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A simultaneous equations model of the relationship between international trade, and economic growth and development with dynamic policy simulations☆

Dominick Salvatore

Department of Economics, Fordham University, New York, NY 10458, USA

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1. Introduction

The contribution of international trade to economic growth and development has long interested economists. However, the large number of empirical studies conducted so far have not completely resolved the controversy of the relationship between international trade and growth and development. The only majority conclusion seems to be that international trade is a "handmaiden" rather than an "engine of growth" (Kravis, 1970; Salvatore, 1983).[1]

Econometric studies in the past are invariably of a single equation type[2], which are clearly inappropriate for two reasons: the first is that they give *biased direct* results because trade and growth and development are clearly simultaneously determined (trade affects growth and development and in turn is affected by the latter). The second reason is that it does not measure the important *secondary* results, such as the effect of trade on international capital flows and therefore indirectly on trade, the effect on absorption and transfer of new technology from abroad, and also the introduction of more efficient managerial techniques.

The present study seeks to overcome most of the shortcomings of previous works by developing a simultaneous equations model that captures the most important direct and indirect

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E-mail address: salvatore@fordham.edu.

[1] For the definitive *general* discussion of the relationship between international trade and economic growth and development see Little, Scitovsky and Scott (1970), Chenery and Syrquin (1975), Bhagwati (2007), Krueger (1978), and Salvatore (2020).

[2] For a typical single equation study see Wang, Liu, and Wei (2004).

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quantitative aspects of the relationship between international trade and economic growth and development. The model is estimated by Full Information Maximum Likelihood, validated by dynamic simulation and utilized to conduct dynamic policy and other counterfactual simulations.

2. A dynamic model of trade, growth and development

The following model is the reduced form for estimation derived from the structural model discussed in Salvatore (1983) and Salvatore and Hatcher (1991). It is the same reduced form of the model for estimation presented used in Salvatore (1993), which proved to be very robust.[3]

$$DY_t = a_0 + a_1 I_t + a_2 R_t + a_3 DX_t$$

$$I_t = b_0 + b_1 Y_t + b_2 DY_t + b_3 X_t + b_4 F_t$$

$$R_t = c_0 + c_1 DY_t + c_2 X_t + c_3 R_{t-1}$$

$$X_t = d_0 + d_1 P_t + d_2 W_t + d_3 R_t$$

where.

DY = growth of real per capita income.

I = gross fixed capital formation as a percentage of gross domestic product (GDP).

R = industrial output (manufacturing plus construction) as a percentage of GDP.

DX = growth in percentage of exports to GDP.

Y = real per capita income in US dollars.

X = exports as a percentage of GDP.

F = capital inflows (net imports of goods and services) as a percentage of GDP.

P = ratio of the consumer price index in the nation relative to consumer price index of all market economies.

W = index of real GDP of all market economies.

The first equation of the reduced form of the above model postulates a positive relationship between DY, I and DX, with the coefficient DX measuring the direct relationship of international trade and growth. The second equation postulates a positive relationship between I and Y, DY, X, and F (if foreign capital inflows do not entirely replace domestic investments and savings). The second equation also measures one of the indirect relationships between trade and growth and develoment. In addition, it establishes the simultaneous relationships between I and DY, with DY being a function of I in the first equation and I being a function of DY in the second equation.

The third equation of the model postulates a positive relationship between R and DY, and possibly X, and the lagged value of R. It also establishes the simultaneous relationship between the third and the second equation (and thus indirectly between trade and growth). The fourth equation postulates a negative relationship between P and X and a positive relationship between W and X, and also the indirect simultaneous relationship between trade and growth.

The present study seeks to overcome most of the shortcomings of previous econometric works by developing a simultaneous equations model that captures the most important quantitative *direct* and *indirect,* aspects of the relationships between international trade, on the one

[3] We attempted to improve the model by including the level of real per capita income (Y) in the first equation of the model, also including the degree of technology absorption in the third equation, the level of protectionism, and the extent of the black market in the fourth equation – and they did not improve the fit of the model.

hand, and growth and development, on the other. The model is tested by pooling data for 132 nations (representing all of the advanced and developing nations for which the required data are available – indicated in the Appendix), from 2004 to 2019. The model was estimated by Full Information Maximum Likelihood, validated by dynamic in-sample simulation, and utilized to conduct some of the most often advocated dynamic policies and other counterfactual simulations.

The model was also estimated separately for the 30 advanced nations in the study sample and the 102 developing nations and furthermore, separately, for the 17 large advanced nations and the 13 small nations (defined by the United Nations as nations with less than 10 million people) and also for the 61 large developing nations and for the 41 small developing nations, in order to test if international trade affects each classification of countries differently. For example, corrected for population size, advanced nations in general already trade more than developing nations and thus the latter can be expected in general to benefit more than the former from international trade. In addition, large countries can be expected to be tempted more than the small nations in trying to achieve economies of scale by protectionism, which could hamper their growth and development.

3. Relationship between trade and growth for advanced and developing countries

1. All Countries (Advanced and Developing Countries)

3.1. Empirical results and analysis

3.1.1. Estimation, validation, and implications of the model

We estimate the model using FIML for all the 132 counties in sample (advanced and developing) for 2004–2019. Table 1 presents the estimates and standard errors of the model's parameters.

Looking at the results for all the 132 countries in the study sample, we can see that the model fits the data well. Most of the model's estimated coefficients have the theoretically expected sign, and half are statistically significant at better than the 5% level. DY depends on DX; I primarily depends on X and F; R on DY and lagged R; and X on R. Trade is positively and significantly related to growth, as can be seen from the value of coefficient a3. Further, exports (coefficient b3) has a strong positive and statistically significant impact on capital formation. So, we must regard trade as a handmaiden of growth rather than the engine of growth. We also see that exports are negatively related to industrialization, but the magnitude of c2 is small and statistically insignificant.

Further, R is also positively related to X and statistically significant. The ratio of prices in the nation relative to the market prices has a positive but insignificant effect on exports. Further, the index of real GDP of market economies does not affect exports for the countries under study.

It is important to test the validity of the estimated model and the coefficients. To do that, we perform a dynamic simulation of the model over the sample period.[4]

Using the exogenous time series but only the starting values of the endogenous variables, the model generates historical simulated values for the endogenous variables. Table 2 presents the historical and simulated average annual values for the study period. We see that the RMSE of

[4] The Newton method was used for dynamic simulations.

Table 1
Full Information Maximum Likelihood Estimates, 2004–2019.

	All Countries	
Parameter	Estimated Coefficient	Standard Error
$DY_t = a_0 + a_1I_t + a_2R_t + a_3DX_t$		
a0	1.0593	0.7860
a1	0.0512	0.0408
a2	0.0077	0.0089
a3	0.0533 ***	0.0056
$I_t = b_0 + b_1Y_t + b_2DY_t + b_3X_t + b_4F_t$		
b0	11.3507 ***	1.3207
b1	0.0000	0.0000
b2	-0.3051	0.2030
b3	0.2950 ***	0.0287
b4	-0.0875 ***	0.0110
$R_t = c_0 + c_1DY_t + c_2X_t + c_3R_{t-1}$		
c0	-1.5409	1.2542
c1	1.1397 ***	0.1484
c2	-0.0173	0.0690
c3	0.9748 ***	0.0517
$X_t = d_0 + d_1P_t + d_2W_t + d_3R_t$		
d0	11.6717 **	4.6605
d1	0.0181	0.0191
d2	0.0000	0.0000
d3	0.7712 ***	0.0623
Number of observations	2112	

Note: *** , ** and * represents significance at 1%, 5% and 10% respectively.

Table 2
Historical and Simulated Average Annual Values, 2004–2019.

	All Countries			
	DY	I	R	X
Historical	2.53	22.91	27.43	40.21
Model	2.50	22.98	27.45	40.03
RMSE	4.09	6.24	2.18	27.50

the simulated values are close to the historical values, with DY diverging less than 1.2% and I, R, and X generally by less than 0.0%.

Even though the model is highly aggregative and was formulated to analyze average long-run growth, it also captures relatively well most short-run intercountry variations in DY, I, R, and X. Table 3 presents Theil's inequality coefficients (T) and their decomposition into bias (B), variance (V), and covariance (C) proportions. T values suggest 45% or more of the actual short-run intercountry variations in DY for all four groups of countries. More than 87% and 96% of the variation in I and R, respectively, were predicted, and 69% or more of variation in X for all the four groups of countries. The decomposition of T into its components is also near-optimal, with practically no error due to bias for all endogenous variables and all the132 countries, and with a large proportion of the error due to imperfect covariance (over which nothing can be done).

Table 3
Theil's Inequality Coefficients and their Decomposition.

	All Countries			
	DY	I	R	X
T	0.55	0.13	0.04	0.31
B	0.00	0.00	0.00	0.00
V	0.70	0.58	0.01	0.49
C	0.30	0.42	0.99	0.51

3.2. Dynamic policy simulations

The policymakers could attempt to increase its growth rate by operating on the exogenous variables regarded as policy instruments. In the current setup, these policy instruments are the growth in the percentage of exports to GDP (DX), the level of capital inflows as a percentage of GDP (F), and the ratio of the consumer price index in the nation relative to the consumer price index of all market economies (P).

Historically DX was 1.02% for all the countries in the study sample. Supposing these growth rates could be increased by 25–1.28%.[5]

This policy simulation (PSDX) is presented in Table 4. This does not impact DY as it remains same at 2.50 as baseline model. PSDX leads to a decrease in I from 22.98 to 22.97. Further, PSDX has no impact on R, as it remains same at 27.45, and X decreases from 40.03 to 39.99.

The results suggest that PSDX is not very effective in increasing DY because the historical values of DX and the estimated values of a3 are very small. As a result, I, R, and X are also slightly affected. This implies that, in general, the policy of substantially increasing DX is not very effective in promoting growth. The result suggests that the rate of economic growth and development depends primarily on internal conditions, and international trade provides only a weak supporting role.

Most effective would be the policy that attempts to increase the rate of foreign capital inflows by countries. By increasing, I would increase DY. The increase in DY would then increase I, R, and X, further increasing DY and I. Suppose that the developing nations could increase their average F by 25% over historical values, i.e., from − 4.39 to − 3.51. This policy PSF is presented in Table 4 to DY decreasing from 2.50 to 2.48. The result suggests that PSF is ineffective in increasing DY. I remains same at 22.98, R decreases from 27.45 to 27.42, and X decreases from 40.03 to 39.99. We see that PSF is also ineffective in increasing DY.

The third policy variable operates on P. Supposing that the governments can curb domestic inflation by 25%. As P appears explicitly in Equation 4, the strongest effect of this policy PSP is generally to increase X. With c2 being statistically insignificant (Table 1), an increase in X has a slight or no effect on R. DY decreases from 2.50 to 2.49; I decreases from 22.98 to 22.91; R decreases from 27.45 to 27.43; and X decreases from 40.03 to 39.83.

Finally, suppose that the index of real GDP of all market economies (W) was 25% higher than historically. W is an exogenous variable, not a policy variable, from a nation's point of

[5] This could possibly be achieved by reduction in trade barriers of or by advanced nations for exports of developing nations. Here we assume adequate supply responses from developing nations. The 25% increase has been chosen arbitrarily and can be scaled as needed.

Table 4
Dynamic Policy and other Counterfactual Simulation Results Average Annual Values, 2004–2019.

	All Countries			
	DY	I	R	X
B	2.50	22.98	27.45	40.03
PSDX	2.50	22.97	27.45	39.99
PSF	2.48	22.98	27.42	39.93
PSP	2.49	22.91	27.43	39.83
PSDXFP	2.51	22.97	27.45	39.97
CSW	2.49	22.97	27.42	39.98

I = gross capital formation as a percentage of GDP;
R = industrial output as a percentage of GDP;
X = exports as a percentage of GDP;
B = refers to the basic solution/ baseline model (from Table 2) to which the other simulation results are compared;
PSDX = the growth in the percentage of exports to GDP is 25% higher than historically;
PSF = the percentage of foreign capital inflows to GDP is 25% higher than historically;
PSP = the rate of domestic inflation is 25% lower than historically;
CSW = the index of real GDP of all market economies is 25% higher than historically.

view. Here we use this as a purely counterfactual simulation. With CSW, DY would have decreased from 2.50 to 2.49, I decreases from 22.98 to 22.97, R decreases from 27.45 to 27.42, and X decreases from 40.03 to 39.98. We see that PSW is also ineffective in increasing DY.

Further, we combine the three policy simulations operating on DX, F, and P (PSDXFP). We see that with PSDXFP, DY increases from 2.50 to 2.51, I decreases from 22.98 to 22.97, R remains same at 27.45, and X decreases from 40.03 to 39.98. These results are very important because they indicate that the policies most often advocated, such as increasing DX, F, and reducing P (curbing excess domestic inflation), as well as a more rapidly expanding international economy, are not very effective in increasing the rate of growth of real per capita income of the countries at different levels of income. This also indicates the serious difficulty the countries face in achieving substantially higher growth rates.

2. Advanced Countries

3.3. Empirical results and analysis

3.3.1. Estimation, validation, and implications of the model

We estimate the model using FIML separately for all the 30 advanced countries, 17 large, and 13 small countries for 2004–2019. Table 5 presents the estimates and standard errors of the model's parameters. From Table 5, we can see that the signs of the 13 slope coefficients are identical for all the three groups (All advanced, large advanced, and small advanced countries), except for b3, c1, c2, and d3 for large advanced, and a2, a3, b2, and c2 for small advanced countries. These absolute slope coefficients differ significantly from Advanced countries when ran together.

Firstly, looking at the results for All Advanced countries together, we can see that the model fits the data well. All the model's estimated coefficients have the theoretically expected sign, and most are statistically significant at better than the 5% level. DY depends on I, R, and DX; I depends on Y, DY, X, and F; R on lagged R; and X on P, W, and R. Contrary to theory, we find that trade is negatively related to growth for all advaced countries, as a3 is negative and

Table 5
Full Information Maximum Likelihood Estimates, 2004–2019.

	All Advanced		Large Advanced		Small Advanced	
Parameter	Estimated Coefficient	Standard Error	Estimated Coefficient	Standard Error	Estimated Coefficient	Standard Error
$DY_t = a_0 + a_1I_t + a_2R_t + a_3DX_t$						
a0	-5.3242 ***	1.2524	-2.9306 **	1.2527	-6.9224 *	3.8204
a1	0.2003 ***	0.0635	0.0524	0.0872	0.4841 ***	0.1182
a2	0.1087 ***	0.0383	0.1330 ***	0.0450	-0.0817	0.0980
a3	-0.0134 **	0.0065	0.0000	0.0084	0.0503	0.0353
$I_t = b_0 + b_1Y_t + b_2DY_t + b_3X_t + b_4F_t$						
b0	13.8667 ***	1.4497	14.2959 ***	4.1064	11.8985 ***	3.5607
b1	0.0001 ***	0.0000	0.0001 ***	0.0000	0.0002 **	0.0001
b2	2.1176 ***	0.3761	2.5884 **	1.0204	-0.8776	1.2407
b3	0.0499 ***	0.0195	-0.0403	0.0869	0.1339 **	0.0619
b4	-0.3610 ***	0.0982	-0.5137 ***	0.1543	-0.9456 **	0.4083
$R_t = c_0 + c_1DY_t + c_2X_t + c_3R_{t-1}$						
c0	-0.1993	0.5994	0.2200	1.5161	1.4334	1.6050
c1	-0.2152	0.1824	0.1649	0.4325	-0.0998	0.1252
c2	0.0044	0.0110	-0.0008	0.0210	-0.0030	0.0185
c3	1.0084 ***	0.0350	0.9754 ***	0.0680	0.9566 ***	0.0384
$X_t = d_0 + d_1P_t + d_2W_t + d_3R_t$						
d0	-62.5641 ***	21.7006	39.8859 *	22.2541	-53.3381	35.8514
d1	0.2955 **	0.1349	0.0033	0.1189	0.1643	0.2084
d2	0.0000 ***	0.0000	0.0000 *	0.0000	0.0000 ***	0.0000
d3	1.4926 ***	0.2285	-0.9886 **	0.3952	1.4961 ***	0.3542
Number of observations	480		272		208	

Note: ***, ** and * represents significance at 1%, 5% and 10% respectively.

statistically significant, while coefficient b3 has a positive and statistically significant suggesting a positive impact of exports on capital formation. So, we must regard trade as a handmaiden of growth rather than the engine of growth. We also see that exports are positively related to industrialization, but the magnitude of c2 is small and statistically insignificant. On the other hand, R is positively related to X and is statistically significant.

Next, we look at large and small advanced countries separately to investigate the relationship between trade and growth. Looking at the estimated coefficients for large advanced countries from Table 5, we see that all the estimated coefficients have the predicted signs, and most are statistically significant at the 5% level. DY primarily depends on R; I on Y, DY, and F; R on lagged R; and X on W (at 10%), and R. Trade has no impact on growth for large advanced countries, as a3 is zero in magnitude and statistically insignificant and higher in magnitude. Coefficient b3 is negative and statistically insignificant. This suggests that trade has no impact on economic growth for large advanced countries.

Further, we also see that exports are negatively related to industrialization, but the magnitude of c2 is very small and statistically insignificant. Also, R is negatively related to X and is statistically significant. The ratio of prices in the nation relative to market prices has a positive but statistically insignificant effect on exports, and the index of real GDP of market economies has a very low magnitude but positive impact on exports.

Table 6
Historical and Simulated Average Annual Values, 2004–2019.

	All Advanced				Large Advanced				Small Advanced			
	DY	I	R	X	DY	I	R	X	DY	I	R	X
Historical	1.63	22.06	24.00	48.34	1.11	21.11	21.96	37.97	2.30	23.29	26.67	61.89
Model	1.68	22.07	24.01	48.43	1.10	21.11	21.96	38.05	2.27	23.30	26.65	61.93
RMSE	3.45	3.51	1.10	21.86	2.44	2.68	0.77	18.04	4.49	4.09	1.44	19.69

Table 7
Theil's Inequality Coefficients and their Decomposition.

	All Advanced				Large Advanced				Small Advanced			
	DY	I	R	X	DY	I	R	X	DY	I	R	X
T	0.60	0.08	0.02	0.21	0.61	0.06	0.02	0.22	0.59	0.09	0.03	0.15
B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V	0.45	0.01	0.02	0.49	0.52	0.02	0.00	0.54	0.29	0.00	0.02	0.43
C	0.55	0.99	0.98	0.51	0.48	0.98	1.00	0.46	0.71	1.00	0.98	0.57

For small advanced countries, we see that the estimated coefficients have the predicted signs, and most are statistically significant at 5%. DY depends on I; I on Y, X, and F; R lagged R, and X on W and R. Trade is positively related to growth, as a3 is positive but statistically significant. Coefficient b3 has a strong positive and statistically significant impact on capital formation. This suggests that growth for small advanced countries is driven by capital formation. We also see that exports are negatively related to industrialization, but the magnitude of c2 is small and statistically insignificant. On the other hand, R has a strong positive and statistically significant effect on exports. During the study period, the index of real GDP of market economies has a very low magnitude but positive impact on exports.

It is important to note that trade does not impact growth for large advanced and small developed countries. Further, we test the validity of the estimated model and the coefficients. To do that, we perform a dynamic simulation of the model over the sample period.[6]

Using the exogenous time series but only the starting values of the endogenous variables, the model generates historical simulated values for the endogenous variables. Table 6 presents the historical and simulated average annual values for the study period. We see that the simulated values are close to the historical values, with DY diverging less than 3.1%, and I, R, and X generally by less than 0.2%.

Even though the model is highly aggregative and was formulated to analyze average long-run growth, it also captures relatively well most short-run intercountry variations in DY, I, R, and X. Table 7 presents Theil's inequality coefficients (T) and their decomposition into bias (B), variance (V), and covariance (C) proportions. T values suggest 39% or more of the actual short-run inter-country variations in DY for all three groups of countries (All Advanced, Large Advanced, and Small Advanced). More than 91% of the variation in I and R was predicted, and 78% or more of variation in X for all the three groups of countries. The decomposition of T into its components is also near-optimal, with practically no part of error due to bias for all

[6] The Newton method was used for dynamic simulations.

Table 8
Dynamic Policy and other Counterfactual Simulation Results Average Annual Values, 2004–2019.

	All Advanced				Large Advanced				Small Advanced			
	DY	I	R	X	DY	I	R	X	DY	I	R	X
B	1.68	22.07	24.01	48.43	1.10	21.11	21.96	38.05	2.27	23.29	26.67	61.89
PSDX	1.66	22.03	24.02	48.40	1.11	21.11	21.96	37.97	2.28	23.29	26.66	61.90
PSF	1.68	22.07	24.01	48.43	1.12	21.07	21.96	37.92	2.25	23.29	26.65	61.92
PSP	1.66	22.03	24.02	48.44	1.10	21.12	21.96	38.09	2.28	23.27	26.65	61.80
PSDXFP	1.67	22.05	24.01	48.38	1.12	21.09	21.96	38.00	2.22	23.28	26.65	61.87
CSW	1.67	22.07	24.01	48.41	1.11	21.13	21.96	38.07	2.29	23.28	26.66	61.84

I = gross capital formation as a percentage of GDP;
R = industrial output as a percentage of GDP;
X = exports as a percentage of GDP;
B = refers to the basic solution/ baseline model (from Table 2) to which the other simulation results are compared;
PSDX = the growth in the percentage of exports to GDP is 25% higher than historically;
PSF = the percentage of foreign capital inflows to GDP is 25% higher than historically;
PSP = the rate of domestic inflation is 25% lower than historically;
CSW = the index of real GDP of all market economies is 25% higher than historically.

endogenous variables and all the three groups of countries, and with a large proportion of the error due to imperfect covariance (over which nothing can be done).

3.4. Dynamic policy simulations

The policymakers could attempt to increase its growth rate by operating on the exogenous variables regarded as policy instruments. In the current setup, these policy instruments are the growth in the percentage of exports to GDP (DX), the level of capital inflows as a percentage of GDP (F), and the ratio of the consumer price index in the nation relative to the consumer price index of all market economies (P).

Historically DX was 2.00% for All Advanced, 2.09% for Large Advanced, and 1.90% for Small Developed countries. Supposing these growth rates could be increased by 25–2.50% for All Advanced, 2.61% for Large Advanced, and 2.38% for Small Advanced countries.[7]

This policy simulation (PSDX) is presented in Table 8. This decreases DY from 1.68 (baseline model) to 1.66 for All Advanced, increases from 1.10 to 1.11 for Large Advanced, and increases from 2.27 to 2.28 for Small Advanced countries. PSDX also leads to a decrease in I from 22.07 to 22.03 for All Advanced, remains same at 21.11 for Large Advanced, and remains same at 23.29 for Small Advanced countries.

Further, PSDX leads to a slight increase in R from 24.01 to 24.02 for All Advanced, remains same at 21.96 for Large Advanced, and at 26.67 for Small Advanced countries. PSDX also leads to a slight decrease in X from 48.43 to 48.40 for All Advanced, from 38.05 to 37.97 for Large Advanced, and a slight increase from 61.89 to 61.90 for Small Advanced. The results suggest that PSDX is not very effective in increasing DY because the historical values of DX and the estimated values of a3 are very small. As a result, I, R, and X are also slightly affected.

[7] This could possibly be achieved by reduction in trade barriers of or by developed nations demanding more of the exports of developing nations. Here we assume adequate supply responses from developing nations. The 25% increase has been chosen arbitrarily and can be scaled as needed.

This implies that, in general, the policy of even substantially increasing DX is not very effective in promoting growth in Advanced countries. The result suggests that the rate of economic development depends primarily on internal conditions, and international trade provides only a weak supporting role for most nations.

Most effective would be the policy that attempts to increase the rate of foreign capital inflows by nations. By increasing, I would increase DY. The increase in DY would then increase I, R, and X, which in turn would further increase DY and I. Suppose that the countries could increase their average F by 25% over historical values, i.e., from 1.54 to 1.93 in All Advanced, from − 0.01 to − 0.01 in Large Advanced, and from 3.56 to 4.45 in Small Advanced countries. This policy PSF is presented in Table 8, which shows that it remains the same at 1.68 for All Advanced, increases from 1.10 to 1.12 in Large Advanced, and decreases from 2.27 to 2.25 for Small Advanced countries. The result suggests that PSF is ineffective in increasing DY for the advanced countries. It remains same at 22.07 for All Advanced, decreases from 21.11 to 21.07 Large Advanced and remains same at 23.29 for Small Advanced countries. PSF's effect on R is – remains same at 24.01 for All Advanced, remains same at 21.96 for Large Advanced, and decreases from 26.67 to 26.65 for Small Advanced countries, respectively. We see that PSF is also ineffective in increasing DY.

The third policy variable operates on P. Supposing that the governments can curb domestic inflation by 25%. As P appears explicitly in Equation 4, the strongest effect of this policy PSP is generally to increase X. With c2 being very small (Table 5), an increase in X has a slight or no effect on R across the three groups. DY decreases from 1.68 to 1.66 for All Advanced, remains same at 1.10 for Large Advanced and increases slightly from 2.27 to 2.28 for Small Advanced countries; I decreases from 22.07 to 22.03 for All Advanced, increases from 21.11 to 21.12 for Large Advanced and decreases from 23.29 to 23.27 for Small Advanced countries.

Finally, suppose that the index of real GDP of all market economies (W) was 25% higher than historically. W is an exogenous variable and so is not a policy variable from a nation's point. Here we use this as a purely counterfactual simulation. With CSW, DY would have decreased from 1.68 to 1.67 in All Advanced, increased from 1.10 to 1.11 in Large Advanced, and increased from 2.27 to 2.29 for Small Advanced countries. CSW would lead to I remaining same at 22.07 for All Advanced, increases from 21.11 to 21.13 for Large Advanced, and decreases slightly from 23.29 to 23.28 in Small Advanced countries. Further with CSW, R remains same at 24.01 for All Advanced, remains same at 21.96 for Large Advanced, a slight decrease from 26.67 to 26.66 for Small Advanced countries. We see that PSW is also ineffective in increasing DY.

Further, we combine the three policy simulations operating on DX, F, and P (PSDXFP). We see that PSDXFP decreases DY from 1.68 to 1.67 for All Advanced, increases from 1.10 to 1.12 for Large Advanced, and has a decrease from 2.27 to 2.22 for Small Advanced countries. PSDXFP would have decreased I 0.02% points from the baseline model for All Advanced and Large Advanced countries, decreased by 0.01% points for Small Advanced countries. R remains same for All Advanced and Large Advanced countries, while decreases by 0.02% points for Small Advanced countries. On the other hand, X would have increased by 0.05% points in All Advanced and Large Advanced countries, decreased by 0.02% points for Small Advanced countries.

These results are very important because they indicate that the policies most often advocated for developing nations, such as increasing DX, F, and reducing P (curbing excess domestic inflation), as well as more rapidly expanding international economy, are not very effective in increasing the rate of growth of real per capita income of the Advanced countries (large or

small). This also indicates the serious difficulty that the countries face in achieving substantially higher growth rates.

3. Developing Countries

3.5. Empirical results and analysis

3.5.1. Estimation, validation, and implications of the model

We estimate the model using FIML separately for all the 102 developing countries, 61 large, and 41 small countries for 2004–2019. Table 9 presents the estimates and standard errors of the model's parameters. From Table 9, we can see that the signs of the 13 slope coefficients are identical for all the three groups (All Developing, Large Developing, and Small Developing countries), except for b3, c1, c2, and d3 for large advanced, and a2, a3, b2, and c2 for small advanced countries. These absolute slope coefficients differ significantly from Developing countries when ran together.

Firstly, looking at the results for All Developing countries together, we can see that the model fits the data well. All the model's estimated coefficients have the theoretically expected sign, and most are statistically significant at better than the 5% level. DY depends on DX; I depends on DY, X, and F; R on DY and lagged R; and X on R. We find that trade is positively

Table 9
Full Information Maximum Likelihood Estimates, 2004–2019.

	All Developing		Large Developing		Small Developing	
Parameter	Estimated Coefficient	Standard Error	Estimated Coefficient	Standard Error	Estimated Coefficient	Standard Error
$DY_t = a_0 + a_1I_t + a_2R_t + a_3DX_t$						
a0	2.4362 ***	0.7712	1.3452 *	0.7550	3.3305 ***	1.5788
a1	0.0094	0.0393	-0.0008	0.0405	0.0315	0.0752
a2	0.0023	0.0095	0.0565 ***	0.0150	-0.0600 ***	0.0159
a3	0.0485 ***	0.0063	0.0450 ***	0.0077	0.0316 **	0.0133
$I_t = b_0 + b_1Y_t + b_2DY_t + b_3X_t + b_4F_t$						
b0	10.9629 ***	1.8192	12.3566 ***	1.2691	19.7499 *	11.0316
b1	0.0000	0.0000	0.0002 ***	0.0001	-0.0002 **	0.0001
b2	-0.4993 *	0.2769	0.0315	0.3431	-2.7363 **	1.1713
b3	0.3447 ***	0.0392	0.3003 ***	0.0454	0.2353	0.1698
b4	-0.1003 ***	0.0134	-0.1315 ***	0.0187	-0.0747 ***	0.0245
$R_t = c_0 + c_1DY_t + c_2X_t + c_3R_{t-1}$						
c0	-2.3352	1.6420	-0.8647	0.8607	-2.7224	3.4186
c1	1.2366 ***	0.2115	1.3165 ***	0.2707	1.1058 **	0.5040
c2	-0.0184	0.1037	-0.0151	0.1116	-0.0276	0.0711
c3	0.9850 ***	0.0743	0.9076 ***	0.0858	1.0477 ***	0.0419
$X_t = d_0 + d_1P_t + d_2W_t + d_3R_t$						
d0	11.8840 **	5.3073	6.4814	4.0318	36.0843 **	15.3782
d1	0.0264	0.0206	-0.0323	0.0238	0.1219	0.1388
d2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
d3	0.7287 ***	0.0685	0.8317 ***	0.0567	0.4463 ***	0.1587
Number of observations	1632		976		656	

Note: ***, ** and * represents significance at 1%, 5% and 10% respectively.

related to growth for all developing countries, as a3 is positive and statistically significant, and coefficient b3 has a positive and statistically significant suggesting a positive impact of exports on capital formation. So, we must regard trade as a handmaiden of growth rather than the engine of growth. We also see that exports are negatively related to industrialization, but the magnitude of c2 is small and statistically insignificant. On the other hand, R is positively related to X and is statistically significant.

Next, we look at large and small developing countries separately to investigate the relationship between trade and growth. Looking at the estimated coefficients for large developing countries from Table 9, we see that all the estimated coefficients have the predicted signs, and most are statistically significant at the 5% level. DY primarily depends on R and DX; I on Y, X, and F; R on DY and lagged R; and X on R. Trade has positive impact on growth for large developing countries, as a3 is positive in magnitude and statistically significant and higher in magnitude. Coefficient b3 is positive and statistically significant. This suggests that trade has positive impact on economic growth for large developing countries.

Further, we also see that exports are negatively related to industrialization, but the magnitude of c2 is very small and statistically insignificant. Also, R is positively related to X and is statistically significant. The ratio of prices in the nation relative to market prices has a statistically insignificant effect on exports, and the index of real GDP of market economies has a statistically insignificant impact on exports.

For small developing countries, we see that the estimated coefficients have the predicted signs, and most are statistically significant at 5%. DY depends on R and DX; I on Y, DY, and F; R on DY and lagged R, and X on R. Trade is positively related to growth, as a3 is positive and statistically significant. Coefficient b3 has a positive but statistically significant impact on capital formation. This suggests that growth for small developing countries trade and capital formation. We also see that exports are negatively related to industrialization, but the magnitude of c2 is small and statistically insignificant. On the other hand, R has a strong positive and statistically significant effect on exports. During the study period, the index of real GDP of market economies has a very low magnitude positive impact but statistically insignificant impact on exports.

It is important to note that trade does not impact growth for large developing and small developing countries. Further, we test the validity of the estimated model and the coefficients. To do that, we perform a dynamic simulation of the model over the sample period.[8]

Using the exogenous time series but only the starting values of the endogenous variables, the model generates historical simulated values for the endogenous variables. Table 10 presents the historical and simulated average annual values for the study period. We see that the simulated values are close to the historical values, with DY diverging less than 1.7%, and I, R, and X generally by less than 0.4%.

Even though the model is highly aggregative and was formulated to analyze average long-run growth, it also captures relatively well most short-run intercountry variations in DY, I, R, and X. Table 7 presents Theil's inequality coefficients (T) and their decomposition into bias (B), variance (V), and covariance (C) proportions. T values suggest 41% or more of the actual short-run inter-country variations in DY for all three groups of countries (All Developing, Large Developing, and Small Developing). More than 91% of the variation in DY, 85% in I, 96% in R, and 67% or more of variation was predicted in X for all the three groups of countries. The

[8] The Newton method was used for dynamic simulations.

Table 10
Historical and Simulated Average Annual Values, 2004–2019.

	All Developing				Large Developing				Small Developing			
	DY	I	R	X	DY	I	R	X	DY	I	R	X
Historical	2.80	23.17	28.45	37.81	3.02	22.49	28.64	29.87	2.47	24.17	28.16	49.63
Model	2.76	23.21	28.46	37.67	2.97	22.50	28.65	29.93	2.43	24.25	28.16	49.70
RMSE	4.26	6.84	2.40	27.93	3.90	6.38	2.25	14.57	4.68	7.57	2.62	36.87

Table 11
Theil's Inequality Coefficients and their Decomposition.

	All Developing				Large Developing				Small Developing			
	DY	I	R	X	DY	I	R	X	DY	I	R	X
T	0.54	0.14	0.04	0.32	0.49	0.14	0.04	0.22	0.59	0.15	0.04	0.33
B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V	0.71	0.53	0.01	0.50	0.61	0.52	0.01	0.33	0.66	0.34	0.02	0.68
C	0.29	0.47	0.99	0.50	0.39	0.48	0.99	0.67	0.34	0.66	0.98	0.32

decomposition of T into its components is also near-optimal, with practically no part of error due to bias for all endogenous variables and all the three groups of countries, and with a large proportion of the error due to imperfect covariance (over which nothing can be done). (Table 11).

3.6. Dynamic policy simulations

The policymakers could attempt to increase its growth rate by operating on the exogenous variables regarded as policy instruments. In the current setup, these policy instruments are the growth in the percentage of exports to GDP (DX), the level of capital inflows as a percentage of GDP (F), and the ratio of the consumer price index in the nation relative to the consumer price index of all market economies (P).

Historically DX was 0.74% for All Developing, 0.55% for Large Developing, and 1.01% for Small Devleoping countries. Supposing these growth rates could be increased by 25–0.93% for All Developing, 0.69% for Large Developing, and 1.26% for Small Developing countries.[9]

This policy simulation (PSDX) is presented in Table 12. This decreases DY from 2.76 (baseline model) to 2.75 for All Developing, decreases from 2.97 to 2.95 for Large Developing, and increases from 2.43 to 2.45 for Small Developing countries. PSDX also leads to a decrease in I from 23.21 to 23.20 for All Developing, remains same at 22.50 for Large Developing, and decreases from 24.25 to 24.23 for Small Developing countries.

Further, PSDX leads to a slight decrease in R from 248.46 to 28.44 for All Developing, decreases from 28.65 to 28.63 for Large Developing, and remains same at 28.16 for Small

[9] This could possibly be achieved by reduction in trade barriers of or by developed nations for exports of developing nations. Here we assume adequate supply responses from developing nations. 25% increase has been chosen arbitrarily and can be scaled as needed.

Table 12
Dynamic Policy and other Counterfactual Simulation Results Average Annual Values, 2004–2019.

	All Developing				Large Developing				Small Developing			
	DY	I	R	X	DY	I	R	X	DY	I	R	X
B	2.76	23.21	28.46	37.67	2.97	22.50	28.65	29.93	2.43	24.25	28.16	49.70
PSDX	2.75	23.20	28.44	37.65	2.95	22.50	28.63	29.91	2.45	24.23	28.16	49.74
PSF	2.74	23.20	28.46	37.68	2.97	22.52	28.65	29.93	2.44	24.17	28.18	49.78
PSP	2.75	23.20	28.46	37.65	2.96	22.52	28.65	29.93	2.44	24.18	28.18	49.67
PSDXFP	2.74	23.19	28.46	37.65	2.97	22.51	28.63	29.91	2.45	24.16	28.17	49.80
CSW	2.74	23.22	28.44	37.71	2.96	22.51	28.64	29.92	2.46	24.17	28.19	49.61

I = gross capital formation as a percentage of GDP;
R = industrial output as a percentage of GDP;
X = exports as a percentage of GDP;
B = refers to the basic solution/ baseline model (from Table 2) to which the other simulation results are compared;
PSDX = the growth in the percentage of exports to GDP is 25% higher than historically;
PSF = the percentage of foreign capital inflows to GDP is 25% higher than historically;
PSP = the rate of domestic inflation is 25% lower than historically;
CSW = the index of real GDP of all market economies is 25% higher than historically.

Developing countries. PSDX also leads to a slight decrease in X from 37.67 to 37.65 for All Developing, from 29.93 to 29.91 for Large Developing, and a increase from 49.70 to 49.74 for Small Developing. The results suggest that PSDX is not very effective in increasing DY because the historical values of DX and the estimated values of a3 are very small. As a result, I, R, and X are also slightly affected. This implies that, in general, the policy of even substantially increasing DX is not very effective in promoting growth in Developing countries. The result suggests that the rate of economic development depends primarily on internal conditions, and international trade provides only a weak supporting role for most nations.

Most effective would be the policy that attempts to increase the rate of foreign capital inflows by nations. By increasing, I would increase DY. The increase in DY would then increase I, R, and X, which in turn would further increase DY and I. Suppose that the countries could increase their average F by 25% over historical values, i.e., from − 6.13 to − 4.90 in All Developing, from − 3.60 to − 2.88 in Large Developing, and from − 9.89 to − 7.91 in Small Developing countries. This policy PSF is presented in Table 12 suggstest that DY decreases from 2.76 to 2.74 for All Developing, remains same at 2.97 for Large Developing, and slightly increases from 2.43 to 2.44 for Small Developing countries. The result suggests that PSF is ineffective in increasing DY for the Developing countries. I decreases from 23.21 to 23.20 for All Developing, increases from 22.50 to 22.52 Large Developing and decreases from 24.25 to 24.17 for Small Developing countries. PSF's effect on R is – remains same at 28.46 for All Developing, remains same at 28.65 for Large Developing, and increases from 28.16 to 28.18 for Small Developing countries, respectively. We see that PSF is also ineffective in increasing DY.

The third policy variable operates on P. Supposing that the governments can curb domestic inflation by 25%. As P appears explicitly in Equation 4, the strongest effect of this policy PSP is generally to increase X. With c2 being very small (Table 9), an increase in X has a slight or no effect on R across the three groups. DY decreases from 2.76 to 2.75 for All Developing,

decreases from 2.97 to 2.96 for Large Developing and increases slightly from 2.43 to 2.44 for Small Developing countries; I decreases from 23.21 to 23.20 for All Developing, increases from 22.50 to 22.52 for Large Developing and decreases from 24.25 to 24.18 for Small Developing countries.

Finally, suppose that the index of real GDP of all market economies (W) was 25% higher than historically. W is an exogenous variable and so is not a policy variable from a nation's point. Here we use this as a purely counterfactual simulation. With CSW, DY would have decreased from 2.76 to 2.74 in All Developing, from 2.97 to 2.96 in Large Developing, and increased from 2.43 to 2.46 for Small Developing countries. CSW would lead to I increasing from 23.21 to 23.22 for All Developing, increases from 22.50 to 22.51 for Large Developing, and decreases slightly from 24.25 to 24.17 in Small Developing countries. Further with CSW, R decreases from 28.46 to 28.44 for All Developing, decreases from 28.65 to 28.64 for Large Developing, increases from 28.16 to 28.19 for Small Developing countries. We see that PSW is also ineffective in increasing DY.

Further, we combine the three policy simulations operating on DX, F, and P (PSDXFP). We see that PSDXFP decreases DY from 2.76 to 2.74 for All Developing, remains same at 2.97 for Large Developing, and increases from 2.43 to 2.45 for Small Developing countries. PSDXFP would have decreased I 0.02% points from the baseline model for All Developing, increased by 0.01% for Large Developing countries, decreased by 0.09% points for Small Developing countries. Further R remains same for All Developing, decreases by 0.02% for Large Developing countries, while increase by 0.01% points for Small Developing countries. On the other hand, X would have increased by 0.02% points in All Developing and Large Developing countries, increased by 0.10% points for Small Developing countries.

These results are very important because they indicate that the policies most often advocated for developing nations, such as increasing DX, F, and reducing P (curbing excess domestic inflation), as well as more rapidly expanding international economy, are not very effective in increasing the rate of growth of real per capita income of the Developing countries (large or small). This also indicates the serious difficulty that the countries face in achieving substantially higher growth rates.

4. Conclusions

This study examines the relationship between international trade and economic growth and development for advanced and developing countries, together and separately, as well as for large and small countries, using a simultaneous equations model, for all the 132 countries for which data was available over the 2004–2019 period. The model is estimated by FIML validated by in-sample dynamic simulation, and then used for dynamic policy simulations.

The sign and statistical significance of the estimated coefficients and the dynamic validity simulations strongly support the model empirically. More importantly, the RMSE (the root-mean-square errors) confirm the validity of the model in suggesting a positive relationship between trade, growth and development. We also find that industrialization helps developing nations increase exports more than advanced nations**.** Even though the general results are *similar* (i.e., that trade is a handmaiden rather than an engine of growth), the *direct* results of this

study are unbiased as opposed to the biased results of single equation studies because trade and growth and development are clearly simultaneous. Furthermore, this paper also measures the important *indirect* results between trade, growth and development that single equation studies cannot demonstrate. The same is true for the policy simulations, which reach the fundamental conclusion that the policies most often advocated to increase international trade in order to stimulate growth and development are not very effective.

Appendix

Table A.1
Country list in each group based on country classification.

Country classification	List of countries
Large Advanced (17) (population > 10 M)	Australia, Belgium, Canada, Croatia, Cyprus, France, Germany, Greece, Italy, Japan, Netherlands, Poland, Portugal, Spain, Sweden, United Kingdom, United States
Small Advanced (13) (population < 10 M)	Austria, Denmark, Estonia, Finland, Hungary, Ireland, Latvia, Lithuania, New Zealand, Norway, Slovak Republic, Slovenia, Switzerland
Large Developing (61) (population > 10 M)	Afghanistan, Algeria, Angola, Argentina, Bangladesh, Benin, Bolivia, Brazil, Brukina Faso, Burundi, Cambodia, Cameroon, Chad, China, Colombia, Dem. Rep. Congo, Côte d′Ivoire, Cuba, Dominican Republic, Ecuador, Arab Rep. Egypt, Ghana, Guatemala, Guinea, India, Indonesia, Islamic Rep. Iran, Iraq, Kazakhstan, Kenya, Rep. Korea, Madagascar, Malawi, Malaysia, Mali, Mexico, Morocco, Mozambique, Myanmar, Nepal, Niger, Nigeria, Pakistan, Peru, Philippines, Romania, Russian Federation, Rwanda, Saudi Arabia, Senegal, South Africa, Sri Lanka, Tanzania, Thailand, Tunisia, Turkey, Uganda, Ukraine, Uzbekistan, Vietnam, Zimbabwe
Small Developing (41) (population < 10 M)	Albania, Azerbaijan, Belarus, Bosnia and Herzegovina, Botswana, Bulgaria, Rep. Congo, Costa Rica, El Salvador, Equatorial Guinea, Eswatini, Gabon, the Gambia, Georgia, Guinea-Bissau, Honduras, China Hong Kong SAR, Israel, Jamaica, Jordan, Kyrgyz Republic, Lao PDR, Lebanon, Liberia, Mauritania, Mauritius, Moldova, Mongolia, Namibia, Nicaragua, North Macedonia, Oman, Panama, Paraguay, Sierra Leone, Singapore, Tajikistan, Togo, United Arab Emirates, Uruguay, West Bank and Gaza

Note: Classifications are based on WESP 2019 UN report with the classification.

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