset Expansion due to Successful R&D

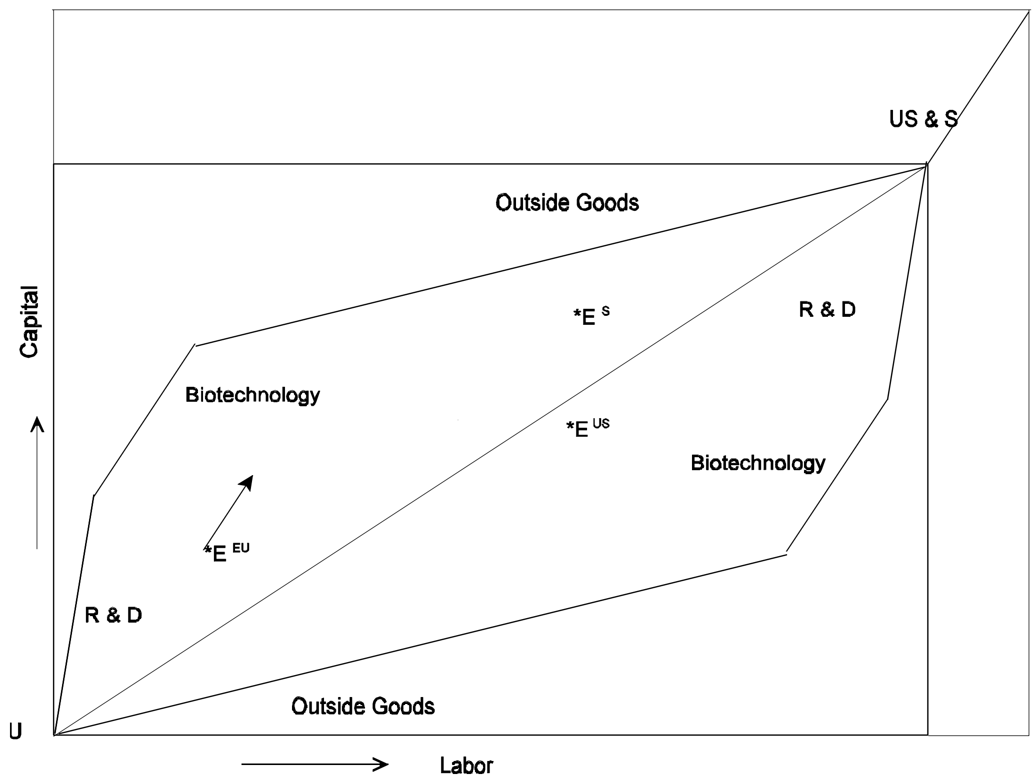
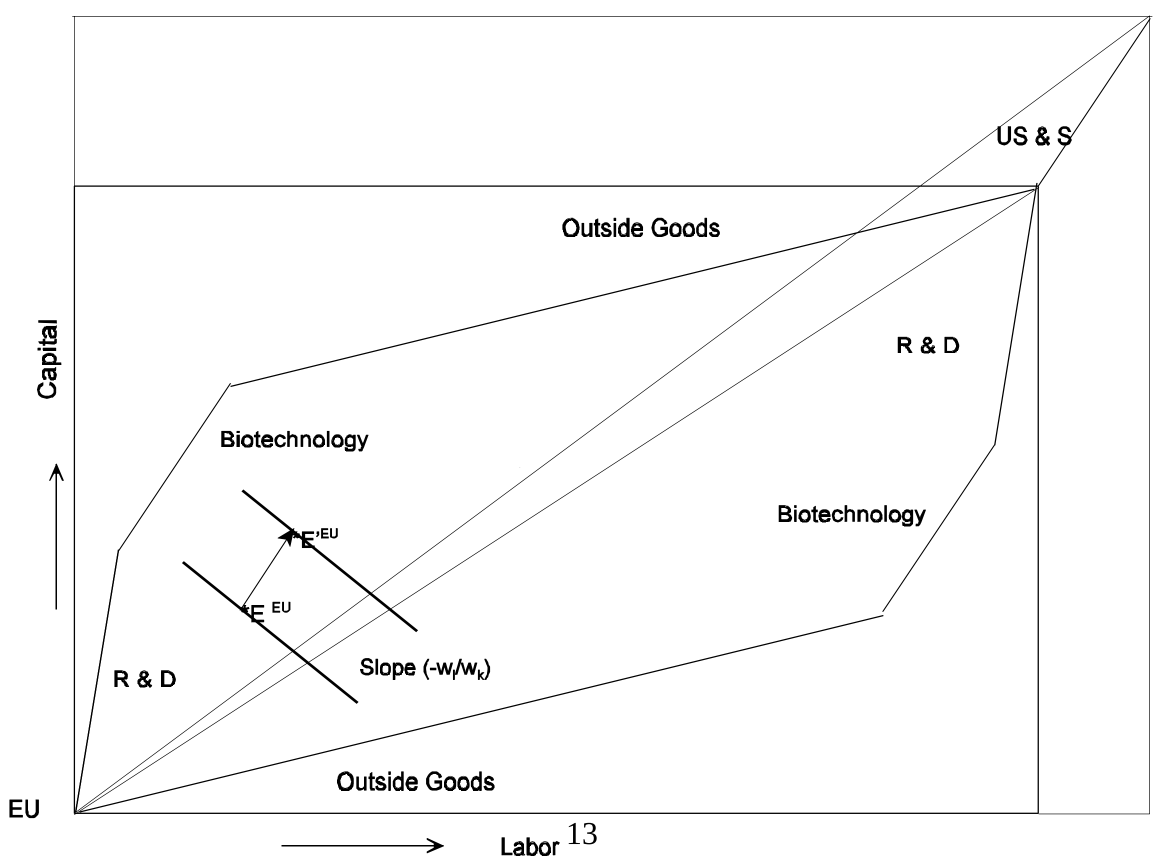


Figure 8. Changes in Relative Factor Endowments from Asset Expansion



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