Economic Inquiry

WHEN IS TRADE PROTECTION GOOD FOR GROWTH?

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The empirical relationship between trade protection and economic growth is surprisingly fragile, as shown in a number of other papers. We address one possible explanation for these findings: that the relationship is contingent on the pattern of comparative advantage, following the endogenous growth literature. Our findings suggest that such contingencies do in fact exist—in particular, the correlation between tariffs and growth is strong and positive for skill-abundant countries—and are robust to the choice of control variables. (*JEL* F13, F43, O19, O24)

I. INTRODUCTION

There is a shared belief among economists, policy makers, and the general public that more open economies grow faster than closed economies. Many international organizations emphasize this correlation: for example, the World Trade Organization proclaims on its website that it has "helped to create a strong and prosperous trading system contributing to unprecedented growth." However, the empirical evidence is mixed. While many studies demonstrate a positive relationship between trade openness and economic growth (Edwards 1998; Frankel and Romer 1999; Sachs and Warner 1995; and many others), others find no evidence of such a relationship. Harrison and Hanson (1999) demonstrate the lack of robustness of several proxies for "openness," for example, while Vamvakidis (2002) finds that the positive correlation between openness and growth exists only after 1970, and Clemens and Williamson (2004) show that the correlation between tariffs and growth was positive prior to World War II and negative after it, which they attribute to changes in the world economy.

Perhaps it is not surprising that empirical work has failed to reach a consensus about the correlation between trade protection and growth, because theory does not generally provide an unambiguously negative relationship. In endogenous growth models in open-economy frameworks such as Grossman and Helpman (1990) and Matsuyama (1992), the relationship between trade policy and growth is frequently a contingent one, in which the effect of trade barriers on growth depends on the pattern of comparative advantage across countries. Rodríguez and Rodrik (2000) expand upon this idea, and also provide a comprehensive and critical review of the empirical literature. As discussed in more detail below, DeJong and Ripoll (2006) allow for contingencies in the correlation between tariffs and growth, based primarily on countries' levels of economic development.

Motivated by open-economy endogenous growth models, we examine the relationship between trade protection and growth in a nonlinear framework, and investigate whether the relationship between trade barriers and growth depends on the pattern of comparative advantage across countries. Using a cross-country regression model, we find that such contingencies do in fact exist, and that the correlation between tariffs and growth is strong and positive for skill-abundant countries. Our results are robust to a number of different specifications of conditioning variables and dependent variables.

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ABBREVIATIONS

EFW: Economic Freedom in the World
OECD: Organization for Economic Cooperation and Development
GAT: General Agreement on Tariffs and Trade
TFP: Total Factor Productivity
WDI: World Development Indicators

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This paper is related to a large literature on openness and growth. As indicated above, many previous empirical studies have assumed a linear relationship between openness and growth. Notable exceptions in which nonlinearities in this relationship are the main focus of the paper are DeJong and Ripoll (2006) and Papageorgiou (2002).[1] In Papageorgiou (2002), trade openness is a threshold variable separating countries into distinct growth regimes; however, openness is not directly included in the growth specification, but operates indirectly, as a separating variable. In contrast, we focus on the potential nonlinearity of the *direct* relationship between trade barriers and growth, and we find evidence that such nonlinearities do, in fact, exist, in that the relationship between tariffs and growth is contingent on the pattern of comparative advantage across countries.

Using a panel of 60 countries, DeJong and Ripoll (2006) investigate the relationship between tariffs and growth and how this relationship depends on income levels. Among higher-income countries, they find a negative correlation between tariffs and growth. Unlike DeJong and Ripoll (2006), we allow for the possibility that the relationship between trade barriers and growth is contingent on the pattern of comparative advantage. Relying on the pattern of comparative advantage, rather than income, as the source of differences in the correlation between growth and tariffs is more consistent with the endogenous growth models, although we do include an interaction between income and tariffs in our sensitivity analysis as a comparison to their paper. We also examine a larger set of countries over a longer time period (a 22-year cross section, instead of 5-year dynamic panels). Since the pattern of comparative advantage is unlikely to change much over short periods of time (but the timing of business cycle fluctuations across countries may be affected by the pattern of comparative advantage), we think that examining the correlation over a longer period of time is more likely to uncover how the relationship between trade protection and growth varies according to comparative advantage.

Our paper is also somewhat related to Nunn and Trefler (2010), who examine the relationship between the skill bias of a country's tariff structure (the degree to which tariffs favor the country's skill-intensive industries) and growth. Their paper mainly focuses on industry-level productivity growth as the dependent variable, and they find that the skill bias of tariffs is strongly and positively correlated with growth. We focus on how the correlation between overall tariffs and growth varies across countries with different patterns of comparative advantage.

The next section presents the empirical framework allowing for nonlinearities in the relationship between tariff protection and growth, and we also discuss the data and constructions of key variables. In Section III, we present the main results and conduct extensive robustness checks. Section IV concludes.

II. EMPIRICAL SETTING AND DATA

We assume that output in country i at time t is produced according to:

$$(1) \qquad Y_i(t) = K_i(t)^{\alpha} \left[A_i(t)H_i(t)\right]^{1-\alpha},$$

where K_i and H_i represent stocks of physical and human capital, and A_i is the level of total factor productivity (TFP). The stock of human capital is given by $H_i = h_i L_i$ where h_i is the average human capital per worker and L_i is the number of workers used in production. The average human capital per worker is given by $h_i = e^{\phi(E_i)}$, where E_i denotes years of schooling and $\phi(E)$ is the efficiency of a unit of labor with E years of education.

An obvious problem with investigating potential nonlinearities in the relationship between tariff barriers and growth is that the number of potential model specifications is nearly infinite while the available data are much more limited. Thus, in this paper, we concentrate on incorporating interaction terms into conventional growth regressions to allow the estimated marginal effect of tariff barriers on growth to differ across countries. We extend the conventional growth regression literature by estimating the following specification:

$$(2) \qquad g_i = \beta_{\tau}\tau_{0i} + \beta_{\tau z}\tau_{0i} \cdot \mathbf{Z}_{0i} + \beta_x \mathbf{X}_{0i} + \varepsilon_i,$$

where g_i denotes the average annual growth in per capita income in country i. The variable

1. Several other papers allow for some form of nonlinearities, although generally not as the primary focus of their work. For example, Clemens and Williamson (2004) allow for contingencies, although their focus is primarily how the relationship between tariffs and growth has changed over time, rather than how it differs across countries. In Minier (2007), the correlation between trade share and growth is one of several explanatory variables found to be robust to alternate specifications of the growth regression when the relationship is allowed to be nonlinear.

τ_{0i} is the initial average tariff rate, $\mathbf{Z}_{0i}$ includes variables that proxy for country i's initial comparative advantage, and $\mathbf{X}_{0i}$ is a set of initial country characteristics. While our explanatory variables are measured at the beginning of the period, we should note that our estimation does not allow us to infer the direction of causality.

Most of our analysis is restricted to 86 countries (the list of countries and construction of key variables are given in the Appendix), and growth is calculated over the period 1985–2007. Initial values are measured in 1985, with stock variables (such as physical and human capital) measured in 1985, and flow variables (e.g., average tariffs, investment/GDP) measured as the average over 1983–1985, following DeJong and Ripoll (2006).[2] The data on output (GDP), population, investment, and labor force are taken from the Penn World Tables mark 6.3 (Heston, Summers, and Aten 2009). Physical capital stocks are constructed by using the standard perpetual inventory method with a 6% depreciation rate. The data on average years of schooling for the population aged 25 and above are taken from Barro and Lee (2010). As in Hall and Jones (1999), for the first 4 years of education, we assume a rate of return of 13.4%; for the next 4 years we assume a value of 10.1%; and finally, for education beyond the eighth year we use 6.8%.

As our measure of tariffs, we follow DeJong and Ripoll (2006) and Rodríguez and Rodrik (2000) in using import duties as a fraction of imports, that is, import-weighted average tariff rates. We consider this to be the most straightforward measure of trade policy available, in addition to the fact that it is available for a wide range of countries. However, to check for robustness and to address the concern that import-weighted tariffs put less weight on the most-binding tariffs, we also present results based on unweighted average tariffs in our sensitivity analysis.

We consider two variables that may affect the marginal correlation between tariffs and growth. The pattern of comparative advantage in a country is fundamentally a function of the relative abundance of various resources. The assumption is that countries endowed with different levels of resources will exhibit different patterns of comparative advantage, and thus the marginal effect of increasing tariffs on growth will differ. Thus, we consider capital and skill intensities as two potential $\mathbf{Z}$ variables.[3] Following Hall and Jones (1999) among many others, capital intensity is measured by the capital-output ratio. Skill intensity, s_0, is measured by the fraction of the population that completed at least secondary school.[4] Alternatively, a country's skill abundance can be measured as its average level of human capital; in our robustness checks, we show that our results are robust to this alternative definition.

We follow a traditional growth specification, including initial log income per capita,[5] investment to output ratio, skill intensity as defined above, average population growth rate, and log average life expectancy as control variables. In addition, we include two dummy variables, one indicating Organization for Economic Cooperation and Development (OECD) membership, and one indicating General Agreement on Tariffs and Trade (GATT) membership. To control for geographic differences that might affect growth rates, we add five variables from Sachs and Warner (1995): dummies indicating that a country is in sub-Saharan Africa, Latin America, East Asia/Pacific, or is landlocked; and the fraction of land area located in a tropical climate.

To control for differences in institutional qualities across countries, we include the government effectiveness measure from the World Bank's Governance Matters Database (Kaufmann, Kraay, and Mastruzzi 2008), averaged over the period 1996–2000. This is one of six measures in their database; they are highly correlated, and including all six does not significantly affect our results. The Economic Freedom in the World (EFW) Database (Gwartney, Lawson, and Norton 2008) provides another measure for institutional quality, which they describe as a

2. For nine countries, tariff data are only available for the late 1970s; for these countries, growth is measured over 1980–2007, and initial values are measured in 1980 for stock variables and 1978–1980 for flow variables. To control for differences in the periods, Equation (2) also includes cohort fixed effects.

3. We also considered the percentage of exports that are primary goods as a direct means of proxying for comparative advantage in primary, rather than manufactured, goods. However, we find that the correlation between tariffs and the interaction term, defined as the product of tariffs and primary exports/total exports, is very high (over 0.9), making the estimates less precise.

4. Skill intensity can also be defined as the ratio of the country's skilled workers (those that completed at least secondary school) to unskilled workers (those with at most some secondary school). Because for a few advanced countries this alternative measure of skill intensity well exceeds 1, using the above measure of skill intensity reduces the influence of these observations. However, our results are not sensitive to using this alternative measure of skill intensity.

5. In our sensitivity analysis, we also consider log output per worker and log TFP as dependent variables.

TABLE 1
Initial Growth Regressions

	I	II	III
τ_0	−0.039 (0.030)	−0.037 (0.025)	−0.053 (0.030)†
$\tau_0 \times s_0$	0.380 (0.177)*		0.307 (0.205)
$\tau_0 \times \ln(K/Y)_0$		0.081 (0.033)*	0.052 (0.038)
s_0	−0.033 (0.014)*	−0.010 (0.010)	−0.027 (0.014)*
$\ln(K/Y)_0$		−0.018 (0.009)†	−0.014 (0.009)
$(I/Y)_0$	0.020 (0.029)	0.047 (0.037)	0.050 (0.037)
$\ln y_0$	−0.017 (0.004)*	−0.016 (0.004)*	−0.017 (0.004)*
Observations	94	94	94
Adj. R^2	0.471	0.473	0.479
Implied marginal effect of τ_0:			
At Q10	−0.032 (0.028)	−0.058 (0.030)†	−0.009 (0.036)
At median	0.007 (0.024)	0.023 (0.027)	0.023 (0.028)
At Q90	0.124 (0.061)*	0.070 (0.040)†	0.116 (0.066)†

Notes: The dependent variable is log growth of income per capita. All regressions include average population growth, log average life expectancy, government effectiveness, regional variables (described in the text), indicator variables for GATT and OECD membership, and cohort fixed effects. Here x_0 represents the initial value of variable x. Numbers in parentheses are heteroskedasticity-consistent standard errors; * and † represent statistical significance at the 95% and 90% level, respectively. In the last panel, the implied marginal effects of tariffs are evaluated at the 10th, 50th, and 90th percentiles of skill (0.019, 0.1215, and 0.427, respectively) in Column I, and the 10th, 50th, and 90th percentiles of capital/output in Column II (−0.254, 0.745, and 1.314, respectively). In Column III, the marginal effect at each value of skill holds the capital/output ratio at its median (0.745).

complete index of legal and property rights. The main advantage of the EFW variable is that it is available for 1980 and 1985, so is a better control for initial institutional qualities. However, the data are available for only 86 countries in our sample, so we first present results without this variable.

III. RESULTS

Table 1 includes the regression results based on Equation (2). Although they are not explicitly shown in this and all subsequent tables, all regressions include average population growth, log average life expectancy, an OECD dummy, a GATT dummy, and cohort fixed effects (to control for differences in periods). In addition, all regressions include geographic variables and the government effectiveness variable (as a measure of institutional quality).

In Column I of Table 1, we present results with tariffs interacted with skill ($\tau_0 \times s_0$) as the only interaction term. The interaction term is positive and statistically significant at the 95% level, although the correlation between tariffs and growth is not statistically significant when evaluated at the median level of skill (the last row of the table). However, at the highest levels of skill, the implied marginal effect of tariffs becomes positive and statistically significant, as seen in the estimated marginal effect at the 90th percentile of skill. As skill increases, the estimated marginal effect becomes statistically significant at the 90% level when skill is equal to 0.249, or approximately the level of France and Panama (24% of the sample), and at the 95% level when skill is equal to 0.383, the level of Denmark (12% of the sample). (Recall that the skill variable is the percentage of the population over age 25 that has at least completed secondary education.)

In Column II, we include an interaction term between tariffs and the capital-output ratio, with fairly similar results. At the lowest levels of the capital-output ratio, the estimated marginal effect of tariffs on growth is estimated to be negative and statistically significant at the 90% level (−0.06 at the 10th percentile of capital output, with a standard error of 0.03), but as the capital-output ratio increases, this marginal effect becomes positive, and is statistically significant at better than 90% at the highest levels of the capital-output ratio. Column III presents results when both interaction terms are included simultaneously. Here, neither interaction term is statistically significant, but, holding the capital-output ratio at its median of 0.745, it remains the case that the implied marginal effect of tariffs on

TABLE 2
Sensitivity Analysis: Explanatory Variables

	I	II	III	Unweighted τ IV	Unweighted τ V
τ_0	−0.055 (0.034)	−0.118 (0.047)*	−0.135 (0.261)	0.020 (0.019)	0.033 (0.023)
$\tau_0 \times s_0$	0.533 (0.199)*		0.474 (0.268)†	0.129 (0.118)	
$\tau_0 \times \ln(K/Y)_0$					0.008 (0.030)
$\tau_0 \times \ln h_0$		0.263 (0.094)*			
$\tau_0 \times \ln y_0$			0.011 (0.034)		
s_0	−0.039 (0.016)*		−0.036 (0.017)*	−0.018 (0.016)	−0.006 (0.010)
h_0		−0.017 (0.014)			
$\ln(K/Y)_0$					0.001 (0.013)
$(I/Y)_0$	0.012 (0.030)	0.017 (0.030)	0.012 (0.031)	0.046 (0.036)	0.035 (0.047)
$\ln y_0$	−0.018 (0.005)*	−0.017 (0.005)*	−0.019 (0.006)*	−0.019 (0.004)*	−0.018 (0.004)*
Observations	86	86	86	76	76
Adj. R^2	0.482	0.491	0.474	0.535	0.524
Implied marginal effect of τ_0:					
At Q10	−0.044 (0.031)	−0.056 (0.030)†	−0.034 (0.047)	0.023 (0.018)	0.032 (0.024)
At median	0.013 (0.025)	0.048 (0.030)	0.017 (0.030)	0.037 (0.017)*	0.039 (0.021)†
At Q90	0.180 (0.069)*	0.160 (0.064)*	0.165 (0.080)*	0.077 (0.045)†	0.043 (0.032)

Notes: All regressions include average population growth, log average life expectancy, government effectiveness, institutional quality, regional variables (described in the text), indicator variables for GATT and OECD membership, and cohort fixed effects. In Columns IV and V, the tariff measure is unweighted tariffs as described in the text. Numbers in parentheses are heteroskedasticity-consistent standard errors; * and † represent statistical significance at the 95% and 90% level, respectively. The last panel of the table gives the marginal effect of tariffs estimated at the 10th, 50th, and 90th percentile of skill in Columns I, III, and IV, of human capital in Column II, and of capital-output ratio in Column V. In Column III, this estimated marginal effect is at the median level of income.

growth is statistically significant and positive at the highest levels of skill.[6]

To examine the robustness of these results, we consider alternative specifications of both the conditioning variables and the dependent variables. In Table 2, we present results with changes to the explanatory variables. In Column I of Table 2, we add a variable measuring institutional quality from the EFW database to the regression of Column I of Table 1. Although the sample size is reduced to 86 observations, the results remain similar to those of Table 1. We include this term in all regressions that follow, although results are robust to dropping it.

In Column I, the estimated marginal effects follow the same pattern as in Table 1, becoming positive at higher levels of skill. Here, the correlation between tariffs and growth is estimated to be positive and statistically significant at the 90% level for 36% of the sample, and at the 95% level for 29% of the sample. The magnitude of the estimates is also larger than the magnitude in Table 1.

6. The estimated marginal effects as the capital-output ratio changes, holding skill at its median, are not statistically significant.

In Column II, we use the log of average human capital in place of skill intensity. In this case, both the linear and interaction coefficient estimates on tariffs are statistically significant. While the correlation between tariffs on growth estimated at the lowest levels of human capital is negative and statistically significant, it is again positive and statistically significant at the highest levels of human capital (see the bottom panel of Table 2).

Column III reports results including initial log income per capita interacted with tariffs as a comparison to DeJong and Ripoll (2006). Including interaction terms on both income and skill does not change our result: the coefficient estimate on the interaction term between tariffs and skill remains statistically significant and positive, while the coefficient on the income–tariff interaction is not statistically significant. The implied marginal effects are also positive and statistically significant at the highest levels of skill (estimated at the median of human capital). However, the correlation between tariffs and its interaction with income is extremely high (around 0.99, see Table A2 in Appendix), so the estimated coefficients on tariffs and income–tariff interaction terms become less precise.

Using panel data, DeJong and Ripoll (2006) find that the coefficient estimate on tariffs is positive and significant, while the coefficient on the income–tariff interaction is negative and significant. However, when we consider only tariffs and income–tariff interaction terms in our regression model as in DeJong and Ripoll (2006), we obtain the opposite results: the coefficient estimate on tariffs is negative and significant (at the 90% level), while the coefficient on the income–tariff interaction is positive and significant (at the 90% level). As discussed in Section I, the correlation between tariffs and economic growth is notoriously non-robust. There are several possible explanations for the disparity between our findings and theirs: our sample is larger, and our estimation is cross sectional rather than panel. We also think that the collinearity problem when both tariffs and tariff–income interaction terms are included is severe, resulting in coefficient estimates that are extremely sensitive to changes in the regression specification (in addition to the well-known decrease in precision). We are concerned that this collinearity problem makes interpreting such results problematic, and so focus on the results when tariffs are interacted with skill intensity and the capital-output ratio (rather than output). In addition, endogenous growth theories typically predict that the correlation between tariffs and growth depends on the pattern of comparative advantage (not income); skill intensity and the capital-output ratio are better proxies for the pattern of comparative advantage.

Column IV replaces our import-weighted tariff measure with unweighted average tariffs, from the EFW database. The data are only available for 76 countries, and not surprisingly, average tariff rates are substantially higher than the import-weighted tariffs we use as our primary measure. Although coefficient estimates on the tariff and skill–tariff interaction terms are statistically insignificant, the (implied) marginal effects of tariffs on growth follow a similar pattern to those in the previous columns. The last column reports results based on the capital-interaction term, and results are qualitatively similar to those reported in Column IV.[7,8]

We also checked whether the results are driven by any particularly influential observations, by using the DFITS statistic to identify countries with residual and leverage values. Our test statistics show that there are no highly influential observations in our sample.[9] For example, Figure 1 represents the partial regression plots obtained from the model in Column I of Table 2. These plots also do not show any apparent outliers.

As a further check of the robustness of our results, in Table 3, we repeat the analysis with two alternative dependent variables. In Column I, the dependent variable is the average annual growth in output per worker (rather than per capita), while it is TFP growth in Column II. The analysis based on TFP growth is important for two reasons. First, although we include initial human capital and capital intensity in our model, the growth rate of output per worker (or per capita) would still be affected by the changes in these variables over time.[10] Second and more importantly, in the endogenous growth models discussed in the introduction, the mechanism through which tariffs affect growth is by reallocating resources to more (or less) productive sectors of the economy. In both cases, the results are qualitatively the same as those reported in Column I of Table 2.

Our analysis indicates a clear relationship between a country's pattern of comparative advantage and the correlation between tariff barriers and economic growth. This relationship is consistent with the predictions of Grossman and Helpman (1990): tariff barriers are positively correlated with growth among

7. Regressions in Columns IV and V include all other control variables as in the other columns. Furthermore, to control for possible outliers, following Estevadeordal and Taylor (2008), we measure tariffs as $\ln(1 + \tau_0)$. The results are similar to those reported if unweighted average tariffs are used.

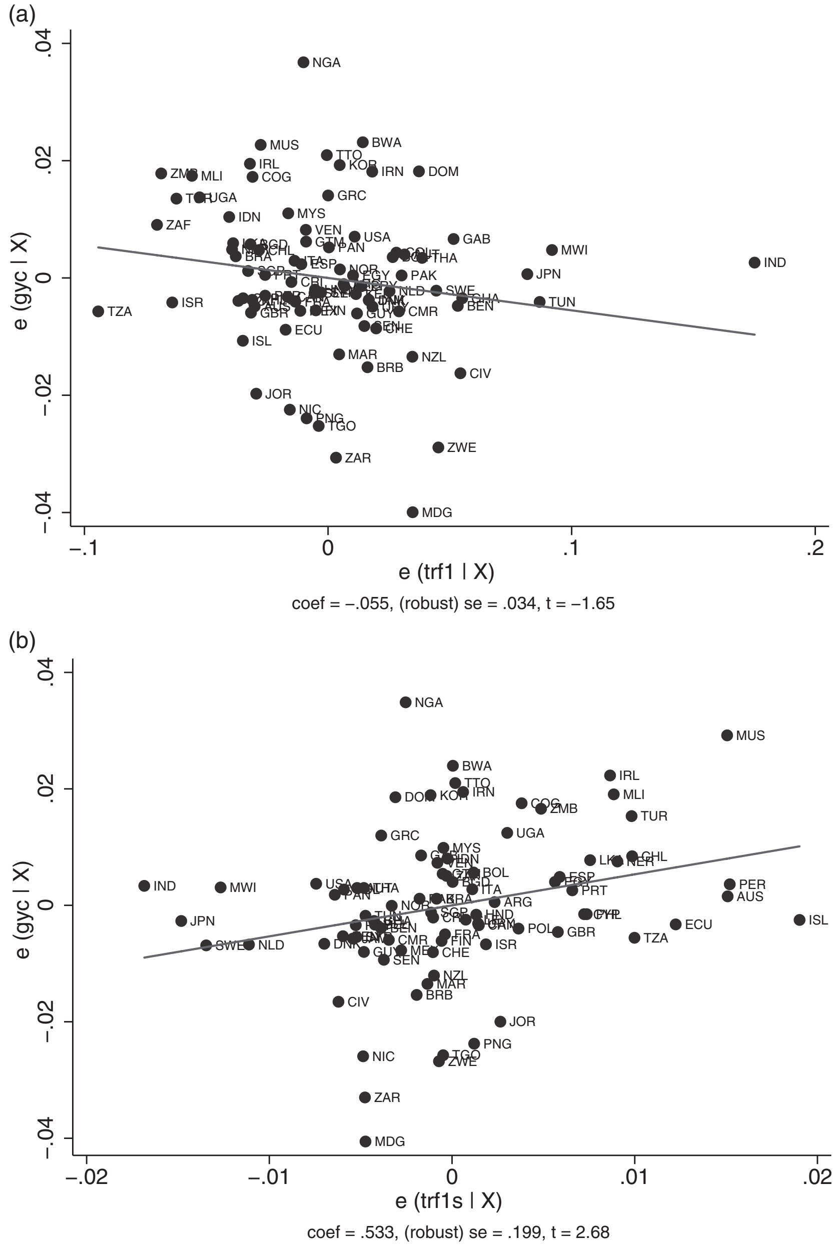
8. We also considered production-weighted tariffs from Nunn and Trefler (2010). While the general pattern of marginal effects was unchanged (marginal effects were negative at the lowest levels of skill, becoming positive as skill increased), degrees of freedom were severely limited, virtually no coefficient estimates were statistically significant, and the time periods covered by the datasets were not well matched.

9. The DFITS statistics is given by $\text{DFITS}_c = r_c\sqrt{l_c/(1 - l_c)}$, where r_c and l_c are residual and the leverage values, respectively, for country c. Besley, Kuh, and Welsch (1980) suggest that a cutoff value of $|\text{DFITS}| > 2\sqrt{k/N}$ (where k is the number of regressors and N is the number of observation) indicates highly influential observations. The DFITS statistics obtained from regressions in Column I of Table 2 range between 0.023 and 0.047, well below the cutoff level $2\sqrt{k/N} = 0.86$.

10. We drop the initial investment-output ratio when TFP growth is the dependent variable, since changes in capital intensity have already been considered when constructing TFP from Equation (1). However, we keep initial skill intensity, consistent with the endogenous growth model in Romer (1990).

FIGURE 1

Partial Regression Plots for the Model in Column I. (A) Tariffs: τ and (B) Interaction Term: $\tau \times s$ (country codes from Penn World Tables mark 6.3)



skill-abundant countries. However, a positive correlation between tariff barriers and growth does not necessarily imply that protection is optimal from a welfare standpoint. As Grossman and Helpman (1990) take pains to note, even though under certain circumstances trade may lead to a decline in the rate of innovation in their framework, a country can still benefit from engaging in trade. Specifically, in their model, international trade provides both the standard

TABLE 3
Sensitivity Analysis: Dependent Variables

Dependent Variable	GDP Per Worker Growth	TFP Growth
τ_0	−0.063 (0.039)	−0.054 (0.043)
$\tau_0 \times s_0$	0.514 (0.236)*	0.562 (0.244)*
s_0	−0.038 (0.018)*	−0.034 (0.018)†
$(I/Y)_0$	0.016 (0.030)	
$\ln y_0$	−0.018 (0.006)*	
$\ln A_0$		−0.018 (0.005)*
Observations	86	86
Adj. R^2	0.434	0.399
Implied marginal effect of τ_0:		
At Q10	−0.052 (0.036)	−0.042 (0.040)
At median	0.002 (0.027)	0.017 (0.033)
At Q90	0.164 (0.080)*	0.194 (0.086)*

Notes: All regressions include average population growth, log average life expectancy, government effectiveness, institutional quality, regional variables (described in the text), indicator variables for GATT and OECD membership, and cohort fixed effects. Numbers in parentheses are heteroskedasticity-consistent standard errors; * and † represent statistical significance at the 95% and 90% level, respectively. The last panel of the table gives the marginal effect of tariffs estimated at the 10th, 50th, and 90th percentile of skill.

static efficiency gains from specialization as well as the opportunity to consume differentiated goods from abroad. Thus, the above results should not be treated as a statement about the desirability of trade protection, but rather as an observation of the existing correlation between tariff barriers and output growth.

IV. CONCLUDING REMARKS

The endogenous growth literature shows that the impact of trade barriers on growth depends on how trade reallocates resources through the economy. For example, in both Grossman and Helpman (1990) and Matsuyama (1992), the impact of trade on growth depends on the pattern of comparative advantage across countries. In this paper, we re-examine the relationship between trade protection and growth in the light of these studies, and find evidence that the relationship is nonlinear. In particular, we find that tariff barriers are most strongly and positively correlated with growth in skill-abundant countries. This contingent relationship is in line with the predictions of Grossman and Helpman (1990), and is robust to multiple alternative specifications.

Our findings are also intuitively compatible with Nunn and Trefler's (2010) finding that the skill bias of tariffs is positively correlated with growth: it seems plausible that skill-intensive countries may have tariff structures biased toward skilled industries.[11] Our results differ, however, from DeJong and Ripoll (2006), who find a negative correlation between tariffs and growth among higher-income countries. Our analysis suggests that the specification based on income levels rather than the pattern of comparative advantage introduces a serious collinearity problem, resulting in coefficient estimates that are highly sensitive to changes in model specification. Largely because of this, we emphasize our results based on the capital-output ratio and skill level, rather than income.

APPENDIX: DATA DESCRIPTION AND SOURCES

We use the following 94 observations in Table 1.[12]

- *North Africa and Middle East:* Egypt, Iran, Israel, Jordan, Morocco, Syria[a], and Tunisia.
- *Sub-Saharan Africa:* Benin[a], Botswana, Burkina Faso[b], Cameroon, Comoros[b], Congo[a], Côte D'Ivoire, Ethiopia[b], Gabon, the Gambia[b], Ghana, Kenya, Lesotho[b], Madagascar[a], Malawi, Mali, Mauritius, Niger[a], Nigeria, Rwanda[a,b], Senegal, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zaire, Zambia, and Zimbabwe.
- *America:* Argentina, Barbados, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala[a], Guyana, Honduras[a], Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago[a], United States, Uruguay, and Venezuela.
- *East & South Asia:* Bangladesh, India, Indonesia, Japan, South Korea, Malaysia, Nepal[b], Pakistan, Philippines, Singapore, Sri Lanka, and Thailand.
- *Europe:* Austria, Belgium, Cyprus, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, and United Kingdom.
- *Oceania:* Australia, Fiji[b], New Zealand, and Papua New Guinea.

The following list defines the variables used in the tables, indicates their sources, and explains how we construct them where relevant.

- *y:* GDP per capita, from Penn World Tables (PWT6.3, 2009).

11. Nunn and Trefler argue that only about one-quarter of the increase in growth due to the skill bias of tariffs is due to this bias *causing* specialization in skilled industries, but discuss the potential endogeneity which may cause the tariff structure in skill-abundant countries to exhibit this bias.

12. [a] indicates that growth rates are over 1980–2007 and other variables are adjusted accordingly, because of missing tariff data as described in the text. [b] indicates that the institutional quality index is not available, so the country is not in the sample of 86 in Tables 2 and 3.

TABLE A1
Descriptive Statistics

Variable	Mean	SD	Minimum	Maximum
y growth	0.016	0.019	−0.056	0.053
TFP growth	0.001	0.022	−0.078	0.039
tariffs (τ)	0.123	0.085	0.000	0.387
skill_0	0.172	0.160	0.004	0.784
$\ln h_0$	0.605	0.311	0.062	1.221
$\ln ky_0$	0.633	0.604	−1.139	1.496
$\ln y_0$	8.511	1.066	6.433	10.288
Inv/GDP	0.189	0.096	0.030	0.565
Pop growth	0.020	0.011	−0.001	0.043
Log life exp.	4.135	0.173	3.674	4.352

There are 94 observations and the variable $\ln ky \equiv \ln(K/Y)$ denotes log capital-output ratio.

TABLE A2
Correlation Coefficients

	τ_0	s_0	$\ln h_0$	$\ln ky_0$	$\ln y_0$
τ_0	1.000				
s_0	−0.513	1.000			
$\ln h_0$	−0.607	0.871	1.000		
$\ln ky_0$	−0.436	0.567	0.696	1.000	
$\ln y_0$	−0.576	0.759	0.828	0.671	1.000
	τ_0	$\tau_0 \times s_0$	$\tau_0 \times \ln h_0$	$\tau_0 \times \ln ky_0$	$\tau_0 \times \ln y_0$
τ_0	1.00				
$\tau_0 \times s_0$	0.31	1.00			
$\tau_0 \times \ln h_0$	0.61	0.81	1.00		
$\tau_0 \times \ln ky_0$	0.26	0.60	0.61	1.00	
$\tau_0 \times \ln y_0$	0.99	0.41	0.69	0.34	1.00

There are 94 observations and the variable $\ln ky_0 \equiv \ln(K/Y)_0$ denotes log capital-output ratio.

- *ky:* Capital-output ratio. Using the investment series data from PWT6.3, capital stock data are constructed with standard perpetual inventory method with 6% depreciation rate. Following Hall and Jones (1999), the initial level of the capital stock for each country is estimated as $K_{60} = I_{60}/(g + \delta)$, where g is the average investment growth rate in physical capital over 1960–1970, and $\delta = 0.06$.
- *h:* Average human capital per worker, estimated as in the main text. The data on average years of schooling are taken from Barro and Lee (2010). Educational attainment data are not complete for Burkina Faso, Comoros, Ethiopia, Madagascar, and Nigeria. For these countries, we use data from neighboring countries, following Nunn and Trefler (2010). For example, for Burkina Faso, we use the average of the educational attainment data from Ghana and Mali.
- *TFP:* Given the data on output, capital, labor (from PWT6.3), and average human capital, we obtain TFP series directly from Equation (1).
- τ : Import-weighted average tariff (i.e., tariffs/imports) from World Development Indicators (WDI). Unweighted average tariff from EFW Database.
- *skill:* Fraction of population aged 25 and above with at least a secondary degree, 1985 (or 1980) from Barro and Lee (2010).
- *Inv/GDP:* Investment/GDP, 1983–1985 (or 1978–1980), from PWT6.3.
- *Pop. Growth:* Average annual population growth rate, 1975–1985 (or 1970–1980), from PWT6.3.
- *Life Expectancy:* Average life expectancy from WDI.
- *Geography:* Five geographic variables from Sachs and Warner (1995). Four are dummy variables indicating that the country is in sub-Saharan Africa, Latin America, East-Asia and Pacific, or is landlocked. The fifth measures the fraction of land located in a tropical climate.
- *Government effectiveness:* From Kaufmann, Kraay, and Mastruzzi (2008), average 1996–2000. Units range from approximately −2.5 to 2.5, and higher values correspond to better governance outcomes.
- *Institutional quality:* A composite index for institutional quality from EFW database (2008). This indicator is measured in units ranging from about 1 to 10, with higher values corresponding to better institutional quality. We use the log value of this index in our regressions.

Table A1 reports the descriptive statistics, and Table A2 presents correlations between the key variables.

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