Biofuels, Trade and the Infant Industry Argument

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Motivation

- Brazil currently has comparative advantage in producing ethanol using sugar-cane
- What will happen with innovation in production technology?
- With such innovation, is it possible for a country such as US to become an exporter of ethanol?
- Draw on Hecksher-Ohlin-Ricardo model and trade in presence of external economies
- Consider implications for public policy towards ethanol production

Background

- **Literature on trade in biofuels focused on partial equilibrium analysis of US policy instruments such as tax credits and import tariffs, e.g., de Gorter and Just (2007)**

- **Other studies analyze prospects for trade in biofuels, focusing on production costs, and land requirements needed to meet current mandates in US and EU, e.g., Kojima *et al*. (2007)**

- **Brazil requires only 3% land to meet 10% share of domestic transport fuel consumption in biofuels, compared to 30% (US), 36% (Canada) and 72% (EU) (OECD, 2006)**

Background

- Simple but predictable story – Brazil has comparative in producing biofuels – based on lower ethanol feedstock costs and relative abundance of land

- Even with trade distortions, Brazil accounts for major share of traded biofuel, which would increase if tariffs were removed, (Elobeid and Tokgoz, 2006)

- Static story, based on current crop yields and existing production technologies. Important to account for technological innovation in next decade, i.e., use of cellulosic feedstock

Trade in Biofuels – Basic Model

- **Basic model assumes:**

- **2 countries j = 1,2 - US and ROW (includes Brazil)**

- **2 factors of production: capital (K) and labor (L)**

- **Goods X_i = 1..3, where X_1 is capital-intensive, while X_2 and X_3 have same factor-intensity, both being land-intensive in production**

- **X_2 and X_3 substitutes in consumption (fuel-blending), X_2 using land embodied in sugarcane, X_3 using land embodied in corn**

Trade in Biofuels – Basic Model

- Assuming technologies are similar across countries, production functions are:

$$X_1^j = f(K_1^j, L_1^j), X_i^j = g(K_i^j, L_i^j), \; j = 1,2; i = 2,3$$

- Total quantity of factors available in world economy is given by vector: $\bar{V} = (\bar{V}_1, \bar{V}_2) \equiv (K, L)$, and

  country j's initial endowment is $V^j = (V_1^j, V_2^j) \equiv (K^j, L^j)$

- Production functions are quasi-concave, and exhibit constant returns to scale, with unit cost functions $c_i(w)$, w being a vector of factor prices

- Preferences are homothetic, share of spending being function only of prices, $\alpha^i(p)$

Trade in Biofuels – Basic Model

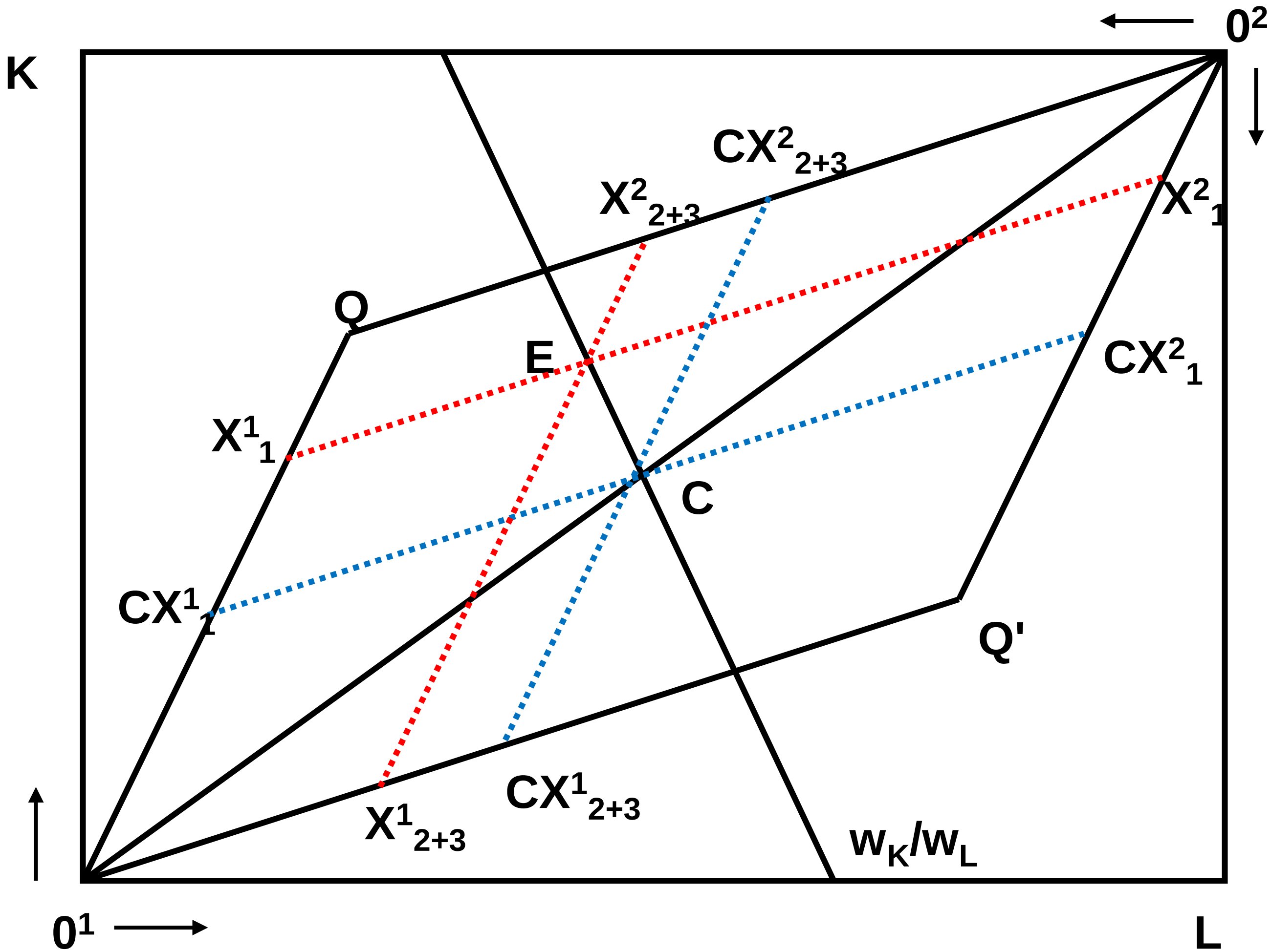
- **From set of assumptions, we can define a factor-price equalization (FPE) set**

  FPE is where factors of production are immobile between countries, but there is an allocation of factors among countries where trade in goods will equalize factor prices

- **In Figure 1, dimensions of box are $\bar{V} = (\bar{K}, \bar{L})$, while dimensions of FPE given by parallelogram $0^1Q0^2Q'$ where 0^1Q is factor employment in industry 1, and $Q0^2$ is factor employment in industries 2 and 3**

- **Combining goods 2 and 3 follows from technology assumptions (Davis, 1995) – also solves dimensionality problem (Dixit and Norman, 1980)**

Figure 1. Comparative Advantage and Trade in Ethanol



Trade in Biofuels – Basic Model

- **Distribution of factor endowments $V^j = (K^j, L^j)$ is at E, US being relatively well-endowed in capital, ROW being relatively well-endowed in land**
- **Slope of line through E is ratio of factor prices w_K/w_L, and C on diagonal from 0^1 to 0^2, represents GDP level of each country**
- **Constructing parallelograms between $0^1Q(0^2Q)$ and E/C, and $0^1Q'(0^2Q')$ and E/C:**

  US (ROW) produces $X^1_1(X^2_1)$ and consumes $CX^1_1(CX^2_1)$ of good 1, and produces $X^1_2=0$, $X^1_3>0$ $(X^2_2>0, X^2_3>0)$, and consumes CX^1_{2+3} (CX^2_{2+3}) of goods 2 and 3

Trade in Biofuels – Basic Model

- **Trade pattern such that US exports capital-intensive good, while importing land-intensive good, and vice versa for ROW which imports capital-intensive good, and exports land-intensive good, vector EC being *factor content of trade***

- **Note: US consumes both sugarcane and corn-based ethanol, but only produces latter, while ROW consumes and produces both**

- **Given stylized facts, seems a reasonable characterization of trade in biofuels, i.e., ROW, including Brazil, has comparative advantage in producing biofuels intensive in use of land**

Trade and Technological Change

- At present, 97% of US ethanol production uses corn as feedstock - corn is processed by either “dry” or “wet” milling to separate sugars, resulting product being distilled and purified into anhydrous ethanol
- Under 2007 US Energy Independence and Security Act, renewable fuel standard requires use of 36 billion gallons of biofuels by 2022
- As part of Act, almost 50% of mandated use of biofuels has to be met by second-generation biofuels such as cellulosic ethanol – which is not as yet in production commercially

Trade and Technological Change

- **Interesting to consider implications for trade in biofuels if US develops technology to produce cellulosic ethanol over next 10-15 years**

- **Based on previous model, introduce good X_4 produced from cellulosic feedstock, and assume it is relatively capital-intensive compared to X_2 and X_3**

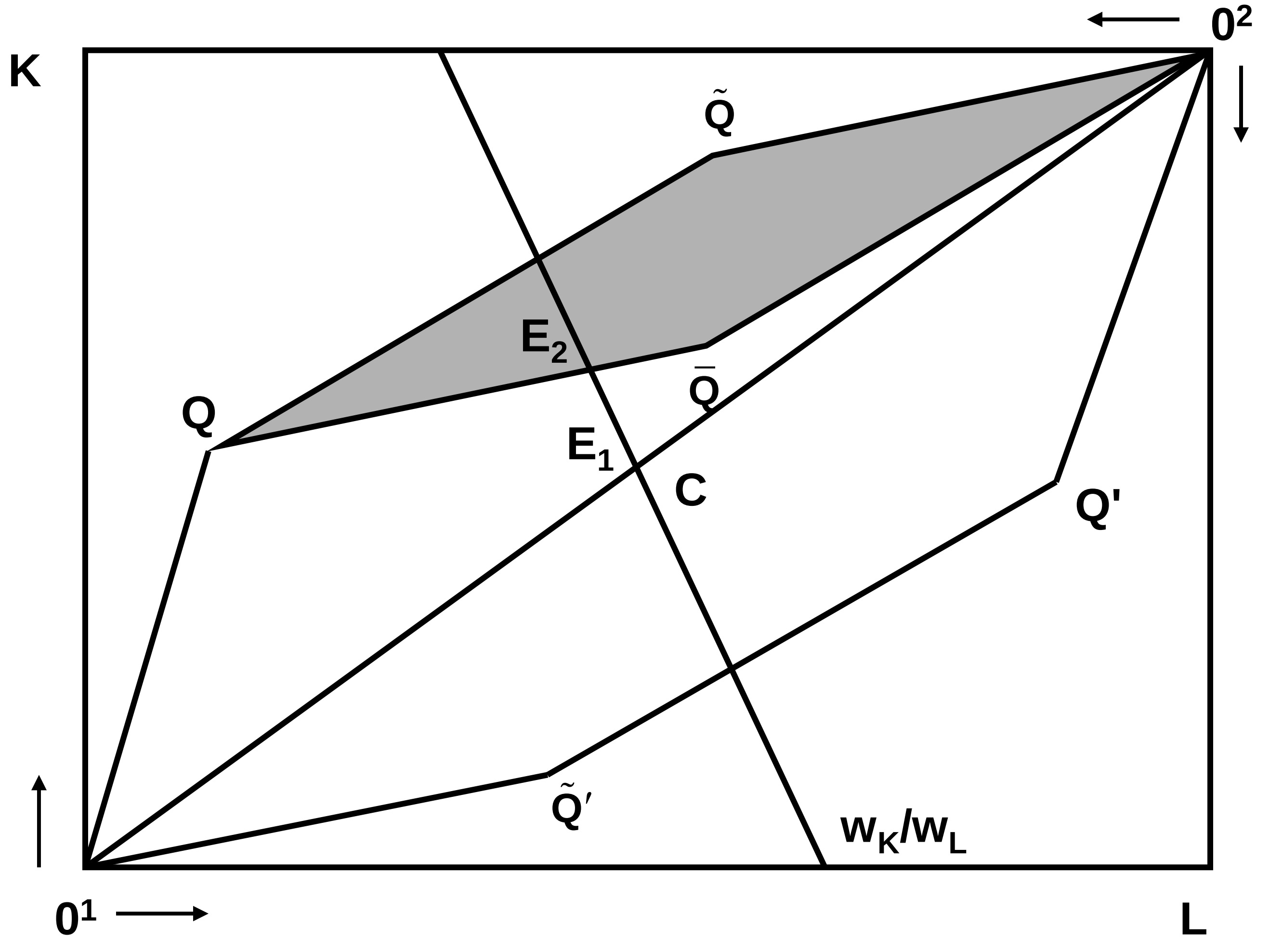
- **US has technical (absolute) advantage in producing X_4, the production function being written as $X_4^j = a^j h(K_4^j, L_4^j)$, j = 1,2, and $a^1 > 1$, which ensures US has technical advantage (Davis, 1995)**

- **Technology for X_4 is constant returns to scale**

Trade and Technological Change

- **In order to generate FPE set through trade in goods, requires industry producing X^4 be located in one country, i.e., US, which is assured by $a^1>1$**
- **In Figure 2, if neither country has absolute advantage in good 4, FPE set is $0^1Q\tilde{Q}0^2Q'\tilde{Q}'$**
- **If US has absolute advantage in producing X_4, FPE set is shaded area $Q\tilde{Q}0^2\bar{Q}$, where:**
  - **0^1Q is factor employment in industry 4**
  - **$Q\tilde{Q}$ is factor employment in industry 1**
  - **$\tilde{Q}0^2$ is combined factor employment in industries 2 and 3**

Figure 2. Specialization and Trade in Ethanol



Trade and Technological Change

- At E_1 no FPE as compared to E_2
- However, at E_1 or E_2, unambiguous US will be net exporter of capital-intensive goods – specializing in cellulosic ethanol X_4, as well as having comparative advantage in X_1
- Implies US continues to import X_2 and X_3 – due to assumption US still has comparative disadvantage in their production, and X_4 differs in factor-intensity
- X_4 more environmentally-friendly, commanding higher price, trade due to overlapping income distributions between US and ROW, i.e., trade in vertically differentiated goods

External Economies and Biofuels

- **Rather than assuming US has absolute advantage suppose it has head-start in X_4, but technology subject to *external economies of scale***
- **Production function for cellulosic ethanol becomes one where, $X_4^j = h(K_4^j, L_4^j; \xi)$, external economies being captured in parameter ξ, where $\delta h(.)/d\xi > 0$**
- **Implies industry operates under increasing returns, although individual firms believe they operate under constant returns**
- **External economies due to industry/country-specific *spillover effects***

External Economies and Biofuels

- **Under these assumptions, equilibrium in Figure 2 holds – US specializes in producing cellulosic ethanol**
- **Kemp and Negishi (1970) argue a country will gain from trade in such a setting**
- **Sufficient condition: value of output obtained under autarky employment levels at post-trade prices is larger in presence of post-trade external effects (Helpman and Krugman 1985)**
- **Specifically, productivity in cellulosic ethanol sector is higher in trading equilibrium due to restructuring of external effects**

Policy and Trade in Ethanol

- **External learning economies are dynamic:**

  - over time firms "learn by doing" resulting in lower unit costs of production

  - as economies are external to firms, knowledge gained from learning spills over to other firms

- **Generates market failure: if future benefits of current production cannot be fully appropriated by a firm or firms due to free riding by other firms, firms under-invest in production**

- **As a result, even with initial technological advantage, US will not necessarily realize benefits of external economies**

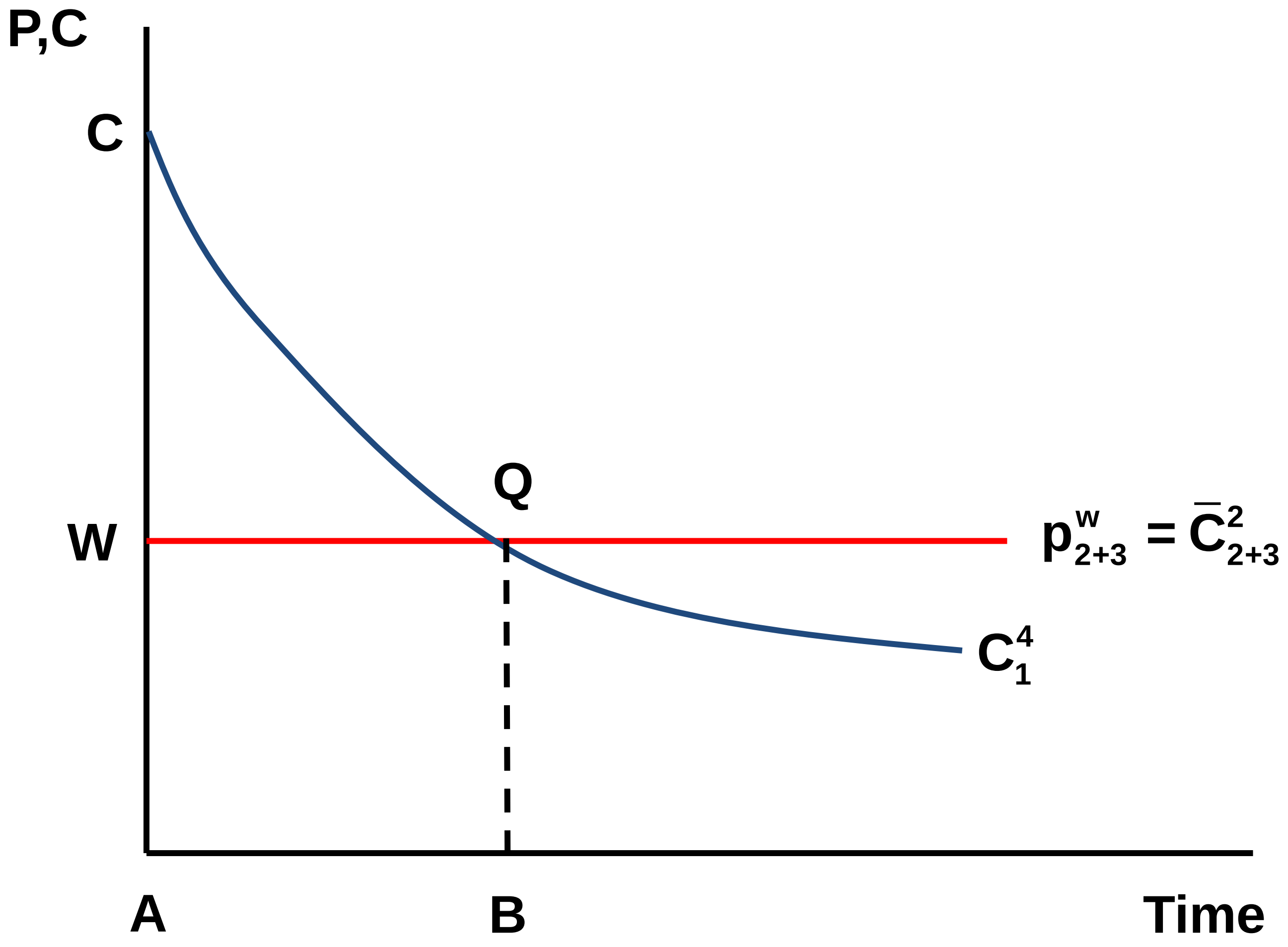
Policy and Trade in Ethanol

- **Suppose ROW ethanol industry is mature, all learning economies having been realized, unit costs being minimized at constant level $\bar{C}^2_{2+3} = p^w_{2+3}$**
- **Over period of time, and some range of cost curve, potential for US firms producing cellulosic ethanol to learn-by-doing, thereby lowering unit costs**
- **However, with spillover effects, no barriers to other firms entering market with same cost level as incumbent firms**
- **In absence of any government intervention, no firm will enter industry 4 while $C^4_1 > \bar{C}^2_{2+3} = p^w_{2+3}$**

Policy and Trade in Ethanol

- **For US cellulosic industry to compete in world market, necessary to provide temporary protection while $C_1^4 > \bar{C}_{2+3}^2 = p_{2+3}^w$**
- **This is *infant-industry* argument for temporary protection – long considered only legitimate exception to free trade (Mill, 1848)**
- **Basic logic shown in Figure 3, where prices/unit costs are measured on vertical axis, time t on horizontal axis**
- **CQ represents potential for US firms to learn-by-doing over period A to B, C_1^4 falling**

Figure 3: Infant-Industry Protection



Policy and Trade in Ethanol

- Possible that minimum unit costs continue to fall below Q, so US firms will be able to compete at world price once, $C_1^4 \leq \bar{C}_{2+3}^2 = p_{2+3}^w$
- To generate this, tariff initially set at t=CW, driving up cost of imported ethanol from ROW to $p_{2+3}^w + t$
- t is then progressively lowered over time to zero at time B, when US firms' costs minimum unit costs are equal to world price of ethanol
- This reinforces two basic ideas of Mill: protection necessary as no US firm will enter X_4 if there are spillovers to other firms; tariff should fall to zero

Policy and Trade in Ethanol

- **If learning economies are *internal* to US firms that enter market, no reason for any temporary protection (Corden, 1974)**
- **Follows from fact that firms can borrow to cover losses when $C_1^4 > \bar{C}_{2+3}^2$, in expectation additional profits will be made when $C_1^4 < \bar{C}_{2+3}^2$, other firms not having benefit of learning-by-doing at that point**
- **Alternative protection of X_4 through subsidy, which should also be temporary (Melitz, 2005)**
- **Under subsidy, US consumers pay world price, i.e., subsidy only corrects for under-production, compared to tariff which distorts US ethanol price**

Policy and Trade in Ethanol

- However, risk that once infant-industry protection is in place, firms will make political contributions to maintain it (Beesley, 2007)
- Latter argument could be made against recent US policy toward corn-based ethanol production, and external economies likely to have been exhausted – if there ever were any (Sheldon, 2008)
- As well as static deadweight losses, US corn-based ethanol policies may be slowing down realization of dynamic learning economies in cellulosic-based ethanol production, and hence US comparative advantage

Policy and Trade in Ethanol

- **Adapting argument by Sauré (2007), firms in US have to decide between producing corn-based or cellulosic-based ethanol technology, but are unable to internalize any learning economies**

- **Firms choose technology with highest returns, i.e., $\max[p_4\{h(V^j;\xi\},p_3\{g(V^j\}], j=1$. Hence, if policies targeted at corn-based ethanol production ensure that $p_4\{h(V^j;\xi\} < p_3\{g(V^j\}, j=1$, firms will not invest in cellulosic production**

- **Recent US ethanol policy should not be seen only in terms of direct trade distortions, but also risk of negative externalities imposed on investment by firms in an alternative technology**