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A TWO-COUNTRY TWO-SECTOR MODEL WITH VINTAGE TECHNOLOGIES

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Abstract: According to Navaretti, Soloaga ve Takacs (2000) many developing countries import a significant amount of used capital goods. This evidence suggests that developing countries' imported capital composition should include a significantamount of used capital goods. This paper develops a two-country, two-sector model by taking the trade in used capital goods into account. One of the sector produces capital goods, the other sector produces consumption goods. In each sector both types of capital goods, new and old, are used in the production. Numerical solution of the model produces results consistent with the evidence provided by Navaretti, Soloaga ve Takacs (2000).

Keywords: Vintage Technologies, Trade, Two-sector Two-country Model, Imported Capital Composition

İKİ ÜLKELİ İKİ SEKTÖRLÜKULLANILMIŞ ÜRÜNLER TİCARETİNE İZİN VEREN BİR MODEL

Özet: Navaretti, Soloaga ve Takacs (2000) makalesi pek çok gelişmekte olan ülkenin önemli ölçüde kullanılmış sermaye malı ithal ettiğini belirlemiştir. Dolayısıyla kullanılmış sermaye malları, gelişmekte olan ülkelerin ithal ettikleri toplam sermaye mallarının belli bir kısmını teşkil etmektedir. Bu çalışmada, kullanılmış sermaye malı ticaretine izin veren iki ülkeli, iki sektörün bulunduğu bir model kullanılmaktadır. Bu sektörler sermaye malı ve tüketim malları üretmektedir. Her iki sektörde de kullanılmış ve yeni sermaye malı birlikte kullanılmaktadır. Modelin sayısal çözümü Navaretti, Soloaga ve Takacs (2000) makalesindeki sonuçları desteklemektedir.

Anahtar Kelimeler: Kullanılmış Ürünler Ticareti, İki Sektör İki Ülkeli Model, İthal Edilmiş Sermaye Malları

I. INTRODUCTION

The composition of imports of capital goods is an important indicator for the development of the country. Caselli and Wilson [1] use composition of capital to make inferences about the cross-country income differences. They look at disaggregated imports of various types of equipment to make inferences on cross-country differences in the composition of equipment investment. They show that the composition of capital has the potential to account for some of the large observed differences in TFP across countries.

Navaretti et al. [2] analyze data on U.S. exports of metalworking machine tools by country of destination, classifying machines according to their vintage and technological characteristics. Their analysis suggests that less developed countries are buying a higher ratio of used to new machinery (see Table 1 below).

This paper uses a two sector North-South model which is a variant of Eaton and Kortum's [3] textbook model. In their model, a high relative price of capital and low price of consumption in developing countries appear. In their framework, both consumption and investment goods are tradable, but trade frictions in the form of iceberg costs make prices different across countries. Additionally, they assume that developing countries are completely specialized in producing consumption goods and import capital goods from developed countries, while developed countries produce both consumption and investment goods and import consumption goods from developing countries.

Eaton and Kortum's [3] model does not take different vintages into account. They consider only trade in new capital. But as Navaretti et al. 's [2] empirical analysis suggests we need to consider vintage technologies in a North-South economy framework.

The paper proceeds as follows. Section 2 provides some data facts taken from Navaretti et al. (2000). Section 3 presents the basic settings of the model. Section 4 has the numerical solution results. Section 5 has some concluding remarks.

II. EMPIRICAL EVIDENCE

The skill factor plays an important role for the choice between new and used machines when new machines embody technical change. Intuition suggests that it would be more appropriate to buy used capital for some developing countries lacking enough human capital. Some empirical support for the hypothesis is provided by Navaretti et al. [2]. They concentrate on US exports of metalworking machine tools in 1990-1994, disaggregated by commodity classification, whether they are new or

used, and country of destination (the data source is U.S. Department of commerce, Bureau of the Census, Exports of Merchandise CD-ROM). The sample covers 38 types of Metalworking machines, aggregated to the six-digit level in the Harmonized System, that are exported to 23 countries. Different types of machines require different types of skills. They develop a skill index for each 10-digit export category, reecting the degree of skill required to operate that type of machine. The index ranges from 1 to 4, increasing with the level of skill required. Looking at the shares (by quantity) of used machinery in total imports of machinery from the U.S., we see that low-income countries import a higher ratio of used to new machinery. When they divide the machines into high-tech (skill indexes 3 and 4) and low-tech (skill indexes 1 and 2) categories, the same pattern emerges. The ratio of used machines to new machines imported is greater for low-income countries than for high-income countries. Table 1 reports these facts. In this table high-income countries have GDP per capita greater than $ 12,000, middle income countries have GDP per capita between $1,300 and $12,000, and low-income countries have GDP per capita less than$ 1,300.

Table.1. Imports of Metalworking Machine Tools from the US.

Importing Countries	Ratio Of Used To New Machinery İmported	Average Index
High-income	0.096	2.93
Middle-income	0.112	2.71
Low-income	0.235	2.63

Source: Navaratti et al. (2000), author's calculations.

III. THE MODEL

The model employs a North-South economy framework with two-sector model in which vintage technologies are introduced hence there are two types of capital, new and old (used). In each sector both new and old capital are used in the production. There are two goods: A consumption good is denoted by *C* and a capital good is denoted by *K* The specification of production technologies is chosen to capture the fact that developed countries are concentrated in equipment production. The North produces both types of goods and specialized in producing capital goods and imports some consumption goods from the South. The South produces only consumption goods. International trade in both types of capital goods and consumption goods is allowed but, for simplicity international borrowing and lending are ruled out.

III.1. The North Economy

The North produces capital goods and consumption goods according to the technologies in Equations (1) and (2). The North is specialized in producing capital goods, hence $A_N > 1$. F is common across sectors and countries. The flow of capital is;

$$k_t^n = A_N F(K_{kt}^{Nn}, K_{kt}^{No}, L_{kt}^N) \quad (1)$$

Here k_t^n is the flow of new capital. N denotes North. n represents new, o represents old. The subscript k stands for capital and c stands for consumption goods. t is the time subscript. Here K_{kt}^{Nn} and K_{kt}^{No} are the amount of new and old capital respectively, used in the production of capital goods in North. A_N captures capital goods technology. L_{kt}^N is the labor used in the production of capital goods in the North.

The consumption good production;

$$C_t^N = F(K_{ct}^{Nn}, K_{ct}^{No}, L_{ct}^N) \quad (2)$$

C_t^N is the output of consumption goods produced by using K_{ct}^{Nn}, K_{ct}^{No} and L_{ct}^N as inputs. Aggregate new capital stock is given by $K_t^{Nn} = K_{kt}^{Nn} + K_{ct}^{Nn}$ and aggregate old capital stock is given by $K_t^{No} = K_{kt}^{No} + K_{ct}^{No}$ and the labor endowment is allocated between the two sectors $L_{kt}^N + L_{ct}^N = L_t^N$ where $L_t^N = 1$ for every t.

The current profit of the firms producing consumption and capital goods are respectively:

$$\pi_{ct}^N = P_{ct}^N C_t^N - w_t^N L_{ct}^N - P_t^{No} R_t^N K_{ct}^{No} - P_t^{Nn} R_t^N K_{ct}^{Nn} \quad (3)$$

$$\pi_{kt}^N = P_t^{Nn} k_t^n - w_t^N L_{kt}^N - P_t^{No} R_t^N K_{kt}^{No} - P_t^{Nn} R_t^N K_{kt}^{Nn} \quad (4)$$

Here, P_{ct}^N denotes the price of consumption goods, P_t^{Nn} and P_t^{No} denote the price of new and old capital respectively, w_t^N denotes the wage and R_t^N represents the interest rate.

The representative agent supplies one unit of labor inelastically and chooses current consumption to maximize;

$$\sum_{t=0}^{\infty} \beta^t U(c_{Nt}^N, c_{St}^N) \quad (5)$$

Here c_{Nt}^N stands for the consumption of home produced goods and c_{St}^N stands for the consumption of foreign (South) produced goods.

Subject to the constraints,

$$K_{t+1}^{No} = K_t^{No}(1-\delta) + K_t^{Nn}(\gamma) - \kappa_t^o \quad (6)$$

This is the transition equation for old capital. δ represents depreciation rate of capital, γ denotes the probability of becoming old for the new capital and κ_t^o denotes North's export of used capital to South. Trade occurs after production and across countries.

$$K_{t+1}^{Nn} = K_t^{Nn}(1-\gamma) + k_t^n - \kappa_t^n \quad (7)$$

This is the transition equation for new capital. κ_t^n is the North's export of new capital to the South. k_t^n is the flow of new capital. And the budget constraint of representative agent in the North;

$$P_{ct}^N c_{Nt}^N + d^C P_{ct}^S c_{St}^N + P_t^{Nn} K_{t+1}^{Nn} + P_t^{No} K_{t+1}^{No} =$$

$$w_t^N + P_t^{Nn}(1 + R_t^N)K_t^{Nn} + P_t^{No}(1 + R_t^N)K_t^{No} + P_t^{Nn}\kappa_t^n +$$

$$P_t^{No}\kappa_t^o \quad (8)$$

Trade frictions are in the form of iceberg costs: For good $l = K, C$, the source country must ship d^l units in order for one unit to arrive at the destination. Since the North imports some consumption goods from the South, its price on arrival is $d^C P_{ct}^S$ .When the North exports both types of capital, κ_t^n and κ_t^o are both positive, then the agent earns the amount $P_t^{Nn}\kappa_t^n + P_t^{No}\kappa_t^o$.

III.2. The South Economy

The South produces only consumption goods and exports some of the consumption goods to the North and imports capital goods from the North.

$$C_t^S = A_S F(K_t^{Sn}, K_t^{So}, L_t^S) \quad (9)$$

Here *S* stands for the South. C_t^S is the output of consumption goods produced by using inputs K_t^{Sn}, K_t^{So} and L_t^S.

Aggregate capital stock $K_t^S = K_t^{Sn} + K_t^{So}$ and aggregate labor $L_t^S = 1$ for every *t*.

The current profit of the firm producing consumption goods is;

$$\pi_{ct}^S = P_{ct}^S C_t^S - w_t^S - P_t^{So} R_t^S K_t^{So} - P_t^{Sn} R_t^S K_t^{Sn} \quad (10)$$

Here P_{ct}^S denotes the price of consumption goods, w_t^S is the wage, R_t^S denotes the interest rate, P_t^{Sn} and P_t^{So} denote prices of new and old capital respectively.

The representative agent supplies one unit of labor inelastically and chooses current consumption to maximize;

$$\sum_{t=0}^{\infty} \beta^t U(c_{St}^N) \quad (11)$$

subject to the constraints;

$$K_{t+1}^{So} = K_t^{So}(1-\delta) + K_t^{Sn}(\gamma) + \kappa_t^o \quad (12)$$

The transition equation for old capital is given in Equation (12). Again δ denotes the depreciation rate and γ denotes the probability of becoming old for new capital. κ_t^o denotes the South's import of used capital from North.

$$K_{t+1}^{Sn} = K_t^{Sn}(1-\gamma) + \kappa_t^n \quad (13)$$

Here κ_t^n denotes the South's import of new capital from the North. And the budget constraint of the representative agent in the South;

$$P_{ct}^S c_{St}^S + P_t^{Sn} K_{t+1}^{Sn} + d^K P_t^{Nn}\kappa_t^n + P_t^{So} K_{t+1}^{So} + d^K P_t^{No}\kappa_t^o =$$

$$P_{ct}^S c_{St}^N + w_t^S + P_t^{Sn}(1 + R_t^S)K_t^{Sn} + P_t^{So}(1 + R_t^S)K_t^{So} \quad (14)$$

d^K is the iceberg cost. When the South imports some new capital goods from the North, its price on arrival is $d^K P_t^{Nn}$.

The resource constraints for the whole economy;

$$c_{Nt}^N + c_{St}^S + c_{St}^S = C_t^N + C_t^S \quad (15)$$

$$K_{t+1}^{Nn} + K_{t+1}^{Sn} = (K_t^{Nn} + K_t^{Sn})(1-\gamma) + k_t^n \quad (16)$$

$$K_{t+1}^{No} + K_{t+1}^{So} = (K_t^{No} + K_t^{So})(1-\delta) + (K_t^{Nn} + K_t^{Sn})\gamma \quad (17)$$

IV. RESULTS

F is taken common across sectors and constant returns to scale in new capital, old capital and labor:

$$F(K_{ct}^{Nn}, K_{ct}^{No}, L_{ct}^N) = (K_{ct}^{Nn})^{\alpha}(K_{ct}^{No})^{\theta}(L_{ct}^N)^{1-\alpha-\theta}$$

$$F(K_{kt}^{Nn}, K_{kt}^{No}, L_{kt}^N) = (K_{kt}^{Nn})^{\alpha}(K_{kt}^{No})^{\theta}(L_{kt}^N)^{1-\alpha-\theta}$$

$$F(K_{ct}^{Sn}, K_{ct}^{So}, L_{ct}^S) = (K_{ct}^{Sn})^{\alpha}(K_{ct}^{So})^{\theta}(L_{ct}^S)^{1-\alpha-\theta}$$

The results are obtained by solving the model numerically at the steady state. Tables 2 and 3 present the numerical results. Since the North is specialized in producing capital goods the technology parameters A_N, A_S are chosen accordingly. The wage rate in the North is taken as $w^N = 1$ and the utilities are log utilities.

The benchmark states the results for the benchmark parameters. The other columns in the Tables 1 and 2, show the results which obtained by changing the specified parameter while keeping the rest of the benchmark parameters.

In the North, the amount of new capital used in the production of consumption goods exceeds the amount of old capital used. The same pattern is observed for the capital goods sector as well.

In the South, for the consumption goods sector the amount of new capital is less than the amount of old capital used in the production. Therefore, the numerical results suggest that old capital constitutes the larger portion of total capital stock whereas in the North the opposite is valid. This pattern is consistent with the empirical evidence presented in Navaretti et al.

Table.2. Numerical Solution

	Benchmark	γ 0.001	Γ 0.03	A_S 1.3	A_S 1.8
K_c^{Nn}	1.90	1.79	2.19	1.92	1.92
K_c^{No}	0.97	0.87	1.27	0.98	0.99
K_k^{Nn}	0.83	0.84	0.83	0.83	0.83
K_k^{No}	0.04	0.03	0.09	0.04	0.04
K^{Sn}	1.12	1.10	1.07	1.48	1.63
K^{So}	1.25	1.21	1.33	1.40	1.77
L_c^N	0.95	0.95	0.94	0.95	0.95
L_k^N	0.01	0.01	0.03	0.01	0.01
κ^n	0.011	0.01	0.032	0.015	0.016
κ^o	0.001	0.003	0.014	0.002	0.001
κ^o/κ^n	0.09	0.30	0.44	0.13	0.063

Benchmark: α=0.2, θ=0.1, δ=0.01, γ=0.01, A_N=1.9, A_S= 1.1

Taking the ratio of the imported old capital to the imported new capital gives the consistent results with Navaretti. The last row of the Table 2 presents the ratios.

Table.3. Numerical Solution

	Benchmark	γ 0.001	γ 0.03	A_S 1.3	A_S 1.8
P^{Nn}	0.35	0.35	0.38	0.35	0.35
P^{No}	0.35	0.34	0.32	0.35	0.34
P_c^N	1.00	1.03	0.98	1.00	1.00
P^{Sn}	2.88	2.62	3.17	0.86	3.23
P^{So}	1.29	1.20	1.28	0.46	1.49
Pc^S	0.85	0.85	0.76	0.51	0.82
w^S	0.71	0.71	0.63	0.54	1.26

Benchmark: α=0.2, θ=0.1, δ=0.01, γ=0.01, A_N=1.9, A_S= 1.1

Table 3. presents the numerical results for the prices. If we compare the consumption goods prices across North-South, the consumption goods price is lower in the South which is consistent with Hsieh and Klenow [4]. In the South, the price of old capital goods is lower than the price of new capital. The capital goods prices in the South are higher than the prices in the North. This finding is consistent with Eaton and Kortum [3]. However, the equipment (capital goods) prices predicted by Eaton and Kortum's [3] model are inversely related to those reported in Robert Summers and Alan Heston's International Comparison Program of Prices data (CIC) [5]: while according to Summers and Heston's data [5], [6] developed countries have higher equipment prices than developing countries, Eaton and Kortum's model predicts the opposite.

V. CONCLUSION

In this paper a two country, two sector model is used in which trading in old (used) capital is allowed. The model is solved numerically in the steady state.

If we look at across vintages (new and old capital) we see that the amount of old capital in the South is higher than the amount of new capital as seen in the data. In the North the level of new capital is greater than the level of old capital as seen in the data. Hence the numerical results capture the level of vintages.

The benchmark case predicts higher capital goods prices in South than in North and higher consumption goods prices for the North. Hence my model captures the fact that consumption goods prices are cheaper in poor countries.

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