Staff Paper

North-North-South Ag-Biotech Policy: Implications for Growth and Trade

Dave D. Weatherspoon
James F. Oehmke
Christopher A. Wolf
Anwar Naseem
Mywish Maredia
Amie L. Hightower

Staff Paper #99-51 **October 1999**

Department of Agricultural Economics
MICHIGAN STATE UNIVERSITY
East Lansing, Michigan 48824

North-North-South Ag-Biotech Policy: Implications for Growth and Trade

by

Dave D. Weatherspoon*, James F. Oehmke, Christopher A. Wolf, Anwar Naseem, Mywish Maredia and Amie L. Hightower

24 pages

Key Words: Biotechnology; International Trade; Heckscher-Ohlin-Samuelson; Economic Growth

Abstract:
This paper examines the impact of European Union policy on genetically modified organisms on trade flows and economic growth. Restrictive European Union policies on biotech production and consumption result in: an effective export subsidy of capital to the South; new trade flows; North America being the dominant producer of biotech research and development; the South being a dominant producer of biotech products; and the European Union being the dominant producer of traditional agricultural products.

* Dave D. Weatherspoon
Dept. of Ag. Econ. — Ph: 517-353-9850
Michigan State University — Fax: 517-432-1800
East Lansing, MI 48824-1039 — email: **weathe42@msu.edu**

North-North-South Ag-Biotech Policy: Implications for Growth and Trade

The last five years have seen a dramatic rise in the commercialization of agricultural biotech products. Since the introduction of transgenic corn, cotton and soybeans in 1996, the global area planted to commercial transgenic crops increased to 27.8 million hectares in 1998 - one of the highest adoption rates for new technologies by agricultural industry standards (James, 1998). However, the production of transgenic crops and other ag-biotech products, is not yet a truly global phenomenon as it is highly concentrated among a few countries. In this paper we examine the impact of European Union (EU) policy on genetically modified organisms on trade flows and agricultural economic growth. We find that restrictive EU policy on biotech production and consumption may result in: an effective export subsidy of capital to the South; new trade flows; North America being the dominant producer of biotech R&D; the South being a dominant producer of biotech products; and the European Union will be the dominant producer of traditional agricultural products.

In 1998, the United States accounted for 75% of all transgenic crops grown, with Argentina and Canada accounting for another 23% (James, 1998). Three primary factors explain the biotech dominance of the United States. First, the United States has historically had a leadership role in most high technology areas, including biotech. In 1996, for example, there were 1,287 biotech firms in the United States employing 118,000 workers compared to 716 firms and 27,500 workers in all of Europe (Ernst and Young, 1997). US firms earned US$14.6 billion in revenues and spent US$7.9 billion in research and development (R&D), whereas European firms earned only US$1.4 billion and spent only US$1.2 on R&D. Second, weak technological capability, inadequate protection of intellectual property rights (IPRs), and lack of biosafety standards in developing countries have deterred private companies from investing in or selling biotechnologies in developing countries. With time, this is likely to change since many developing countries are building a technological base, strengthening their intellectual property right systems, and putting into place biosafety protocols for approving biotech products. Whether biotech products gain widespread acceptance in developing countries is still uncertain, and is as likely to be decided by political factors as scientific or economic merit. Third, in contrast to US and Canadian consumers, European consumer concerns over possible negative health and environmental impacts of biotech products have been very strong, resulting in restrictive governmental policies on production and consumption. Consumer backlash has also led many food processors and retailers in Europe to decide against selling or importing biotech products.

European Union restrictive biotech policies have led to considerable disruption in trade flows of biotech products. For example, US corn exports to the European Union dropped by 96% from the 1996-97 season to the 1997-98, as a consequence of European Union rejection of shipments containing any amount of grain produced from transgenic seed. Consequently,

> "Archer Daniels Midland Co., for example, says it will pay extra for a certain type of soybean created through traditional breeding [and] A.E. Staley Manufacturing Co. won't take bioengineered corn that hasn't been endorsed by the European Union. ...The EU usually represents 5 percent of American corn exports; now it accounts for less than 1 percent," (St. Louis Post-Dispatch).

In light of the impact these policies are having on world trade in the coming years, it is important that this issue be analyzed in a comprehensive manner. In endeavoring to do so in this paper, we analyze the static and dynamic effects of policies concerning the production and consumption of genetically modified agricultural products utilizing the dynamic Heckscher-Ohlin-Samuelson (H-O-S) trade model presented in Dinopoulos, Oehmke and Segerstrom. In the next section we present the basic model framework and investigate trade effects of biotech production and consumption policies. In the following section on biotech R&D and growth, we extend the model to investigate the dynamic effects of biotech research and development on economic growth and trade flows. We conclude with a discussion of the implications for economic growth, welfare and the trade patterns for the European Union, North America and the South, under restrictive EU biotech policies.

The Model

In this model we consider three trading blocs differentiated by their relative R&D capabilities, capital-labor ratios, and regulatory policies relevant to biotech production and consumption. Two of the trading blocs are in the North - North America (NAm) and the European Union (EU) - and one in the South (S). Each block is characterized by three sectors: an outside good sector, a biotech sector, and the R&D sector. The outside good 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. We utilize a unique neo-Schumpeterian approach to investigate biotech R&D and innovation. The underlying assumptions of this approach are that:

- R&D is inherently a risky investment,
- biotech 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
- the lure of monopoly profits draws firms into the R&D process.

Each assumption broadly represents a part of the biotech industry. (See Dinopoulos for further details about this neo-Schumpeterian approach).

Models utilizing this approach have a rich history of application in the economics literature. Endogenous growth resulting from research and development was shown by Grossman and Helpman to be an important element in modern economic growth. Segerstrom, Anant and Dinopoulos have applied the North-South model to economic growth and found that sequential innovation races resulted in economic growth. In this paper we combine and extend the North-South model from Segerstrom, Anant, and Dinopolous and the North-North model from Dinopoulos, Oehmke, and Segerstrom to examine the evolution of trade patterns, innovation, and competitive advantage in biotech products.

The assumptions concerning initial endowments for each trading block are as follows: capital/labor (K/L) ratios are given as $(K/L)^{NAm} > (K/L)^{EU} > (K/L)^{S}$, agricultural research and development expenditures are $R\&D^{NAm} > R\&D^{EU} > R\&D^{S}$, and the gross domestic incomes (GDP) are $GDP^{NAm} > GDP^{EU} > GDP^{S}$. Intellectual property rights (IPRs) and protection are assumed equivalent in North America and European Union but lower in the South. The world consists of two types of governmental policies, those that allow the production and consumption of genetically modified organisms (GMOs) and those that do not. The European Union allows neither production nor consumption of biotech products while the North America and South have no restriction on production.[1] Finally, we assume that the South is unable to produce biotech R&D (although North America and EU firms may conduct R&D in the South using North America and EU production factors).

Production Restrictions

The Heckscher-Ohlin-Samuelson diagram in figure 1 illustrates the initial model assumptions. The bottom left corner is the origin for the European Union while the North America and South make up the balance of the world with their origin at the top right. The European Union is separated to highlight their restrictive biotech policies while North America and South are combined and make up the balance of the world. The endowment (E) points reflect the capital-labor 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 result in factor price equalization across countries. Each line segment represents the equilibrium world allocation of capital and labor to produce R&D, biotech goods, which are themselves the result of R&D, or outside goods. For example, the vector from EU to A_w represents the world allocation of factors for the production of R&D. The relative slopes of the production vectors reveal that R&D is the most capital intensive while outside goods are the most labor intensive.

Each vector with an arrow in figure 1 represents the allocation of a trading block's capital and labor utilized in the production of a specific product. The moratorium on biotech production means that the European Union produces only R&D (graphically represented by the vector from the EU origin to A) and outside goods (vector from A to B). The North America and South trading blocks produce all biotech goods (NAm & S origin to G) as well as the balance of R&D (G to D) and outside goods (D to B). Note that the European Union still engages in R&D, which results in biotech products, even though they are not allowed to produce biotech products.

Figure 2 differentiates North America and the South production activities. The North America origin is at the endowment point for the European Union (B in figure 1). The endowment point for North America and the South is $E^{NAm\&S}$. The sectoral factor allocations are represented by dotted vectors in figure 2. Assuming that the South initially conducting no R&D due to its capital intensity, the mapping of the outside goods and biotech sector determines the production levels. Therefore, North America produces all of the R&D products when considering only the North America and the South only (represented by the vector from NAm origin to H). Both North America and the South produce outside goods (vector from I to J for North America and vector from M to the northeast origin for the South) and biotech products (vector from H to I for the North America and vector from J to M for the South). With the restriction of no biotech goods produced by the European Union, the result is that the South is a major producer of biotech outputs (vector from M to J). The South may become the dominant producer of biotech products by devoting the greatest amount of its resources to this type of production (| MJ | > | HI |). This is more likely to result if North America's capital/labor ratio becomes sufficiently high so that it specializes in R&D rather than producing both R&D and biotech.

The fact that the South is an early adopter and producer of new innovations is not a standard result from the typical N-S or N-N-S trade models. The product life cycle in a N-S or N-N-S trade model is typically that an innovation is developed and produced in North America, production begins in the European Union and, once that market is saturated, the South produces the good (Vernon; Gandolfo). In the traditional model, North America enjoys the monopoly rents, the European Union faces monopolistic competition and the South faces pure competition in the market. This new result, given the technology policy restriction by the European Union, transfers the monopolistically competitive market from the European Union to the South. With aggressive intellectual property rights laws, the South may even be the first producer of certain biotech products from R&D races.

Effects of Consumption Restrictions

To this point we have focused on production decisions. Consider the consumption decisions and the resulting trade effects. Assuming homothetic preferences, the European Union and the NAm&S consumption points, C^{EU} and $C^{NAm\&S}$, lie on the diagonal (figure 3). Trading takes place along the factor price ratio line ($-w_l/w_k$) which is determined by world equilibrium. The factor content of trade is represented by a vector from the endowment point to the consumption point. (Note that the EU endowment point is the same point as the origin for North America.) The result is that the European Union consumes more labor intensive outside goods than it produces, therefore the European Union will import the balance of its outside goods from NAm&S (vector from E^{EU} to C^{EU}). North America, like the European Union, will import labor intensive outside goods and export capital intensive goods to the South (vector from $E^{NAm\&S}$ to $C^{NAm\&S}$). This vector, $E^{NAm\&S}$ to $C^{NAm\&S}$, represents the factor content of trade between North America and South only. The South's trade mix is the opposite. These short-run results are standard Heckscher-Ohlin-Samuelson outcomes.

When the biotech consumption restrictions are enforced, the results become more interesting. Figure 4 illustrates heuristically what happens to EU trade when the 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 EU consumers will not consume biotech goods. Instead, EU consumers prefer outside goods which are labor intensive goods. The trade vector from the EU endowment to the diagonal reflects the trade under homothetic preferences as discussed in figure 3. When the restrictive policy is implemented, the consumption point is on the new contract curve, which means that the European Union imports 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, through productivity increases. To represent growth in a Hecksher-Ohlin-Samuelson framework, we follow Dinopoulos, Oehmke and Segerstrom 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. Following Dinopoulos, Oehmke and Segerstrom, 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 5). Following Dinopoulos, Oehmke and Segerstrom, this increase is in proportion to the capital/labor 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 NAm&S to NAm&S' in figure 5. (The points E^{NAm} and E^{S} have been re-scaled so that the vector from NAm&S' to E^{NAm} and NAm&S' to E^{S} in figure 5 are equivalent to NAm&S to E^{NAm} and NAm&S to E^{S}, in figure 3.) The discovering firm owns the first biotech innovation, and consequently the increase in efficiency-adjusted factors. This firm is located in North

America with probability $R\&D^{NAm}/R\&D$ and in the European Union with probability $R\&D^{EU}/R\&D$. The expected increase in efficiency-adjusted factors for North America and European Union are the world increase in efficiency-adjusted factors multiplied by the probability that the firm is located in North America or the European Union. The expected increase in the North America efficiency-adjusted factor endowment is represented by the vector from E^{NAm} to E^{NAm}'. The expected increase in the EU efficiency-adjusted factor endowment is represented by the vector from E^{EU} to E^{EU}'. The South, owning none of the R&D firms, receives no increase in efficiency-adjusted factors after the initial R&D discovery.

The effects of the discovery 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. Motivated by findings of the existence and properties of the steady-state equilibrium in Dinopoulos, Oehmke and Segerstrom, we assume the existence of a steady-state in which R&D expenditures and monopoly rents are constant for each R&D race. In this case, the net effect of the discovery of innovation 2 on industry monopoly rents is nill. That is, the asset increases described in figure 5 are ‘a one time shift only.’

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.

Using efficiency-adjusted factor endowments, the effects of innovation 1 becoming publicly accessible are depicted in figure 6. The increased efficiency of biotechnology production is represented by the shift in the second origin from NAm&S' to NAm&S". This vector is drawn with the same capital/labor ratio employed in biotechnology production. The length from NAm&S' to NAm&S" is determined by the increase in efficiency attributable to the innovation. The vector from NAm&S to NAm&S" 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 from NAm&S to G at the new technology level. Assume the effect of the innovation is to increase productivity by (λ-1). The same level of production can be achieved by increasing the quantity of capital and labor by (λ-1) 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 NAm&S' to NAm&S".

The increased effective factor endowments are obtained by the producers of the biotechnology product: North America and South. The new effective endowments are represented by E^{NAm}", E^{S}", and E^{EU}". The level of the endowment changes are $(\lambda - 1)$HI for North America, where NAm&S" to E^{NAm}" (in figure 6) equals NAm&S' to E^{NAm}'+$(\lambda - 1)$HI (from figure 2), and $(\lambda - 1)$JM for the South, where NAm&S" to E^{S}' (in figure 6) equals NAm&S' to E^{S}'+$(\lambda - 1)$JM (from figure 2).

Since the European Union produces no biotech, there is no increase in the effective factors of production employed in the European Union. Thus $E^{EU\prime} = E^{EU\prime\prime}$. Similar increases in the effective endowments for North America and the South occur as each successive generation of biotechnology becomes publicly accessible. The effective EU endowment remains unchanged.

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 labor. Since the South is initially relatively labor abundant, it too becomes more abundant in effective capital. The effect on North America is less clear. If the initial endowment E^{NAm} is more capital abundant than is the use of capital in biotech production, then increases in effective endowments along the capital/labor ratio determined by biotech production will make North America relatively less capital intensive. The European Union itself is not affected by increases in effective endowment, after the initial R&D-driven increase. Thus, as the world becomes more capital abundant, the European Union becomes relatively less capital abundant and more labor abundant.

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 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 European Union 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 European Union will lower its agricultural related GDP. It is unclear whether trade from North America and the South will increase or decrease. North America and the South are expected to continue producing all three goods.

Conclusions

The major results of this paper may be summarized as follows: under the restrictive EU policies on biotech production and consumption North America will be the dominant producer of R&D; the South may be the dominant producer of biotech products; and the European Union will be the dominant producer of outside goods (traditional agricultural products). These results are interesting because they imply that over time the European Union 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 trade models. Given the restriction on consumption and production of biotech products in the European Union, the product life cycle for biotech R&D in our model goes from North America directly to the South versus in the North-South trade models where it would have gone from North America to the European Union and then to the South. The South is expected to become the dominant producer of biotech outputs. It is conceivable that the South will not only produce the raw biotech products in the long run but will also add value to those products for export to the rest of the world (*i.e.*, Europe may import refined products such as cotton shirts that originate from Bt cotton grown in the South).

These results indicate positive potential economic growth in the South. Second, the European Union 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 European Union is expected to decrease. The EU firms will conduct their R&D somewhere, hence, they will choose to invest in North America or the South depending on the intellectual property rights, biosafety regulations, and the risk of producing that particular product.

The overall effect of the restrictive EU biotech policies is 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 become a player in the R&D market.

Endnotes

[1] The authors recognize that there are countries in the South that will not allow the production or consumption of biotech products in their respective nations, however, on average, the South will be a major player in the biotech industry.

[2] This is a departure from Dinopoulos, Oehmke and Segerstrom, who model quality improvement in the high-technology product. In their model, consumers benefit directly from the higher quality once the innovation becomes public knowledge.

References

Dinopoulos, E., J. Oehmke, and P. Segerstrom. "High-Technology-Industry Trade and Investment: The Role of Factor Endowments." *J. Int. Econ.* 34 (February 1993): 49-71.

Dinopoulos, E. "Schumpeterian Growth Theory: An Overview." *Osaka City Univ. Econ. Rev.*, Vol. 29, 1994.

Ernst and Young. *Biotech 97 Alignment. The Eleventh Industry Annual Report.* Ernst and Young, Palo Alto, CA, 1996.

Gandolfo, G. *International Trade Theory and Policy*. Springer, New York, NY, 1998.

Grossman, G. and E. Helpman. *Innovation and Growth in the Global Economy*, Cambridge, Mass.: MIT Press, 1991.

James, C. "Global Review of Commercialized Transgenic Crops:1998" *ISAAA Briefs* No. 8. ISAAA: Ithaca, NY, 1998.

Segerstrom, P. "Innovation, Imitation and Economic Growth." *J. Pol. Econ.*, 99(1991).

Segerstrom, P., T. Anant, and E. Dinopoulos. "A Schumpeterian Model of the Product Life Cycle," *Amer. Econ. Rev.*, 80(December 1990): 1077-1091.

Steyer, R. "European Protests Could Slow Use of Bioengineered Crops." St. Louis Post-Dispatch, May 22, 1999.

Taylor, J. "ConAgra Unit Plans To Market Genetically Engineered Corn," Omaha World Herald, June 6, 1999.

Vernon, R. "International Investment and International Trade in the Product Cycle." *Quart. J. Econ.* 80(1966):190-207.

Figure 1. Factor Content of production with no EU Biotech Production

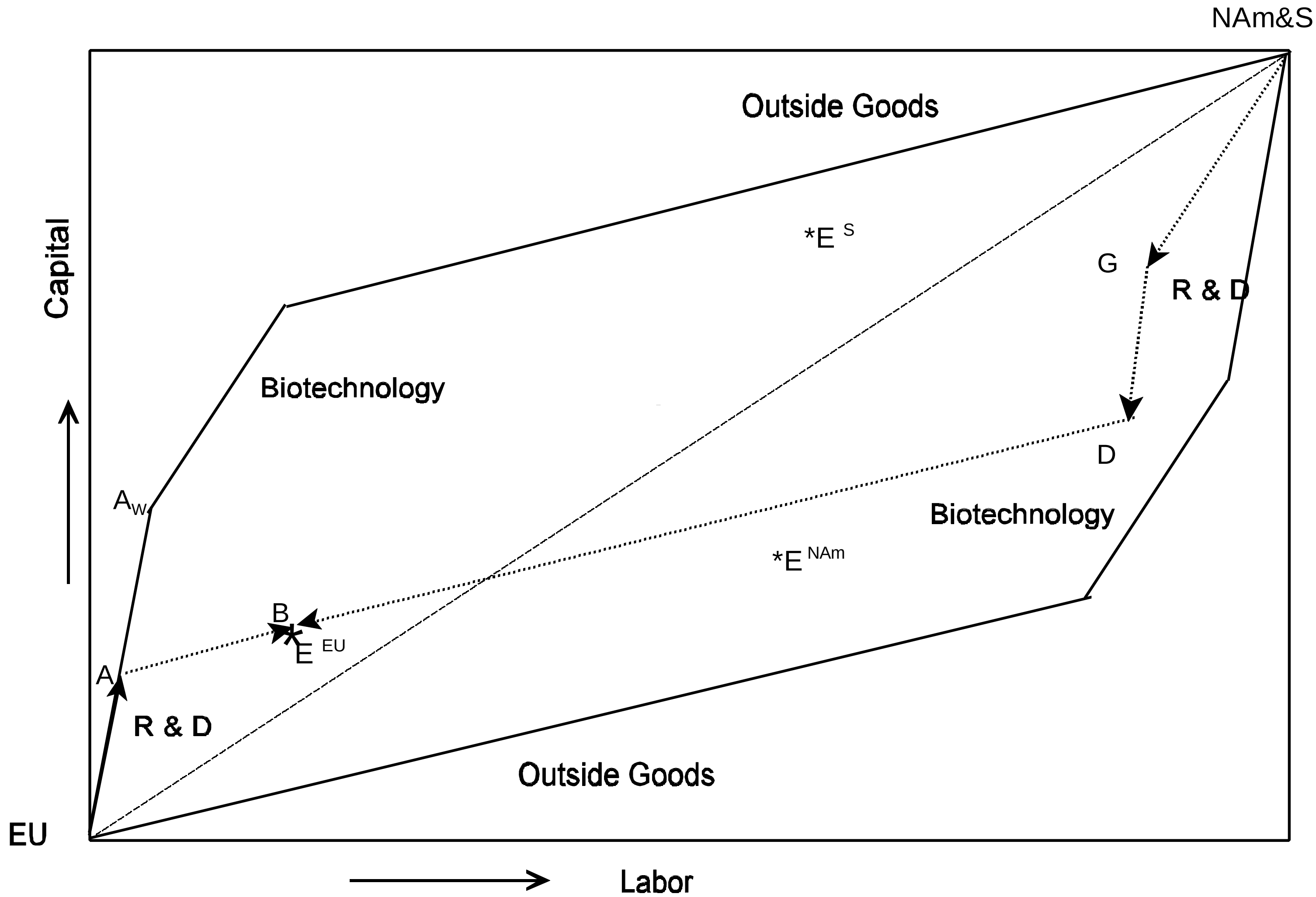

Figure 2. North America and South Endowments and Production

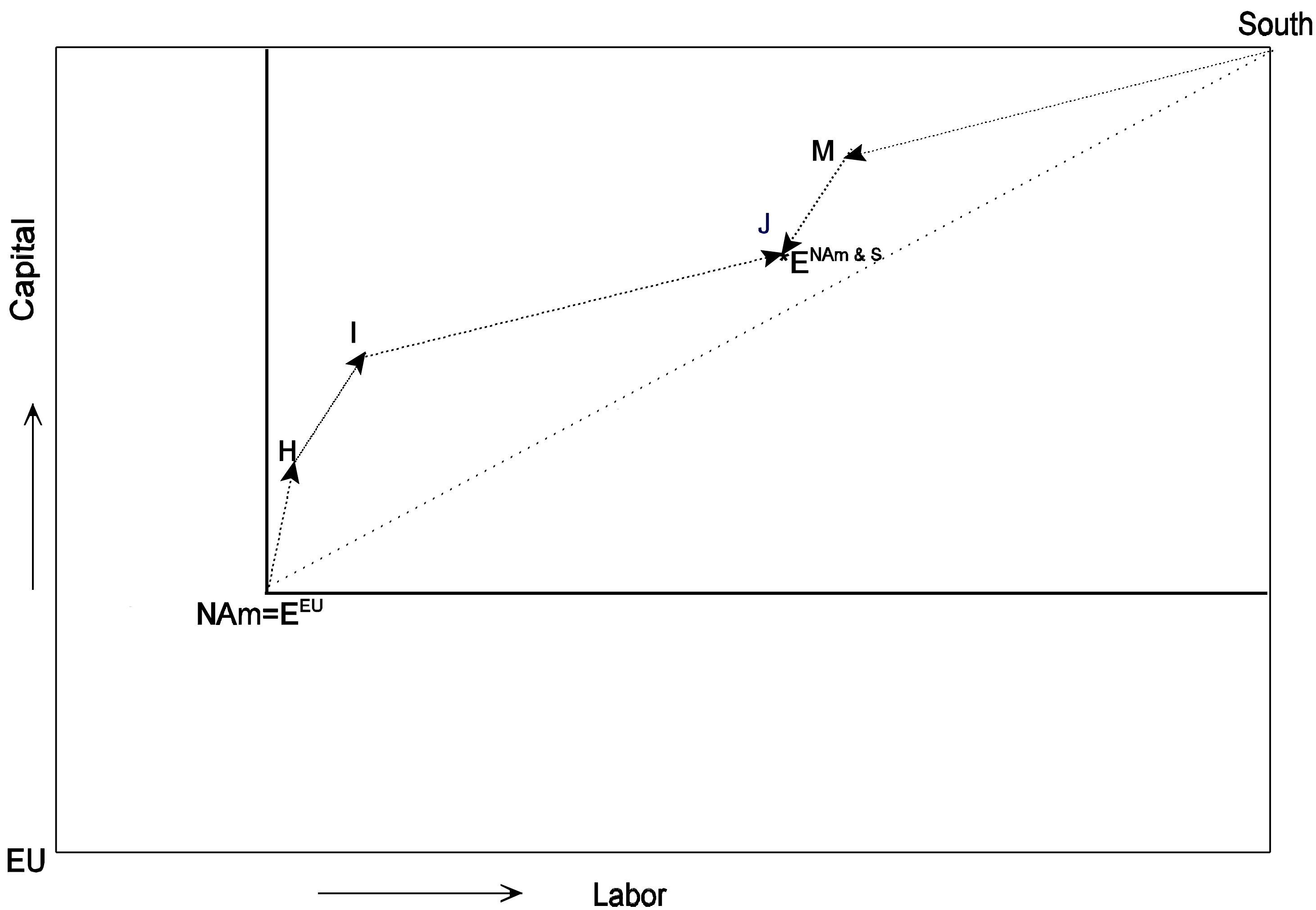

Figure 3. Factor Content of International Trade

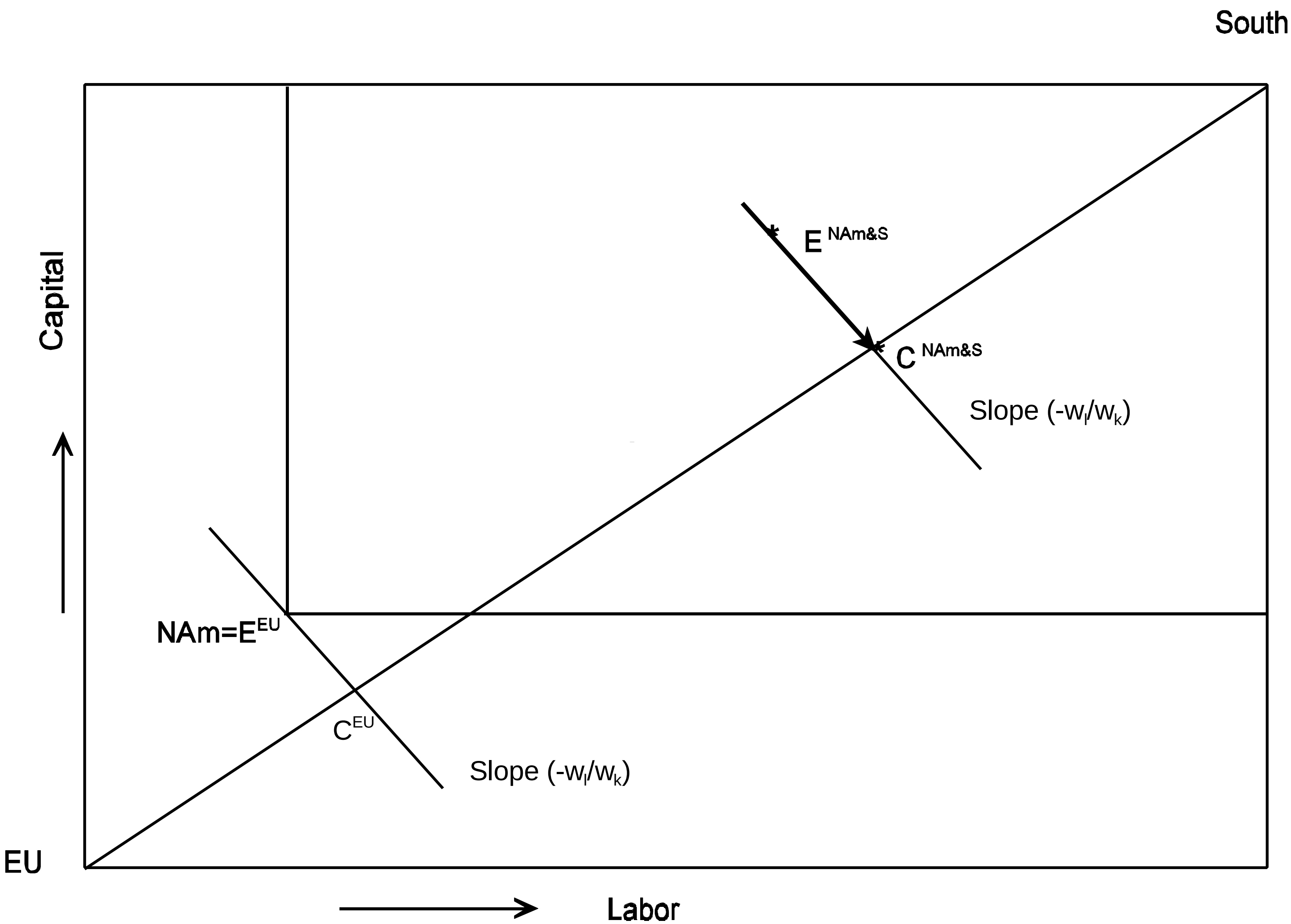

Figure 4. Factor Content of Consumption and Trade with EU Biotech Consumption Restriction.

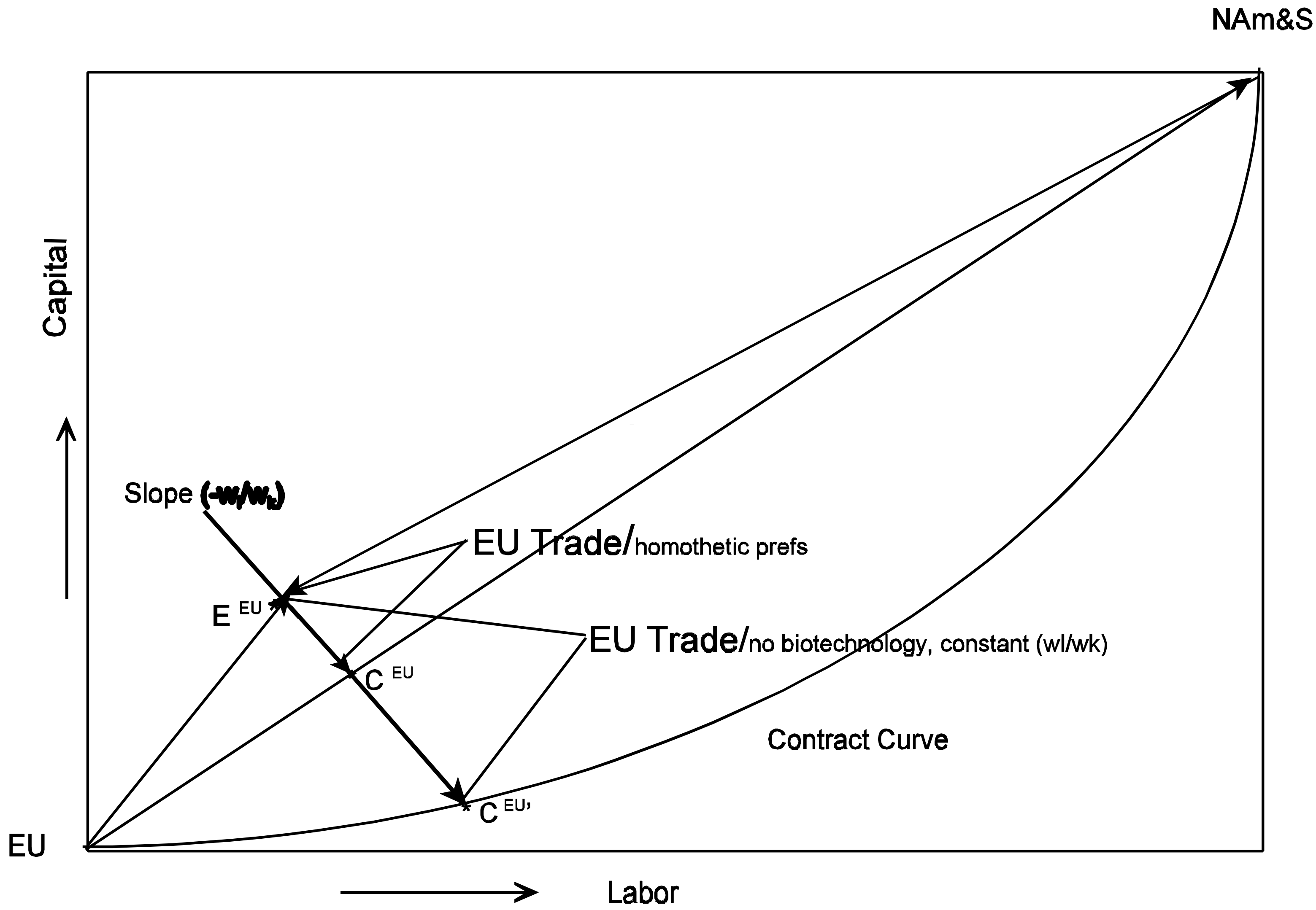

Figure 5. Asset Expansion and Expected Asset-Adjusted Endowments

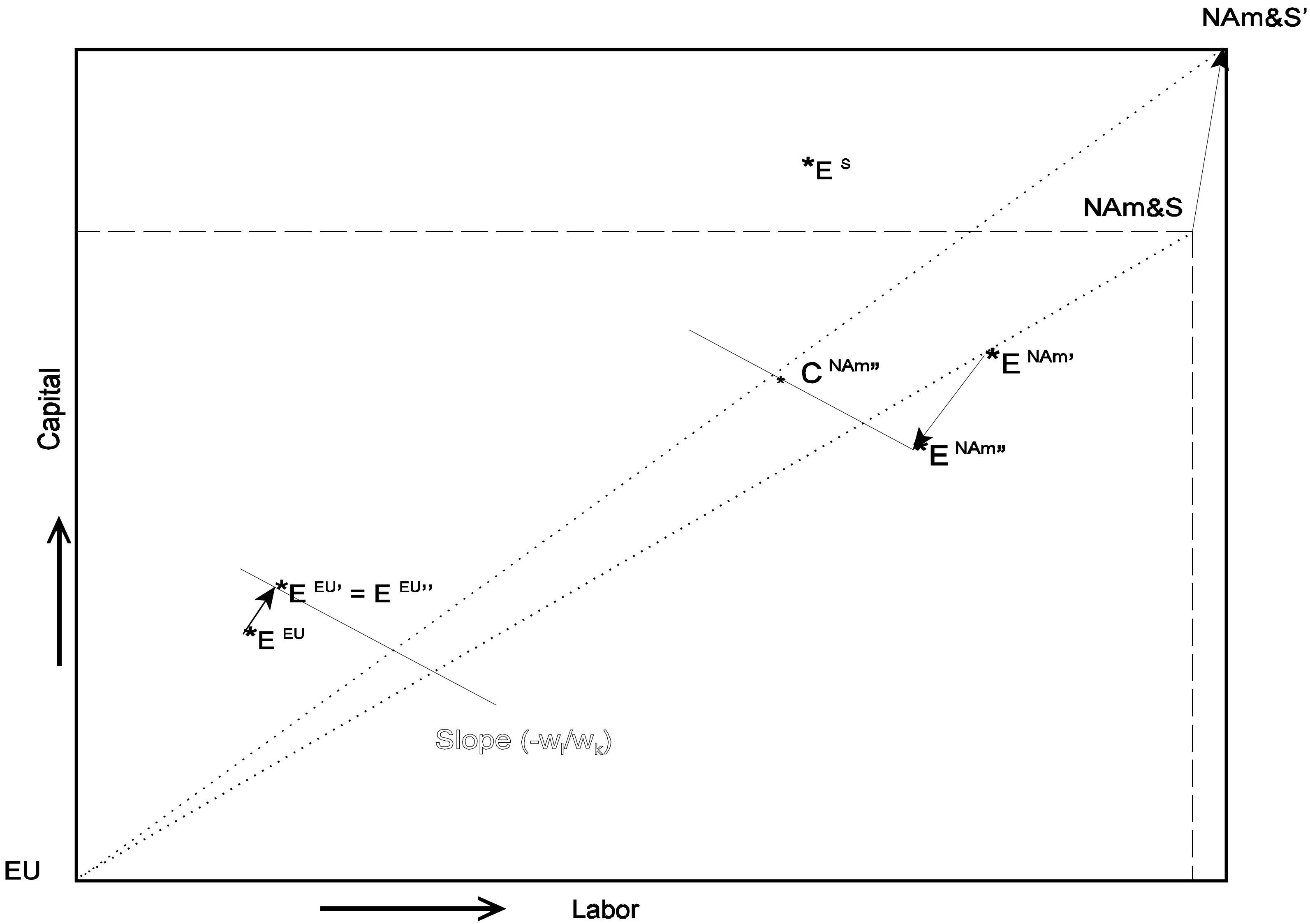

Figure 6. Effective Factor Content of Production, Consumption and Trade