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European Trade and Foreign Direct Investment U-Shaping Industrial Output in Central and Eastern Europe: Theory and Evidence

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Abstract

We examine industrial output in Bulgaria, Hungary, Poland, and Romania during 1989–95 in terms of pretransitional product trade orientation. The growth of EU-oriented output within sectors of industry, ex-post trade, and market liberalization, is modeled as foreign direct investment induced Schumpeterian (vertical) waves of product innovation. The growth of non-EU-oriented output within sectors is modeled as unobservable deterministic heterogeneity. The results indicate that the gap observed in industrial output performance when comparing Eastern European to former Soviet countries is mainly explained by the inherited presence of EU-oriented production and its unconstrained growth over the transition period.

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SUMMARY

We examine industrial output in Bulgaria, Hungary, Poland, and Romania during 1989–95 in terms of pretransitional product trade orientation. Borenszstein and others (1998) estimated the effect of foreign direct investment on the economic growth of developing countries using the endogenous growth model of Romer (1990) as their theoretical framework. In the same spirit we undertake the empirical counterpart of the endogenous growth model of Aghion and Howitt (1992) to model the growth of pretransitional EU-oriented output within sectors of industry. The dynamics of EU-oriented output, ex-post trade, and market liberalization are modeled theoretically and empirically as EU-induced Schumpeterian waves of vertical product innovations. Using panel data techniques we estimate the growth of non-EU-oriented output within sectors as unobservable deterministic heterogeneity.

Our results suggest that the EU-oriented component of industrial output is a first best outcome that reflects the eradication of distortions that existed in the microeconomic environment of the planning system. These products were already exported to the European Union before 1989 and were viable in a market economy at the start of transition. The use of foreign capital and expertise of European companies allowed them to privatize and restructure with ease and take full advantage of increased market access to the European Union.

The evolution of non-EU industrial output is estimated to follow the same path as that in countries of the former Soviet Union. We would not expect the determinants of firm performance that existed under central planning and traded within the CMEA before the event of transition to be different in samples of firms from Central and Eastern European countries or countries of the former Soviet Union. The gap observed in industrial output performance when comparing Central and Eastern European countries or countries of the former Soviet Union is hence mainly explained by the inherited presence of EU-oriented production.

I. Introduction

We examine the evolution of industrial output in Bulgaria, Hungary, Poland, and Romania over the period 1989–95 in terms of product trade orientation prior to the transition process. Before transition some products traded with the West while other products were sold only into the Soviet Bloc. The former products were viable in a market economy while the latter were privileged producers in an artificial market. The thesis of this paper is that pre-transition EU oriented products made an easy transition to private ownership and efficient structures with the aid of foreign investment and expertise. Given time, research into product innovations allowed them to fully exploit the increased access to the European Market and expand. The collapse of the artificial market and the loss of State privileges made the transition period very difficult for pre-transition non-EU oriented products. The evolution of industrial output and changing sector composition is determined by the offsetting experiences of products, as dictated by pre-transition trade orientation, during the transition process. Hoekman and Djankov (1997) document the movements and compositional changes in exports to the EU and to the previous CMEA in these countries during the transition process. At the start of transition these open economies already exported more to Europe than to the centrally planned market. With the introduction of the market system and trade agreements and the corresponding reduction of trade restrictions, outlined in Rodrik (1994), we observe an expansion in export growth to the EU over the period 1990–96, which was particularly evident from 1993 onwards. Rodrik (1994) noted that the re-orientation of products, previously directed to CMEA, to the EU market was not a feature of the transition period. The export share of previously CMEA oriented trade declined rapidly in the first few years of transition with a slight recovery over the period 1993–96. This analysis on the evolution and changing composition of exports suggests that one should document the fortunes of EU and non-EU oriented production during the first six years of transition. We do this in a matrix of big and small countries, slow and fast reformers.

We model the growth of EU oriented output within sectors of industry, both theoretically and empirically, ex post trade and market liberalization as endogenous Schumpeterian waves of vertical product innovation. These waves were induced by the increased access to the EU market and EU investors. Borenszstein, and others (1998) estimated the effect of Foreign Direct Investment (FDI) on the economic growth of developing countries using the endogenous growth model of Romer (1990), Grossman and Helpman (1991) and Barro and Sala-I-Martin (1995) as their theoretical framework.

In the same spirit we undertake the empirical counterpart of the endogenous growth model of Aghion and Howitt (1992) as our theoretical framework. We prefer to model innovations, or technical process, as vertical innovations within products rather than horizontal diffusions from outside the product.

We merge three important data sets that allow us to undertake an empirical investigation of the dynamic processes put forward in the theoretical section of this paper. *The LICOS Industrial Data Base* contains industrial output data by branch/sector of Industry in

2-digit NACE classification by country. *The EUROSTAT Trade Statistics* is a high quality database containing annual data on trade flows, to and from CEE countries, by 7-digit NACE classification. Finally the *Bocconi FDI Data Base* contains information on 2385 investment operations across twelve host countries including, Bulgaria, Hungary, Poland, and Romania, by 2-digit NACE classification. Using panel data techniques we estimate the growth dynamics of EU oriented output ex-post trade and market liberalization as EU induced Schumpeterian waves of vertical product innovations, and non-EU oriented output within sectors as unobservable deterministic sector and country specific heterogeneity. Our results suggest that transition issues such as reallocation, restructuring and disorganization were not of first order importance when considering the EU oriented component of industrial output. This might be expected given that these products already exported to the EU before transition, thereby minimizing the need to restructure the products attributes and hence attracting the use of foreign capital and partial to full foreign ownership that took full advantage of increased market access.

The evolution of non-EU industrial output is estimated to follow the same pattern as that observed CIS countries. Hence the faster recovery, or the U-Shape industrial output, observed in CEE as compared with CIS countries is mainly explained by the inherited presence of EU oriented production and its unconstrained growth over the transition period. Our main conclusion is that trade orientation is the key indicator of performance during transition.

In Section II we write down the theoretical framework and the reduced form to be estimated in our empirical section. In Section III we describe and undertake an analysis of the data used in our empirical work. We undertake our econometric analysis and tabulate our results in Section IV. Finally, we make our conclusions and review their compatibility with the current literature on the U-shaped industrial output curve.

II. Endogenous Product Growth and Trade Liberalization: The Schumpeterian Approach

Our framework for modeling growth is based on the Aghion and Howitt (1992) endogenous growth model. In our model growth is induced by endogenous shifts in the demand function rather than shifts in the production function. We also allow the steady state level of investment in our model to be determined endogenously in a two-stage framework. Trade and market liberalization ensured that product specific investments became an endogenous outcome driven by international market forces. Investment under the planning system was determined by the State. We proxy the effects of liberalization as exogenous shifts in consumer willingness to pay (or international market size), S, and exogenous shifts in the internationally determined outside option, A, for product specific investment resources. In this model we wish to derive the impact of these factors on the expected evolution of product specific investment, output and price dynamics in steady state equilibrium.

In the model, product specific investment resources, which may be foreign, are allocated between current production and research. The research is aimed at increasing the expected arrival of vertical innovations that in turn will alter the consumer willingness to pay for the product. As in Ahion and Howitt (1992), the maintained assumption is that innovations (endogenous shifts in the demand curve) within the product category are undertaken in a least cost manner via the entry and exit of firms, changes in ownership, rather than restructuring of practices within firms. Growth in the model is determined by Schumpeterian waves of firm *creative destruction* within products, with the intervals between each wave being determined by the level of investment and the share that is being allocated to research for product innovation. We model product growth in a two-stage framework. In Stage I the investment decision is made conditional on having perfect foresight on the uncertain outcomes of Stage II. Hence we model stage two first.

A. Stage II

We assume a given and continuous amount of product specific investment resources, I, which can be used either in current production (x) or in research (n). Research seeks to develop an improved vertical attribute for the product type. The research is aimed at creating an "innovation" that will make the current product obsolete when the new product arrives on the market. Innovations are assumed to arrive randomly with a Poisson arrival rate of λ for each unit of investment put into research. Growth in this model is generated from a succession of uncertain arrivals of product innovations with new ownership. The expected arrival rate of such innovations is determined by λn.

The following equation acts as an accounting equation,

$$I = x + n \tag{1}$$

The investment allocation between current production and research will equalize the expected discounted rate of return from the allocation. The following *arbitrage equation* is also binding,

$$r_t = \lambda V_{t+1} \tag{2}$$

r_t is rate of return accrued by an investment resource dedicated to current production while λV_{t+1} is the discounted expected rate of return that results from allocating a unit of investment to the search for a new innovation. One should note that t denoted the current level of innovation and not time. The value of V_{t+1} is determined by the following asset equation,

$$RV_{t+1} = \pi_{t+1} - \lambda n_{t+1} V_{t+1} \tag{3}$$

The left-hand side is the discounted expected income from the licence to produce a product with the (t+1) innovation level over the expected duration of its life. The right-hand side is the rent flow minus the expected loss when a new innovation arrives. The net present value of an asset yields a certain π_{t+1} until it disappears, which it does at the expected rate of λn_{t+1}, the expected duration of monopoly rents. The model becomes operational by solving for x from the following optimization problem,

$$\underset{x}{Max}\ \pi_t = (P_t - r_t)x_t \tag{4}$$

We model our inverse demand curve and production function as an exact form. The results of the model are robust to general specifications. Thus,

$$P_t = \frac{S\gamma^t}{Y_t} = \frac{S\gamma^t}{x_t^\alpha} \tag{5}$$

where the Cobb Douglas production function exhibits decreasing returns to scale $0 < \alpha < 1$. The size of the market, S, or willingness to pay, shifts by a factor γ each time a new product arrives with an innovation in its vertical attribute. Each incumbent producer faces an exogenous market size defined in terms of S and the vertical attribute. Market size has two components. The endogenous component depends on the historical number innovations undertaken for the product including that undertaken by the current manufacturer before entering the market. The exogenous component, S, is predetermined by exogenous factors such as the degree of market regulation and trade liberalization.

The optimal manufacturing level within a product niche is determined by a monopoly. The solution function for the above optimization problem and the sign of the partial derivatives are as follows,

$$x_t = \left(\overset{+}{S}\ \overset{+}{\gamma^t}\ \overset{-}{r_t} \right) = \left(\frac{S(1-\alpha)\gamma^t}{r_t} \right)^{1/\alpha} \tag{6}$$

Using (1) and (6) we can express r as a function of the n conditioned on (5) holding. We express this relationship and its partial derivatives in the steady state as follows,

$$r = g\begin{pmatrix} + & + & - & + \\ S & \gamma^t & I & n \end{pmatrix} = \frac{S(1-\alpha)\gamma^t}{(I-n)^\alpha} \tag{7}$$

In the steady state we drop the subscript t except in the case of the endogenous vertical attribute whose given value to the incumbent depends on the number of innovations undertaken in history. Using the arbitrage equation (2), and equation (6) we can also express r_t as a function of the n_{t+1}. This relationship and the partial derivatives in the steady state are given as,

$$r = f\begin{pmatrix} + & + & - & + & - \\ S & \gamma^{t+1} & n & \lambda & R \end{pmatrix} = \left(\frac{\lambda\alpha}{(R+\lambda n)(1-\alpha)}\right)^\alpha \left(S(1-\alpha)\gamma^{t+1}\right) \tag{8}$$

We undertake comparative static exercises on our accounting and arbitrage equations, (7) and (8), assuming a steady state equilibrium and that (5) is binding. We express the partial derivatives of the solution functions in terms of the partial derivatives of the above equations.

$$\begin{aligned} r^0\begin{pmatrix} + + - + - \\ S\gamma I \lambda R \end{pmatrix} &: r_s^0 = g_s > 0 \ \textit{and}\ r_I^0 = \left(\frac{g_I f_n}{f_n - g_n}\right) < 0 \\ n^0\begin{pmatrix} 0 + + + - \\ S\gamma I \lambda R \end{pmatrix} &: n_s^0 = 0 \ \textit{and}\ n_I^0 = \left(\frac{g_I}{f_n - g_n}\right) > 0 \end{aligned} \tag{9}$$

The explicit solution function for (9) can be found in Appendix I. In the steady state equilibrium we are concerned with the impact of I and S on the allocation of resources between production and research, and on the equilibrium rate of return to investment projects. The greater the amount of investment resources available, the bigger the allocation to research. This in turn increases the expected arrival rate of innovations in equilibrium. The rate of return to current and future projects falls as the expected life cycle of each innovation is shortened. A change in the exogenously determined market size has no effect on the allocation of investment between current production and research, but it does increase the current and discounted expected rate of return on a unit of investment. This will be important for the determination of steady state investment in Stage I.

B. Stage I

In Stage I the level of steady state investment is determined in full anticipation of the expected outcomes in Stage II. Investment maximizes the steady state rate of return net of an exogenous outside option, A. We express the steady state optimization problem as the

following,

$$\underset{I}{Max}\ \Omega = (r^0 - A)^{\varepsilon} \tag{10}$$

The first order condition takes account of the changes in the steady state rate of return as investment changes. This is expressed as follows,

$$\Omega_I = \varepsilon\left(r^0\left(\overset{-\,+}{I,S}\right) - A\right)^{\varepsilon-1} \frac{\partial r^0}{\partial I}\left(\overset{-\,+}{I,S}\right) = 0 \tag{11}$$

Taking (11) as our equilibrium equation, we can perform comparative static exercises, using (9) and the first and second derivatives of (7) and (8), with respect to all the exogenous variables in our model on steady state investment. The explicit functional form for the steady state level of investment can be found in Appendix I. We report our results as follows,

$$I^0\left(\overset{-++\,+-}{AS\gamma\lambda R}\right) \tag{12}$$

The exogenous level of market size and the endogenous shift in the market size after each innovation have a positive impact on the overall level of steady state investment. Factors such as a rising outside option or discount rate in evaluating expected future returns from innovations reduce steady state investment levels. Equation (11) has the property that investors in steady state equilibrium only earn an expected return equal to the outside option. We turn to the analysis of steady state output and price dynamics in the event of endogenous movements in investment resources made available to products in the aftermath of trade liberalization.

Steady State Output Dynamics

Using the expression for (6) in steady state, we can express the corresponding output as follows,

$$Y^0_{t+1} = x^{0^{\alpha}}_{t+1} = \gamma Y^0_t \tag{13}$$

The expected growth rate is a random step function, the interval between each step being exponentially distributed by steady state level of λn. This is determined, amongst other

things, by the steady state level of investment and the other factors in (9). Investment in turn depends on the exogenous size of the market and the outside option for investors in addition amongst other factors. Expected growth in our steady state equilibrium can be expressed as follows,

$$\dot{y} = \lambda n^{0}\left(I^{0}\left(\overset{+}{S},\overset{-}{A}\right)\right)\ln\gamma \tag{14}$$

The expected growth in steady state output during real times, τ, depends on the amount of innovations that take place over the defined real time interval,

$$\ln y_{\tau+1} = \ln y_{\tau} + \psi(\ln\gamma) \tag{15}$$

where the expected growth rate of output over a defined real time interval depends on the expected number of innovations ψ over the interval as dictated by equation (14). Output for defined real time intervals is expected to grow at an increasing rate. Innovations or endogenous increases in the market size ensure that the innovation rate itself is expected to increase over time. Trade and market liberalization, through its effect on market size and on the outside option for investors, is also an important determinant of the level of investment and hence the steady state level of current production and its expected growth overtime. An increase in the endogenous level of investment increases both x and n but lowers the ration of x/n. The expected growth path of output is higher on two accounts. Innovations are expected to arrive at a greater rate over defined real time intervals due to an increase in overall investment, but also because greater share is allocated to research. The core implication of our model is that a product facing a positive investment shock due to trade liberalization (the free movement of goods and capital between countries) will increase steady state output, but will also concentrate more of the increased investment resources into research. Thus, the expected rate of output growth increases with increasing convexity overtime. The expected benefits of the positive shock are spread overtime.

Steady State Price Dynamics

By substituting (6) into (5) and setting $r = A$ to satisfy the condition in (11), we can express the steady state prices as follows

$$P = \frac{A}{(1-\alpha)} \tag{16}$$

The price for the product after trade and market liberalization is a mark-up on the outside option for investment resources. The mark-up tends to zero as the degree of competition in the market increases ($\alpha \rightarrow 0$). The prediction of the model is that price

movements in steady state overtime become independent of output movements. We would expect the export price of goods to reflect their trading partners in the event that they compete for the same pool of investment resources.

Implications for Sector Output Dynamics

Assuming products from independent submarkets and investment is product specific, we aggregate over products to predict their contribution to the evolution of sector output. Our theory predicts that as product specific investment grows with trade liberalization, a higher share will be allocated to research for product innovation. This in turn is predicted to induce an initial expansion in sector production and a large expansion in sector growth overtime induced by increasing rates of *creative destruction* within products experiencing positive investment shocks. The above model shows how the role of discrete changes in investment patterns in (14) and (15) will form the basis of our empirical agenda. We first describe and undertake a brief analysis of the data used in our empirical work.

III. SECTOR ANALYSIS OF INDUSTRIAL OUTPUT, EU EXPORT ORIENTED PRODUCTS AND EU FOREIGN DIRECT INVESTMENT

We wish to examine the forces behind sector and industrial output growth in Bulgaria, Hungary, Poland, and Romania over the period 1989–95. Three important data sets are merged which allow us to undertake an empirical investigation of the dynamic process put forward in the theoretical section of this paper. We describe each data set and undertake an analysis of the variables we intend to use in the empirical section of the paper.

The LICOS Industrial Data Base

This data base contains industrial output data by branch/sector of Industry in the NACE classification outlined in Table 1 over the period 1989–95. An INCO-COPERNICUS project (CIPA-C-93-0003) on the region converted data from official sources, using a common methodology, to a common NACE classification system. We have constant output data for all our four countries by sector of industry in the form of a cumulative output index. The value of this index is always equal to 1 in base year 1989 for all branches.

Using this data we can analysis the degree of sector heterogeneity in the evolution of Industrial output in Bulgaria, Hungary, Poland, and Romania over the period 1989 and 1995. We undertake the analysis with a number of simply indices. We calculate a discrete measure of growth over the period t-1 to t in sector i and country j as the following,

$$g_{ijt} = \left(\frac{Y_{ijt} - Y_{ijt-1}}{(Y_{ijt} - Y_{ijt-1})/2} \right) \qquad \textbf{(17)}$$

We wish to examine the contribution of rising and declining sectors to the overall evolution of output. To do this we sum the growth rates of each rising sector (POS), weighted by the sector size S_{ijt}, and sum of the absolute growth rates of each declining sector (NEG) weighted by their size S_{ijt},

$$\begin{aligned} POS_{jt} &= \sum_{i=1}^{n} S_{ijt} g_{ijt} \qquad if\ g_{ijt} > 0 \\ NEG_{jt} &= \sum_{i=1}^{n} S_{ijt} |g_{ijt}| \qquad if\ g_{ijt} < 0 \end{aligned} \qquad \textbf{(18)}$$

The net change in industrial output and the excess reallocation of output between sectors within countries over and above that necessary to generate the net outcome are calculated as follows,

$$\begin{aligned} NET_{jt} &= POS_{jt} - NEG_{jt} \\ EXCESS_{jt} &= POS_{jt} + NEG_{jt} - |NET_{jt}| \end{aligned} \qquad \textbf{(19)}$$

In Table 2 we outline the year to year growth rates in industrial output, the contribution of rising and declining sectors to the overall net changes in industrial output, and the excess reallocation of output between sectors within Bulgaria, Hungary, Poland, and Romania.

The U-Shaped Industrial Output Curve can be seen to be present in all four countries. Bulgaria and Romania had negative growth rates till the end of 1993 and since then we observe a recovery. Romania grew strongly one year later than Bulgaria. It is only since 1992 that we observe simultaneous expansions and contractions of sectors inducing reallocations of output across sectors to be significant in Bulgaria and Romania.

Structural change in Poland started earlier. We observe a large collapse in output in the period 1989–90 followed by large reallocations of output between sectors in the following years up to the end of 1992 and stable and homogenous growth in all sectors since. The collapse in Hungarian output was spread over the years up to 1992 and output was reallocated across sectors in the period 1992–93.

As shown in Figure 1 the initial size distributions of sectors within each country were similar coming out of the planning system in 1989. Even though the timing of change in sector composition of output was very different in each of the four countries the final size distributions of sectors converged again by 1995. As indicated in Table 3 the variation in the absolute change in sector size across countries was less than the variation between different sectors within countries over the period 1989–95. This indicates that structural change tended to be induced by common sector specific shocks rather than country specific shocks. In Figure 2 we examine the shift in the size distributions of sectors with countries and to the shift to the right in the distribution. This indicates that by 1995 sectors that were initially small in 1989 increased their share of output relative to the traditional large sectors. Heterogeneity in sector experience is present throughout this period and its determinants seem to be common across all four countries. We show that intra-sector compositional changes are the driving force behind the observed differences in sector experience. To allow us estimate the role of intra-sector compositional changes over this period in terms of EU versus non-EU oriented production, we turn to an analysis of the trade data by sector of industry.

EUROSTAT Trade Statistics

This high quality database contains annual data on trade flows by 7-digit product categories between the 12 Member States and some 200 non-Community countries. We obtained imports from Bulgaria, Hungary, Poland, and Romania for the period 1988–95 for the EU12. In order to link the foreign trade data with the data on industrial output we used the NACE CLIO (1970) product classification system (see "Système européen de comptes économiques intègrès" EUROSTAT, Luxembourg, 1979). The IMF financial statistics yearbooks provide the value of trade flows in 1989 prices. The trade data is in 1000 ECUs. The deflator used in this case was the CPI in the twelve Western European countries reported in the country tables in the IMF Financial Yearbook. We used the weighted sum of the CPI for EU12 with weights equal to the countries' respective shares of their GDP in a common currency.

Hoekman and Djankov (1997) provide us with a good analysis of the export structure in Central and Eastern Europe. Table 4 is constructed from their analysis. There are a number of important observations to be made. First, the export share of the EU at the start of the transition process was greater than CMEA trade. Secondly, we observe the export share both to former centrally planned economies and to the EU changing in a dramatic fashion. A large initial decline in exports to the former CMEA is observed up to 1993 with a recovery only evident in the later period of 1993–96. The positive impact of EU trade was apparent in early periods, but the real expansion can only be observed in the later period.

In Table 6, we report, among other things, the distribution of export share by sector of industry in 1988 and the initial size of sectors in industry, averaged over the four countries. We note that all sectors of industry contained products that were exported to the EU before 1989 and the larger sectors in industry under the planning system had the greater share of industrial exports to the EU. We wish to examine the experience of products at the 7-digit

level of Industry within these 2-digit sectors over the period 1989–95. We do this by constructing the following products for EU Export Creative Destruction Index (CDI) for each 2-digit sector of Industry in country j over a defined period t-1 to t. We express the index as in the following,

$$CDI_{ijt} = \sum_{i=1}^{k} \left[\frac{x_{kijt}}{X_{ijt}} \left(\frac{|x_{jijt} - x_{kijt-1}|}{|x_{kijt} + x_{kijt-1}|/2} \right) \right] \tag{20}$$

We construct the CDI in sector i of county j in period t from the export level of products, k, at the 7-digit level of industry. For each product we calculate the absolute change in the level of exports over the period t-1 to t and divide it by the average size of the product exports over the defined time interval. This term is bounded between 0 and 2. To get the size weighted average of product turbulence classified with 2-digit sectors of industry we aggregate over products up to the sector level. Each products contribution is weighted by the share of its exports in ijt to the overall sectors exports, X, in ijt. Expansions and contractions, entry and exit of product categories for EU export, generate turbulence and move the index closer to two. This is likely to reflect firm turnover and the introduction of products with better verticle attributes as outlined in our theoretical section.

In Table 5 we examine the year to year evolution of our CDI index by Country, weighting by the size of sectors within industry. To allow us see whether the smaller sectors experience was different we also report the index where each sector is given an equal weight. In Hungary the average product exported to the EU generated turbulence in the order of 22 percent of its export size over the period 1989–90. This turbulence increased over time, particularly after 1993, to the order of 82 percent of product export size over the period 1994–95. Giving an equal weighting to the size weighted product experience of each sector we observe that the products in the smaller sectors generated more turbulence. These patterns are also transparent in the other three countries.

In Table 6, the presence of products of EU export creative destruction, averaged over the four countries, is evident in all sectors. With the exception of basic metal and fuel production, the index is greater in sectors that were traditionally small in output and in their share of EU exports under the planning system. In all sectors the size-weighted turbulence of products is greater in the later period, 1992–95. By 1995 sectors such as leather products, wood products, electrical and optical equipment, and transport equipment, that were traditionally small sectors had, on average, product turbulence greater than 100 percent of the export size in the previous year. In the last column of Table 6 we document a concentration index of product sizes within sectors, averaged across the four countries. We report an augmented Herfdinahl index which is normalized for the number of products in the sector by subtracting the value of the standard index. The closer the index is to one, the further away the sector of industry is from having a distribution of equal export share across products. In general we find that bigger sectors do not have a higher concentration of products in export

structure as compared with smaller sectors, with the exception of fuels production. In addition concentration levels do not rise over time. In fact product share of sector exports is in many cases becoming slightly more fragmented.

Our analysis suggests that the factors behind the evolution of the CDI coefficient seem to be sector specific and common across countries. Aturupane, Djankov, and Hoekman (1997) and McDowell and Thorn (1998) document a large increase in intra-industry trade between the EU and Central East European countries over this period, 90 percent of which is verticle in nature. They also find that 85 percent of the variation in vertical intra-industry trade is not country specific but industry specific, which is consistent with our analysis. They report that higher levels of intra-industry trade are observed in those sectors engaged in vertical product differentiation and foreign direct investment. We now turn to the analysis of the initial EU foreign direct investment flows in 1990 by sector of industry and by country. Investment is the key determinant of the reduction in real time creative destruction intervals in our theoretical model. We intend to model observed patterns in our CDI index using initial EU foreign direct investment flows by sector of industry. With the instrumental values of our CDI index, we estimate the portion of sector growth in each country that can be explained by vertical innovations in product categories exporting to the EU over the period 1989–95 and use panel data techniques to model non-EU output as deterministic unobservable *ij* heterogeneity.

Bocconi Foreign Direct Investment Data Base

These data were collected as part of a research project commissioned by DG III of the European Commission (Ref: SUB/96/83328/U.B.), from two general sources. First, published lists of foreign investors collected by national investment promotion agencies and international organizations. These agencies were interviewed in March and April 1997. Secondly, from Journals, Specialized Magazines and Newspapers. The data bank contains information on 2385 investment operations across twelve host countries including, Bulgaria, Hungary, Poland, and Romania, by NACE code. The amount of initial investment, in Millions of ECUs, were aggregated to the higher level of 13 NACE manufacturing branches (DA,DB,...,DM) by summing up over FDI operations. To be counted as FDI, the investment should ensure a lasting interest and control in the management of an enterprise. The investment can be Greenfield investment but the majority was an acquisition or a joint venture. The reliability of the data, cumulated initial values of investments, compares favorably with official FDI flows measured by EUROSTAT, European Union Direct Investment Yearbook 1996, on a home country basis for the period 1992–94.

In Table 7 we summarize the data on the amount of initial FDI investments in 1990 (millions of ECUs) aggregated up to he level of our 13 NACE manufacturing branches of industry. Hungary and Poland attracted the larger share of the investment flows. Macro-stability was a key factor in attracting the flows (see EBRD, *Transition Report*, various years). Investments were also sector specific, with some traditionally small sectors attracting large investments. The distribution across the sectors was similar in each country but the

magnitude was higher in each sector in the Visegrad countries. Many of the FDI investments were joint ventures, an hence the values of FDI could suggest that much larger investment activities were present. In the next section we undertake an econometric analysis.

IV. The Econometric Analysis

In this section we estimate the impact of the product for EU export creative destruction index on sector output changes, as stated in the reduced forms of (14) and (15), with panel data modeling techniques. The CDI variable is instrumented using initial EU foreign direct investment flows, initial sector size, sector, country and year dummies, and interactions terms. We use the predicted values to model growth in sector *i*, country *j* during the interval *t*-1 to period *t*. We wish to decompose sector growth into that determined by the observable EU trade developments (induced by innovations in products using foreign capital), unobservable but deterministic sector developments (market developments in non-EU products) and a random element. The growth model may be written as follows,

$$Growth_{ijt} = \alpha + \beta_1 \hat{CDI}_{ijt} + \beta_1 (\hat{CDI}_{ijt} x\, ISIZE_{ij}) + \beta_3 YEAR_t + v_{ij} + \varepsilon_{ijt} \qquad \textbf{(21)}$$

To evaluate whether the instrumented values of CDI had a heterogeneous impact by size of sector, it is interacted with initial sector size, ISIZE. Unobserved heterogeneity in sector *ij* is controlled for by the inclusion of a unit specific residual, *vij*, that is comprised of a collection of factors not in the regression that are *ij* specific and constant over time. In addition to controlling for the collection of factors not related to the EU trade that are *ij* specific and constant, we control for *ij* time varying effects with YEAR. For example, we have no data on the product turbulence within sectors generated from the negative impact of the decline and recovery of the former CMEA market. We also do not have data to control directly for disorganization and other supply side problems that may constrain such products performance. The intercept and trend in the regression allows us to estimate the baseline intercept shift and evolution overtime of the unobservable deterministic factors for the region. The recovered sector *ij* fixed and time varying effects will be subtracted from the overall intercept shift and time trend to estimate the unobserved deterministic sector *ij* effect.

The results of our instrumented regression on sector output growth are presented in Table 8. The instrumented CDI has a significant positive impact on growth, but its estimated impact depends on sector size. Although smaller sectors exhibit more turbulence in product categories, the estimated impact on growth per unit of change is less compared with large sectors.

In Table 9 the growth rate in (21) by sector *ij* is decomposed into the portion of growth estimated to have been induced by innovations in products for EU export, and

deterministic unobservable factors related to the collapse of the CMEA market. We sum over sectors, weighting by sector size, in each year to get the contribution of EU and Non-EU products performance to the aggregate growth rate of manufacturing output. The net change predicted shows us the estimated impact of these compositional changes within sectors on aggregate industrial growth. Excess reallocation is the sum of the absolute, size weighted, growth rates of EU and non-EU products by sector over and above that necessary to generate the observed net growth rate predicted for manufacturing output. The greater the simultaneous expansion of EU and contraction of non-EU products within sectors the bigger the index.

We also report the predicted net change in the manufacturing year to year growth rate and the reallocation of output within sectors to producing EU rather than previously CMEA oriented products, given equal weights to all sectors. This illustrates whether the smaller sectors are predicted to have had a different experience.

Comparing the within sector analysis in Table 9 to the between sector analysis in Table 2 we see that most of the observed changes in the aggregate output curve are induced by changes within sectors rather than between sectors. The U-shape in industrial output results from the net impact of offsetting developments within sectors. Products for EU export induced sector growth in each year, but the effect is particularly strong from 1993 onwards. Products previously sold into the CMEA market collapsed in the first few years of transition and only recovered in Hungary and Poland after 1994. In Table 9 we see that the experience was heterogenous across sectors. In particular, by giving equal weights to the smaller sectors we observe two points. First, the U-shape in the net change predicted for manufacturing output due to the within sector experience is flatter. In the early periods the CMEA shock did not dominate the benefits of the EU trade shock as much as in the larger sectors. In the latter periods the dominance of the EU trade shocks were not as great as in the larger sectors. Secondly, the reallocation of output within sectors to EU oriented products away from previously CMEA directed products was not as a great in smaller sectors. Although the smaller sectors did not perform as well on the basis of EU exports, they still increased their share of industrial output over time. This was because they suffered much less from the power of the CMEA shock and its slow recovery.

In Table 10 we report the sector analysis averaged over the four countries. The countries had a similar sector specific experience. The estimated EU trade shock and the collapse of the CMEA shock on each sector are reported as well as the actual output growth experience of the sector in question. We see clearly the points inferred from Table 9 when considering the experience of small versus large sectors.

Our econometric work allows us to estimate the evolution of non-EU industrial production. In Figure 3 we compare the evolution of non-EU oriented industrial output in CIS to our four CEE countries. We observe a relatively steep decline in non-EU industrial output in the first few years of transition in CEECs. One can argue that the CEECs started initial restructuring (reductions in over-manning) earlier since we observe a convergence between

cumulative output indices of the two groups of countries in the later years of transition. The graph illustrates the U-shape in CEE industrial output resulted mainly from the existence of EU oriented production before 1989 and its rapid expansion since then fueled by the increased access to the EU market and EU investment.

V. Conclusions

We have shown that the experience of EU oriented output within sectors has been fundamentally different to that estimated fro non-EU oriented products. Greater access to the EU market and foreign investors has induced growth with increasing convexity over time in all sectors of each country but particularly in traditionally larger sectors. This growth was in product categories that already exported to the EU before transition in 1989. The dynamics of EU oriented output, ex-post trade and market liberalization, is modeled theoretically and empirically as EU induced Shumpeterian waves of verticle product innovations. Our results suggest that transition issues such as reallocation, restructuring and disorganization were not of first order importance when considering this component of industrial output. This might be expected to the EU before 1989, thereby minimizing the need to restructure product attributes. The use of foreign capital and expertise of European companies allowed them to privatize and restructure with ease and take full advantage of increased market access to the EU.

The evolution of non-EU industrial output is estimated to follow the same pattern as that observed CIS countries. Hence the faster recovery, or the U-shape industrial output, observed in CEE as compared with CIS countries is mainly explained by the inherited presence of EU oriented production and its unconstrained growth over the transition period. Our main conclusion is that trade orientation is the key indicator of performance during transition.

The shape of the non-EU component of industrial output varies from sector to sector. In some cases we observe a U-shape while in others an inverse J-curve. It is unlikely, as in the case of EU oriented output, that this component of industrial output is an efficient outcome induced solely by trade and market liberalization. Most of the theoretical literature thus far explains the collapse of industrial output as an inefficient outcome driven by supply side rigidities that constrain the transition process. Do supply side constraints tell the full story?

As outlined in Blanchard (1997), there are two key elements of the transition process, reallocation and restructuring. Reallocation refers to the movement of production away from state to private ownership. Restructuring refers to changing the level and technical composition of labor and capital in search of cost and productive efficiency in production. A distinction can be made between initial restructuring and deep or strategic restructuring. Initial restructuring refers to reducing over-manning levels in response to the hardening of budget constraints. Deep or strategic restructuring requires that fundamental actions be taken aimed

at improving the long-run performance of the firm. This type of restructuring can include various actions such as an increase in investment into new technology, vertical innovations in products, and replacement of obsolete capital. In the absence of distortions, the level of output that results from the transition process should be a first best outcome that reflects efficient eradication of distortions that existed in the microeconomic environment of the planning system. This was the experience of EU oriented output but not of non-EU oriented output.

To date the theoretical explanations put forward for the initial collapse in non-EU industrial output are based on the presence of supply side rigidities that constrain the transition process. Atkeson and Kohoe (1995) blame the presence of labor market frictions that result from the sector shifts within output and a lack of investment into the reorganization of human capital. Wei Li (1994) explain the decline by noting that while central planners behaved like a single vertically integrated monopoly liberalization lead to multiple monopolies charging monopoly prices to downstream monopolies constraining the transition process. Blanchard (1997) explains the decline as a second best outcome driven by the presence of downward real wage rigidities during transition. Finally, Blanchard and Kremer (1997) and Roland and Verdier (1997) provide us with the microeconomic foundations for understanding why *disorganization* in the links of production, led to a short-term output contraction after market liberalization and a recovery thereafter. Blanchard and Kremer (1997) model "disorganization" as disruption in the production links that had been established during central planning. Under central planning bilateral relationships existed between suppliers and buyers. Liberalization of the market gave suppliers and outside option. An assumed presence of information asymmetries on the outside option of suppliers created disruption in their model. Firms cannot find out the price that alternative buyers are willing to pay to the supplier. As a result they may not pay a price that prevents suppliers switching to new buyers, thus creating disruption in the production links and a fall in output during transition.

Roland and Verdier (1997) also model "disorganization" in production during the transition process. They focus on the role of search frictions created from the desire to find new partners in the chain production. The outside option is endogenous in a model of two sided search and matching. In the long-term more efficient opportunities are available to all. Suppliers and buyers will maintain existing links until one finds a better match. Search by many bad buyers creates congestion and reduces the quality of matches in the short term. The fall in output is not generated by the breakdown of supplier and buyer relationships that existed in the planning system but due to the assumption that investments will not be undertaken in production until a long-term partner is found. No investments take place during search. Aggregate output in the years after liberalization contracts due to a fall in investment demand and the failure to replace obsolete capital.

Do the above supply side theories tell the whole story? The firms producing products traditionally exporting to the CMEA had three choices: exit, re-orient their production to Western markets, or improve the technical efficiency of production to make products of the quality required to compete on previously CMEA markets. The latter was driven by the

decline in market demand and the availability of foreign imports. Rodik (1994) rules the second choice out. For traditional firms that did not exit, problems of reallocation, restructuring and disorganization may have become first order in importance. Yet, this may have been induced by changes in taste patterns and competitive pressure from imports in the previously named CMEA market. The interaction of the demand shock with supply side rigidities may well be the determinant of the collapse and slow recovery that is estimated by us in our empirical work in CEE countries. These issues can only be disentangled using firm level data on a sample of firms that existed under central planning *and* traded within the CMEA before the event of transition.

Table 1: Total Manufacturing D (NACE)

Sector #	Sector Name	D	NACE
1	Food, Beverage and Tobacco	DA	(15,15.1-8,15.9,16)
2	Textiles and Textile Products	DB	(17,18)
3	Leather and Leather Products	DC	(19.1-2,19.3)
4	Wood Products	DD	(20)
5	Paper, Printing and Publishing	DE	(21,22)
6	Fuels Production	DF	(23)
7	Chemicals Products, Fibers	DG	(24, 24.1/2/7, 24.3-6)
8	Rubber and Plastic Products	DH	(25,25.1,25.2)
9	Mineral Materials and Products	DI	(26,26.1-4)
10	Basic Metals and Fab. products	DJ	(27,28)
11	Machinery, excluding electrical	DK	(29)
12	Electrical and Optical Equipment	DL	(30,31,32,33)
13	Transport Equipment	DM	(34,35)
14	Other Manufactured Products	DN	(36)

Table 2: Aggregate Growth Rate of Manufacturing and Sector Heterogeneity

Year	89-90	90-91	91-92	92-93	93-94	94-95
(i) Bulgaria						
Rising Sectors	.001	.003	0	.012	.159	.076
Declining Sectors	.204	.272	.176	.144	.015	.006
Net Change	-.20	-.27	-.18	-.13	.14	.07
Excess Reallocation	.002	.01	0	.024	.03	.013
(ii) Hungary						
Rising Sectors	.0003	.0001	0	.056	.104	.080
Declining Sectors	.117	.211	.202	.015	0	.004
Net Change	-.12	-.211	-.202	.041	.104	.08
Excess Reallocation	.0005	.0003	0	.031	0	.009
(iii) Poland						
Rising Sectors	.0005	.107	.091	.117	.119	.094
Declining Sectors	.346	.107	.075	0	0	.002
Net Change	-.346	.0004	.016	.117	.117	.092
Excess Reallocation	.001	.214	.150	0	0	.004
(iv) Romania						
Rising Sectors	0	0	.002	.010	.068	.112
Declining Sectors	.254	.178	.138	.054	.026	0
Net Change	-.254	-.178	-.136	-.044	.042	.112
Excess Reallocation	0	0	.004	.019	.052	0

Table 3: The Dispersion of the Absolute Change in Sector Size 1990-95

(i) Across Countries		(ii) Within Countries	
Sector	Dispersion (1990-95)	Country	Dispersion (1990-95)
1	.31	Bulgaria	1.59
2	.56	Hungary	2.34
3	1.01	Poland	2.72
4	.70	Romania	2.45
5	.41		
6	.76		
7	1.06		
8	.71		
9	.71		
10	1.69		
11	.91		
12	1.07		
13	.75		

Table 4: Structure of Exports to Former CMEA Markets and The EU 1990-96

Country	Export	Growth*	Share of Exports**					
			EU			CMEA		
	1990-93	1993-96	(90)	(93)	(96)	(90)	(93)	(96)
Bulgaria	13.4	22.3	40	46	51	30	16	19
Hungary	7.1	14.3	50	56	71	34	14	21
Poland	5.9	16.2	51	70	69	33	11	21
Romania	6.2	16.7	36	40	54	35	11	10

Source: Heckman and Djankov (1997)
*Annual Average Percentage Growth
**Percent

Table 5: Year to Year Growth in (Sector Size Weighted and Equal Weights (E)) EU Export *Creative Destruction* Overtime by Country

Country	1989-1990	1990-1991	1991-1992	1992-1993	1993-1994	1994-1995
Bulgaria	.22	.50	.67	.61	.77	0.93
(E)	.31	.64	.83	.76	.92	1.00
Hungary	.22	.41	.51	.58	.63	.82
(E)	.26	.47	.63	.67	.75	.96
Poland	.35	.48	.53	.53	.63	.85
(E)	.34	.54	.62	.67	.77	.99
Romania	.62	.65	.65	.77	.73	.84
(E)	.56	.70	.75	.84	.78	.81

Table 6: Products for EU Export *Creative Destruction* by Sector (Averaged Over Countries).

(a) Creative Destruction Index, Average over 1989-92
(b) Creative Destruction Index, Average over 1992-95
(c) Intial Share of EU Exports in 1988
(d) Initial Size of Sector in 1989
(e) Concentration of Product Contribution by Sector 1995 (1989)

Sector	(a)	(b)	©	(d)	(e)
1	.40	.47	.16	.22	.36 (.40)
2	.45	.64	.08	.08	.36 (.31)
3	.67	1.3	.02	.02	.59 (.50)
4	.61	.88	.04	.02	.27 (.28)
5	.59	.80	.05	.03	.62 (.71)
6	.58	.87	.19	.10	.59 (.78)
7	.51	.56	.14	.09	.41 (.37)
8	.43	.63	.02	.03	.54 (.50)
9	.57	.83	.03	.04	.27 (.32)
10	.46	.81	.18	.14	.29 (.32)
11	.43	.69	.06	.08	.23 (.29)
12	.45	.85	.03	.10	.30 (.39)
13	1.0	1.4	.03	.07	.43 (.31)

Table 7: EU FDI in 1990

(i) By Sector, Across Countries

Sector	Mean Value (Mill. ECUs)	Coefficient of Variation	Sector Size 1989
1	407.0	.87	.22
2	46.0	.96	.08
3	1.5	1.77	.02
4	3.8	.62	.02
5	47.3	.97	.03
6	3.5	1.77	.10
7	127.3	.73	.09
8	42.8	1.31	.03
9	160.3	1.65	.04
10	89.8	1.01	.14
11	61.5	.67	.08
12	545.0	1.30	.10
13	124.8	1.00	0.7

(ii) Within Country, Across Sectors

Country	Mean Value (Mill. ECU's)	Coefficient of Variation	
Bulgaria	8.2	2.4	
Hungary	250.9	1.8	
Poland	227.0	1.1	
Romania	24.9	1.1	

Table 8: Regression Results

	Fixed Effects Model
R^2 (Overall)	0.24
Growth*	
Constant	-.35 (7.8)*
CDI	-.06 (0.5)
CDI x ISIZE	2.3 (2.1)*
Year	.06 (4.7)*
Observations	306
Heterosced.	$\chi2(52)= 15.3$
AR1	$\chi2(1) = 7.62$
AR4	$\chi2(4) = 1.41$

*a. T-statistics in parenthesis

b. Significant at the 5% level.

c. Use predicted Values of CDI instrumented with initial values of FDI, initial sector size, country, sector and year dummies, and their interactions. Interactions of Year x Country x Sector are included in the Fixed Effect Model. Only Fuels Production in Bulgaria and Romania turn out to have a different time varying ij effect compared to that estimated in the overall pooled sample.

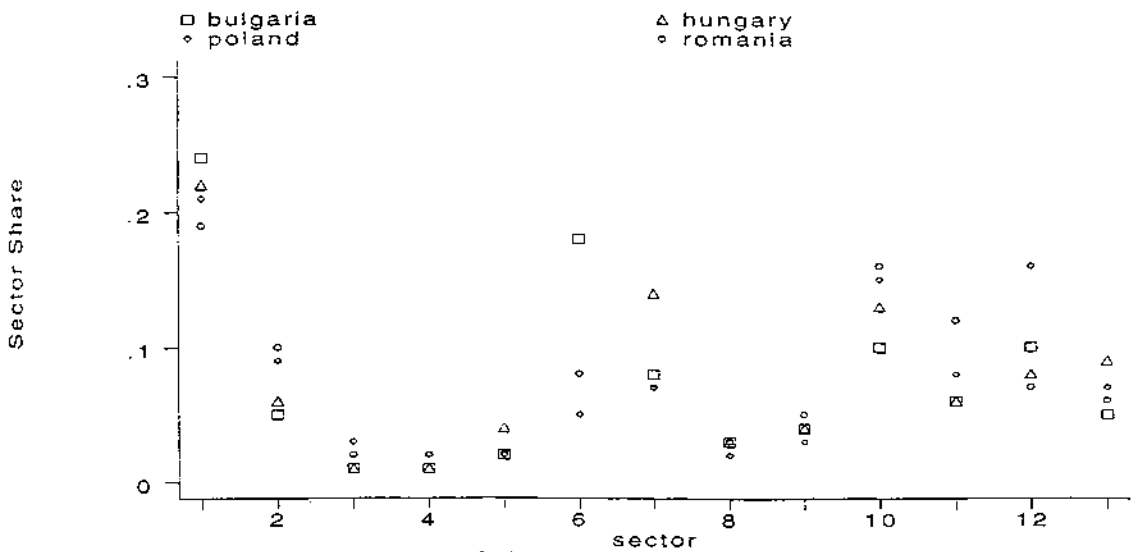
Table 9: Aggregate Growth Rate of Manufacturing and Within Sector Heterogeneity

(i) Bulgaria						
Year	**89-90**	**90-91**	**91-92**	**92-93**	**93-94**	**94-95**
EU Products	.08	.11	.14	.15	.20	.24
Non-EU Products	-.40	-.33	-.26	-.17	-.12	-.05
Net-Change Pred.	-.32	-.22	-.12	-.02	.08	.19
Excess Reallocation	.16	.22	.28	.30	.24	.10
Net-Change Pred. (Equal Weights)	-.28	-.19	-.11	-.01	.06	.14
Excess Reallocation (Equal Weights)	.12	.15	.19	.24	.17	.08
Hungary						
EU Products	.07	.09	.11	.13	.16	.18
Non-EU Products	-.28	-.24	-.17	-.11	-.04	.01
Net-Change Pred.	-.21	-.15	-.06	.02	.12	.19
Excess Reallocation	.14	.18	.22	.22	.08	0
Net-Change Pred. (Equal Weights)	-.20	-.12	-.05	.02	.01	.17
Excess Reallocation (Equal Weights)	.10	.14	.17	.18	.01	.04
(iii) Poland						
EU Products	.09	.11	.13	.15	.17	.17
Non-EU Products	-.27	-.21	-.15	-.11	-.04	.05
Net-Change Pred.	-.18	-.10	-.02	.04	.13	.22
Excess Reallocation	.18	.22	.26	.22	.08	0
Net-Change Pred. (Equal Weights)	-.15	-.07	.01	.08	.16	.24
Excess Reallocation (Equal Weights)	.12	.16	.21	.12	.05	.01
(iv) Romania						
EU Products	.16	.17	.19	.20	.21	.22
Non-EU Products	-.36	-.32	-.26	-.19	-.13	-.07
Net-Change Pred.	-.20	-.15	-.06	.02	.12	.19
Excess Reallocation	.32	.34	.39	.37	.22	.10
Net-Change Pred. (Equal Weights)	-.23	-.16	-.08	.01	.06	.13
Excess Reallocation (Equal Weights)	.22	.23	.25	.26	.17	.08

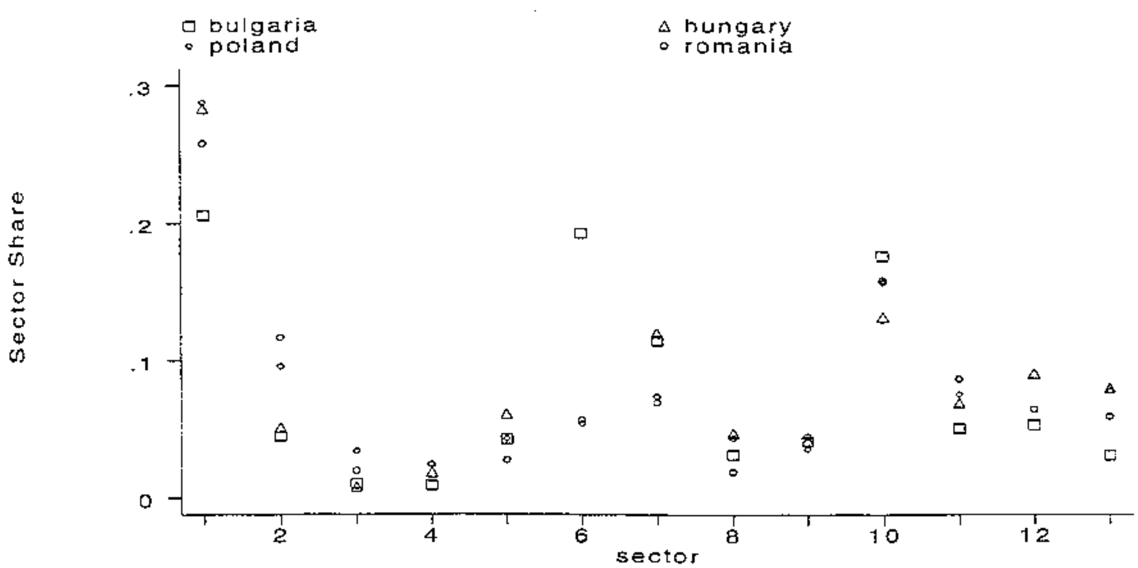
Table 10: Contributions to annual growth by Sector (Averaged Over Countries) made by
EU Products for Export (a) and Non-EU Products for Export (b);
Actual annual growth by Sector (Averaged Over Countries) (c); and Initial Size of Sector

Sector		89-90	90-91	91-92	92-93	93-94	94-95	Sector Size (1989)
1	a	.16	.18	.20	.22	.24	.26	.22
	b	-.37	-.31	-.25	-.19	-.13	-.07	
	c	-.12	-.11	-.05	-.06	.06	.05	
2	a	.05	.06	.08	.10	.11	.13	.08
	b	-.27	-.21	-.15	-.10	-.03	.03	
	c	-.12	-.19	-.13	-.02	.08	-.01	
3	a	.03	.03	.03	.04	.04	.05	.02
	b	-.22	-.16	-.10	-.04	.02	.08	
	c	-.24	-.10	-.15	-.06	.01	-.01	
4	a	.02	.02	.02	.03	.03	.04	.02
	b	-.16	-.10	-.04	.02	.08	.14	
	c	-.11	-.13	-.02	-.04	.15	-.01	
5	a	.02	.03	.03	.04	.05	.05	.03
	b	-.13	-.07	-.01	.05	.11	.17	
	c	-.18	-.14	.09	.13	.14	.09	
6	a	.15	.18	.17	.21	.23	.25	.10
	b	-.50	-.40	-.29	-.18	-.07	.03	
	c	-.38	-.44	-.09	.08	.20	.12	
7	a	.05	.07	.10	.12	.14	.16	.09
	b	-.30	-.24	-.18	-.12	-.06	.00	
	c	-.24	-.15	-.15	-.04	.07	.05	
8	a	.02	.02	.03	.04	.04	.05	.03
	b	-.20	-.14	-.08	-.02	.04	.10	
	c	-.25	-.16	-.04	.03	.07	.08	
9	a	.04	.05	.06	.07	.08	.09	.04
	b	-.23	-.17	-.11	-.05	.01	.07	
	c	-.16	-.24	-.13	.03	.05	.07	
10	a	.13	.16	.18	.21	.23	.26	.14
	b	-.37	-.31	-.25	-.19	-.13	-.07	
	c	-.31	-.26	-.11	.03	.16	.09	
11	a	.06	.08	.09	.11	.13	.14	.08
	b	-.32	-.26	-.20	-.14	-.08	-.02	
	c	-.25	-.24	-.19	-.10	-.001	.19	
12	a	.08	.11	.13	.16	.19	.21	.10
	b	-.36	-.30	-.24	-.18	-.12	-.06	
	c	-.37	-.16	-.38	.05	.12	.10	
13	a	.15	.17	.18	.20	.22	.23	.07
	b	-.37	-.31	-.25	-.17	-.13	-.07	
	c	-.31	-.30	-.23	.06	.02	.19	

Figure 1: Distribution of Sector Size Across Countries

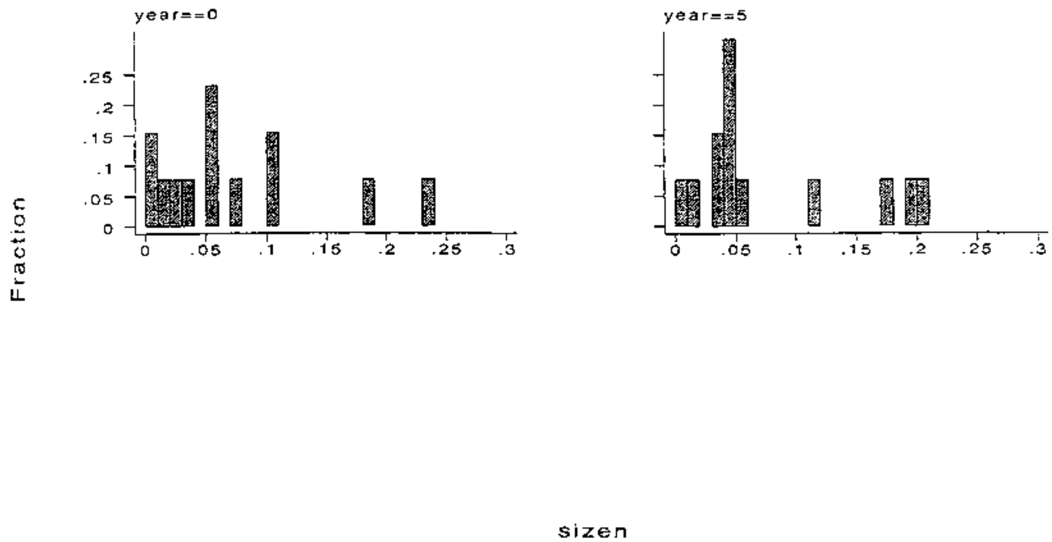


Initial Distribution of Sector Size Across Countries

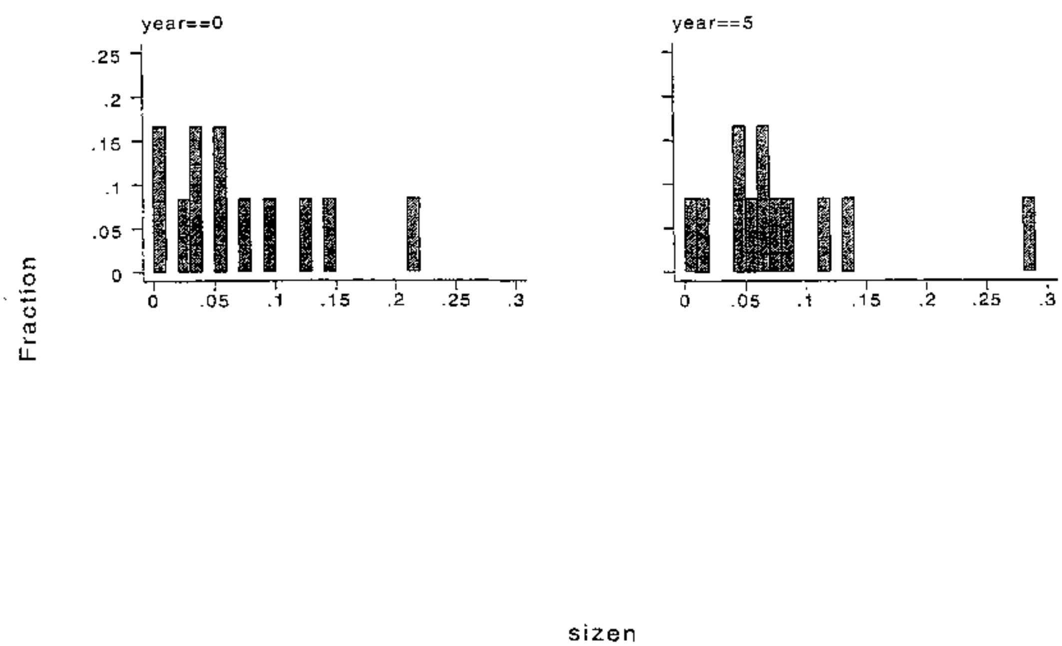


Final Distribution of Sector Size Across Countries

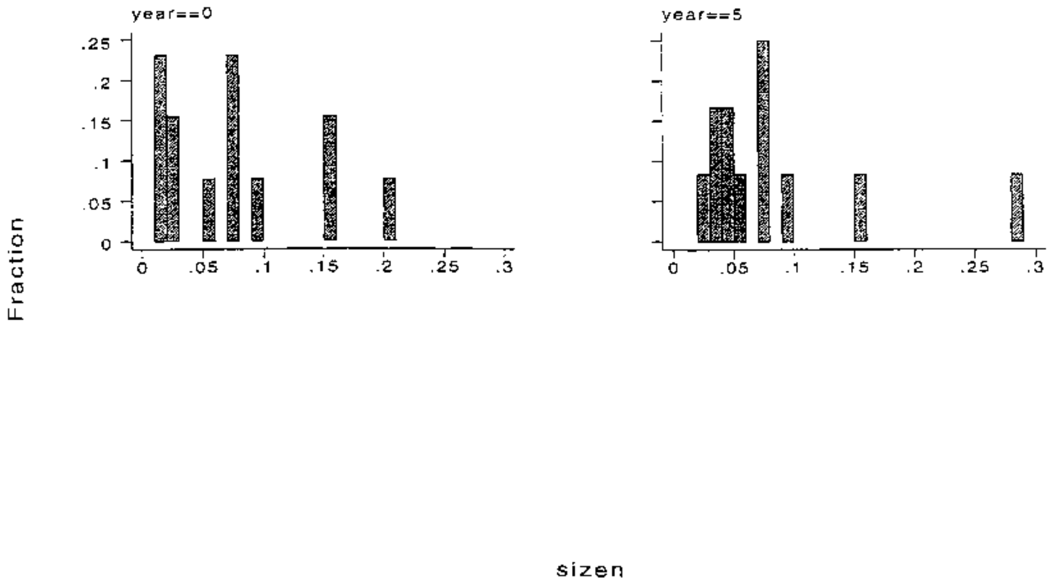
Figure 2 : Distribution of Sector Size Within Countries



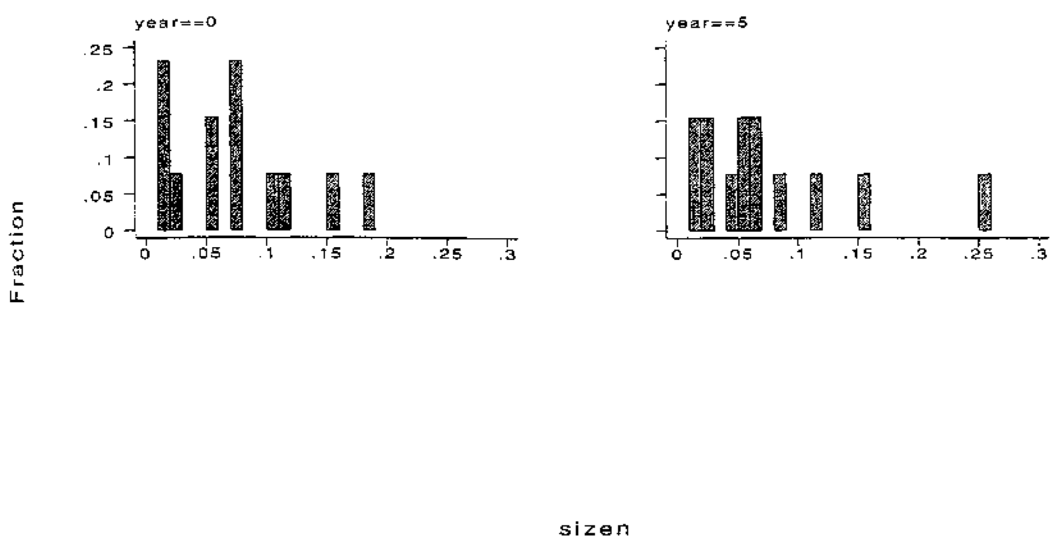
Distributions of Sector Size, Bulgaria



Distributions of Sector Size, Hungary

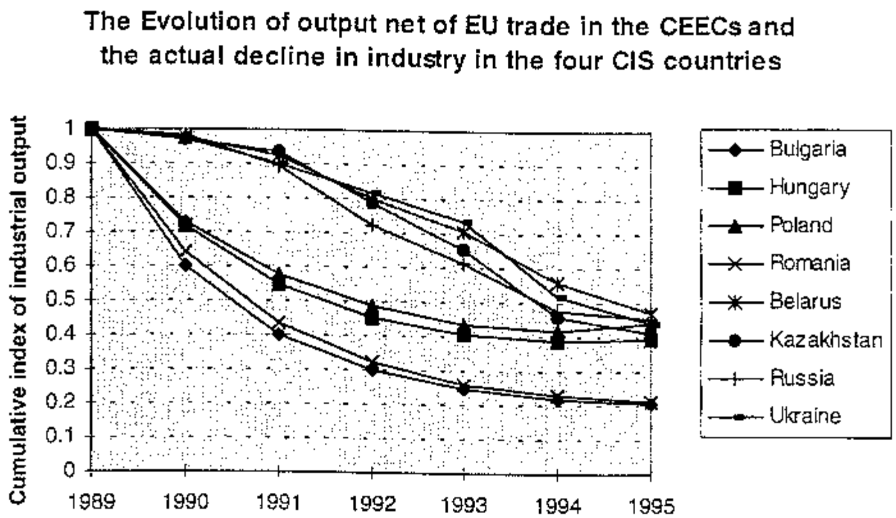


Distributions of Sector Size, Poland



Distributions of Sector Size, Romania

Figure 3: Trends in Industrial Output



Stage II

The accounting equation (1), arbitrage equation (2) and the asset equation (3) constitute the core of the model. At any period t an innovator who has a monopoly on producing good x_t chooses its value by maximizing the following profit function taking (5) as given:

$$\pi_t = \max_{x}[P_t(x_t)x_t - r_t x_t] \tag{A1}$$

This profit maximization yields the following value for x:

$$x_t = \left(\frac{S(1-\alpha)\gamma^t}{r^t}\right)^{1/\alpha} = x_t\left(\overset{+}{S}, \overset{-}{\gamma^t}, \overset{-}{r_t}\right) \tag{A2}$$

Using accounting equation and (A2) gives (taken I_t as given):

$$r = \frac{S(1-\alpha)\gamma^t}{(I-n)^\alpha} = g\left(\overset{+}{S}, \overset{+}{\gamma^t}, \overset{-}{I}, \overset{+}{n}\right) \tag{A3}$$

Applying the envelope theorem (using FOC from profit maximization for x) and using the arbitrage equation, (2) gives a second equation in r:

$$r = \left(\frac{\lambda\alpha}{(1-\alpha)(R+\lambda n)}\right)^\alpha S(1-\alpha)\gamma^{t+1} = f\left(\overset{+}{S}, \overset{+}{\gamma^t}, \overset{-}{n}, \overset{+}{\lambda}, \overset{-}{R}\right) \tag{A4}$$

Solving (A3) and (A4) gives the following optimal levels on n, r, and p:

$$n^0 = \frac{\gamma^{1/\alpha}\lambda\alpha I - R + R\alpha}{(1-\alpha+\alpha\gamma^{1/\alpha})\lambda} \tag{A5}$$

$$r^0 = S(1-\alpha)\gamma^{t+1}\left(\frac{\lambda\alpha}{1-\alpha}\right)^{\alpha}\left[R+\lambda n^0\right]^{-\alpha} \tag{A6}$$

$$P^0 t = \frac{S\gamma^t r_t}{S\gamma^t(1-\alpha)} = \frac{r_t}{(1-\alpha)} \tag{A7}$$

Stage I

The level of investment is endogenous and it is assumed that the optimal level of r resulting from any level of current investment I is perfectly known. The level of investment is determined from the maximization problem in (10): The value of optimal investment in this case is given by

$$I_t^0 = -\frac{R}{\lambda} + (1-\alpha+\gamma^{1/\alpha})\left(\frac{S}{A}\right)^{\frac{1}{\alpha}}(1-\alpha)^{\frac{1}{\alpha}-1}\gamma^{\frac{t}{\alpha}} \tag{A8}$$

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