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The trade-growth nexus in the developing countries: A quantile regression approach

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THE TRADE-GROWTH NEXUS IN THE DEVELOPING COUNTRIES: A QUANTILE REGRESSION APPROACH

NON-TECHNICAL SUMMARY

It is a widely accepted view that among the driving factors of long–run growth, trade plays an important role in shaping economic and social performance. Policy recommendations based on export-led growth and trade liberalization have been at the heart of poverty reduction strategies for many years, and developing countries were encouraged to reduce trade barriers in order to allow for comparative advantages to develop. Theoretical foundations of the positive links between trade openness strategies, growth and poverty reduction come at least from two sources. On the one hand, the neoclassical approach explains the gains from trade liberalization by comparative advantages, be they in the form of resource endowment (as in the Hecksher-Ohlin model) or differences in technology (as shown by the Ricardian model). On the other hand, the endogenous growth literature asserts that trade openness positively affects per capita income and growth through economies of scale and technological diffusion between countries.

The empirical investigation of these theoretical foundations points to a large variation in the distribution of the benefits from trade openness to growth or to economic development. Asian and some Latin American countries that managed to develop export-based strategies have been rewarded with high economic growth, while African countries have remained trailing behind despite efforts to emulate the export-led growth model. To explain this, one strand of the literature emphasizes the conditional aspect of the trade-growth link: trade openness may not be conducive to growth in the absence of an appropriate economic, social and political environment.

Despite the theoretical interest, empirical investigation of this hypothesis of a heterogeneous trade-growth nexus conditional on the country's structural characteristics has not yet received enough attention. In this paper, we examine the relationship between openness and growth for 75 developing countries in the period of 1980-2006. Such a relationship may be plagued by two problems: (i) inconsistent estimates due to omitted variables and/or endogeneous variables that are incorrectly considered as exogenous and (ii) model uncertainty coming from the lack of clear theoretical guidance concerning the choice of regressors. Here, we tackle these two problems by, first, explicitly conducting a formal robustness analysis to identify the growth determinants, using the Bayesian Model Averaging methodology. Second, we address the issue of parameter heterogeneity in the trade-growth relationship by employing a quantile regression analysis which allows to identify possible differences in the trade elasticities of high and low-growth countries. Our results suggest that conditioning on the identified robust determinants, openness has a higher impact on growth among low-growth countries relative to high-growth countries. In addition, we find evidence of significantly larger short-run and

long-run effects for the same group of countries. Both of these results support the idea of a heterogeneous trade-growth nexus among the developing countries. Overall, our findings suggest that while low-growth countries can benefit the most from openness in the long-run, they are also likely to suffer the most from short-run effects of openness.

ABSTRACT

This paper applies quantile regression techniques to investigate how the impact of trade openness on the growth rate of per capita income varies with the conditional distribution of growth. Using formal robustness analyses, we first identify robust variables affecting economic growth (investment, government balance, terms of trade, inflation, and population growth) which we then use as controls in the quantile regression estimations. Our findings suggest a heterogeneous trade-growth nexus: for both the long-run and the short-run, the effect of openness on growth is higher in countries with low growth rates compared to those of high growth rates. Our results cast doubt on earlier literature that finds little effect of openness on growth, and suggest that the implications of parameter heterogeneity in the openness-growth relationship need to be considered before prescribing policies.

JEL Classification: C23; F13; 011
Key Words: Quantile regression, growth-trade nexus, developing countries.

LE LIEN COMMERCE-CROISSANCE DANS LES PAYS EN DEVELOPPEMENT : UNE APPROCHE PAR LES REGRESSIONS QUANTILES

RESUME NON TECHNIQUE

Il est couramment admis que le commerce constitue un déterminant important de la croissance économique à long terme. Les politiques économiques privilégiant la croissance des exportations et la libéralisation commerciale ont été au cœur des stratégies recommandées aux pays en développement. Les origines des fondements théoriques du lien positif entre ouverture commerciale et croissance sont doubles. D'une part, l'approche néoclassique explique les gains tirés de la libéralisation commerciale par les avantages comparatifs, que ceux-ci soient sous la forme de dotations en ressources naturelles (modèle Hecksher-Ohlin) ou de différences technologiques (modèle ricardien). D'autre part, la littérature sur la croissance endogène suppose que l'ouverture commerciale affecte positivement le revenu par tête et la croissance au travers d'économies d'échelle et de la diffusion technologique entre les pays.

L'étude empirique de ces fondements théoriques met en évidence d'importantes variations dans la distribution des gains de croissance économique provenant de l'ouverture commerciale. Les pays d'Asie et d'Amérique latine, qui ont suivi des stratégies basées sur le développement de leurs exportations, ont bénéficié de forts taux de croissance économique, alors que les pays d'Afrique sont restés en retrait, en dépit de leurs efforts pour promouvoir la croissance par les exportations. Afin d'expliquer ces différences, une partie de la littérature met l'accent sur l'aspect conditionnel du lien entre commerce et croissance : l'ouverture commerciale ne pourrait stimuler la croissance en l'absence d'un environnement économique, social et politique approprié.

En dépit de son intérêt théorique, l'hypothèse d'un lien entre commerce et croissance conditionnel aux caractéristiques structurelles d'un pays a été peu testée empiriquement. Dans cet article, nous examinons la relation ouverture-croissance pour 75 pays en développement sur la période 1980-2006. Une telle relation peut être brouillée par : (i) l'incohérence des estimations due à l'omission de variables explicatives et/ou à l'existence de variables endogènes incorrectement traitées comme exogènes et (ii) l'incertitude du modèle provenant d'une absence de considérations théoriques unanimes concernant le choix des régresseurs. Ici nous résolvons ces deux problèmes en procédant à une analyse visant à identifier de façon robuste les déterminants de la croissance par le biais de la méthodologie moyenne mobile bayésienne. Une fois ces déterminants robustes pris en compte, nous pouvons ensuite nous intéresser à la question de l'hétérogénéité de la relation commerce-croissance. Pour cela nous recourons à la technique des régressions quantiles. Nous montrons alors que le lien ouverture-croissance est plus fort pour les pays à faible croissance que pour les pays à forte croissance.

RESUME COURT

Nous estimons des régressions quantiles afin d'étudier l'impact de l'ouverture commerciale sur le taux de croissance des pays en développement. En ayant recours à une analyse de robustesse, nous identifions les déterminants robustes de la croissance économique (investissement, solde budgétaire, termes de l'échange, inflation, croissance de la population), utilisés ensuite comme variables de contrôle dans les régressions quantiles. Nos résultats montrent l'existence d'un lien hétérogène entre commerce et croissance : à court et long termes, l'effet positif de l'ouverture commerciale sur la croissance est plus important pour les pays à faible croissance que pour ceux à forte croissance. Ces résultats qui diffèrent de ceux souvent obtenus dans la littérature (mettant en évidence un faible impact de l'ouverture commerciale sur la croissance) soulignent l'importance de la prise en compte de l'hétérogénéité des pays.

Classification JEL : C23; F13; 011
Mots-clefs : Régression quantile, lien croissance-commerce, pays en développement.

THE TRADE-GROWTH NEXUS IN THE DEVELOPING COUNTRIES: A QUANTILE REGRESSION APPROACH[1]

Gilles Dufrénot[*], Valérie Mignon[**] and Charalambos Tsangarides[***]

INTRODUCTION

The quest for growth continues to attract a lot of interest in developing and emerging countries, as evidenced by the large volume of the literature since the early 1990s. Until the last two decades, it was a widely accepted view that among the driving factors of long–run growth, trade plays an important role in shaping economic and social performance. Policy recommendations based on export-led growth and trade liberalization have been at the heart of poverty reduction strategies for many years, and developing countries were encouraged to reduce trade barriers in order to allow for comparative advantages to develop. Theoretical foundations of the positive links between trade openness strategies, growth and poverty reduction come at least from two sources. On the one hand, the neoclassical approach explains the gains from trade liberalization by comparative advantages, be they in the form of resource endowment (as in the Hecksher-Ohlin model) or differences in technology (as shown by the Ricardian model). On the other hand, the endogenous growth literature asserts that trade openness positively affects per capita income and growth through economies of scale and technological diffusion between countries.[2]

The empirical investigation of these theoretical foundations points to a large variation in the distribution of the benefits from trade openness to growth or to economic development. Asian and some Latin American countries that managed to develop export-based strategies have been rewarded with high economic growth, while African countries have remained trailing behind despite efforts to emulate the export-led growth model. To explain this, one strand of the literature emphasizes the conditional aspect of the trade-growth link: trade openness may not be conducive to growth in the absence of an appropriate economic, social and political environment. Following North (1990), some argue that institutional arrangements

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[2] Examples of seminal papers on these topics are Grossman and Helpman (1991a, 1991b), Rivera-Batiz and Romer (1991), Barro and Sala-i-Martin (1997), and Eaton and Kortum (1999).

(governance and policies), market institutions (bureaucracy and competition) and social norms determine the degree to which trade openness contributes to higher income and growth (see, among others, Dollar and Kraay (2003)). Others, including Krugman (1990), state that the expansion of growth augments a country's income once the rise of growth inputs (capital, labor, education, and infrastructure) are taken into account, suggesting the possibility of various trade-growth relationships under different economic and social environments.

The hypothesis of a heterogeneous trade-growth nexus conditional on the country's structural characteristics has received some theoretical support. For instance, drawing on the experience of some developing countries, Devarajan and Rodrik (1989) use a general equilibrium model to show that trade liberalization can be either welfare-augmenting or welfare-reducing in the presence of imperfect competition or increasing returns. Also, Young (1991) shows that growth can be higher for a country under autarky than under free trade, and Rassekh (2004) provides an overview of theoretical models showing that growth effects from trade openness can be either positive or negative across countries. Despite the theoretical interest, however, empirical investigation of this hypothesis has not yet received enough attention.[3]

In this paper, we pay special attention to the question of heterogeneity of the trade-growth link. More specifically, we test the conjecture that differences in the trade-growth nexus originate from fulfilled or unfulfilled internal preconditions, most of which related to the domestic factors of economic growth (productive infrastructure, human capital, efficient investment, and factor productivity). In particular, we examine the relationship between openness and growth for 75 developing countries in the period of 1980-2006. Such a relationship may be plagued by two problems: (i) inconsistent estimates due to omitted variables and/or endogeneous variables that are incorrectly considered as exogenous and (ii) model uncertainty coming from the lack of clear theoretical guidance concerning the choice of regressors. Here, we tackle these two problems by, first, explicitly conducting a formal robustness analysis to identify the growth determinants, using the Bayesian Model Averaging methodology. By averaging over different competing specifications, this methodology accounts for model uncertainty when making inferences about parameters and predictions. Second, we address the issue of parameter heterogeneity in the trade-growth relationship by employing a quantile regression analysis which allows the investigation of the openness-growth nexus at various points on the conditional growth distribution to identify possible differences in the trade elasticities of high and low-growth countries. While the empirical literature on openness and growth is daunting in its volume, it should be mentioned that very few papers have applied quantile estimators to growth equations. The main contributions are those of Cunningham (2003), Mello and Perrelli (2003) and Osborne (2006). To our best knowledge, only one application of quantile regressions has been made to the trade-growth nexus by Foster (2008). However in the Foster's study, trade is reduced to liberalization and the model specification is rather *ad hoc* in the sense that there is no formal justification of the use of the control variables. In this paper we go further by identifying robust determinants of

[3] A notable exception is Foster (2008) who investigates the link between liberalization and growth. However, the model specification is rather *ad hoc*, and there is no formal justification of the use of the control variables.

growth, leaving the *ad hoc* specification criticism. Our results suggest that conditioning on the identified robust determinants, the impact of trade on growth varies depending on the location of a country on the distribution of per capita growth; openness has a higher impact on growth among low-growth countries relative to high-growth countries. In addition, we find evidence of significantly larger short-run and long-run effects for the same group of countries. Both of these results support the idea of a heterogeneous trade-growth nexus among the developing countries. Finally, we identify significant changes in the conditional growth distribution as a response to openness shocks. Overall, our findings suggest that while low-growth countries can benefit the most from openness in the long-run, they are also likely to suffer the most from short-run effects of openness.

The remainder of the paper is structured as follows. Section 1 discusses the empirical framework by presenting the model and the econometric methodology in the context of the quantile regression approach, and the robustness analysis to identify the growth determinants. Section 2 presents the results from the quantile regressions and offers some policy recommendations. Section 3 concludes.

1. THE EMPIRICAL FRAMEWORK

We consider a regression with trade openness as an explanatory variable among other determinants of the per capita income growth rate. This equation applies to a pool of countries i ($i = 1,\ldots, N$) observed over T periods ($t = 1,\ldots, T$):

$$\Delta \log(y_{it}) = c_i + \alpha \; OPEN_{it} + \Omega \; Z_{it} + \varepsilon_{it} \tag{1}$$

where y is the real GDP per capita, $OPEN$ is an indicator of trade openness and Z is a vector of contemporaneous and lagged values of growth determinants (including the lagged value of y). The double index it refers to a country i observed at time t, and c is a vector of individual fixed effects. We are interested in estimating this model in a way that identifies differences in the response of the per capita income growth rate to changes in trade openness[4] and other growth determinants for countries at various points of the income distribution. The application of quantile regression techniques allows the investigation of possible parameter heterogeneity across the conditional distribution of growth rates.

1.1. Quantile regression principle

The majority of the current empirical literature on the trade-growth nexus—based on cross-section data, OLS and instrumental variables (IV) regressions, panel methods, or matching

[4] In our empirical application, the trade openness variable is measured by bilateral trade forecasted from a gravity equation that includes different usual determinants (see *infra*). This variable captures the multidimensional nature of openness by taking into account transportation costs, trade barriers, …

estimators— assumes parameter homogeneity.[5] However, assuming homogeneous elasticities across countries could lead to an over-fitting of conclusions based on the global population of economies to a particular subset of interest. Said differently, an empirical regularity found (say, a beneficial impact of openness on growth) may differ in its relevance for certain subsets of countries if there is a heterogeneity bias underlying the data. In our investigation, the use of quantile regressions improves upon the usual techniques by uncovering patterns in which the effect of trade openness, given the other determinants of growth, could vary across countries.

Consider the linear model:

$$Y_{it} = X_{it}^{'}\beta + v_{it} \tag{2}$$

where Y is the dependent variable and X is a vector of explanatory variables. The essential feature of a regression analysis is to examine the manner in which a set of explanatory variables affects the conditional distribution of a dependent variable. In the classical econometric techniques (OLS, IV, GMM, and GLS),[6] the component around which the dependent variable randomly fluctuates is the conditional mean $E[Y / X, \beta]$. However, unlike the classical approach, which amounts to estimating the conditional mean of the conditional distribution of Y, the quantile estimator is employed on different quantiles of the conditional distribution.[7]

Let $F(y)$ be the cumulated distribution function of Y. The θ^{th} quantile of Y is defined as the smallest y satisfying $F(y) \geq \theta$. In a regression context, it can be shown that finding θ amounts to obtaining the following estimator of β:

$$\hat{\beta}_\theta = \arg\min_{\beta_\theta} \left\{\sum_{i=1}^{T} H_\theta(v_{it})\right\}, \quad H_\theta(v_{it}) = \theta\, v_{it}^{+} + (1-\theta)\, v_{it}^{-} \tag{3}$$

where v_{it}^{+} is the vector of residuals with positive values and 0 otherwise, v_{it}^{-} is the vector of negative residuals and 0 otherwise. Therefore, we have as many estimators of β (and quantile regression estimates β) as values of $\theta \in (0,1)$ by changing the "representative" individual. The latter can be the mean (as in OLS), the median ($\theta = 0.5$) or any other quantile.

Koenker and Bassett (1978) derive asymptotic normality results for the quantile regression and show that:

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5 For a review of empirical works on trade and growth, please refer to Billmeier and Nanninci (2007).

6 GMM is the Generalized Method of Moments estimation; GLS is the Generalized Least Squares estimation.

7 Quantile regressions have been introduced by Koenker and Bassett (1978). See also the references quoted in Footnote 8.

$$\sqrt{T}\left(\hat{\beta}_\theta - \beta_\theta\right) \approx N\left(0,\, \theta(1-\theta)s(\theta)^2 J^{-1}\right) \quad (4)$$

$$J = \lim_{T\to\infty}\left(X^{'} X / T\right) \quad (5)$$

$$s(\theta) = 1 / f(F^{-1}(\theta)) \quad (6)$$

While the estimation of β is quite simple and requires the use of simplex algorithms (see D'Orey and Koenker (1987)), the estimate of the residual variance and the standard error of the estimated parameters is more complicated, since it requires the estimation of the unknown probability distribution function of y and its derivative. The latter is necessary to estimate the quantile density function $s(\theta)$, also called the sparsity function. Computation of the coefficient covariance matrices is an important part of quantile regression analysis and various approaches are available: bootstrap re-sampling methods, direct methods based on Siddiqui difference coefficients and kernel density (see Koenker and Bassett (1982), and Koenker (1994)).

We use the quantile regression methodology to estimate (1) and investigate the possibility of differences between the elasticities of high and low-growth countries. We pay particular attention to the selection of the control variables $\boldsymbol{Z}$ in (1), as well as concerns of possible endogeneity of the regressors (see Sections 1.2 and 1.3 below, respectively). In particular, we are interested by the causal link between openness and growth, more specifically by the behavior of the coefficient α in Equation (1). Estimates will be presented for three quantiles ($\theta = 0.25, 0.5, 0.75$). Also, we examine the manner in which the trade-growth nexus differs at the tails of the conditional distribution by considering graphs corresponding to different quantiles between the 10th and the 90th. Further, we examine how openness alters the conditional distribution of growth in developing countries, by simulating a positive or negative openness shock. We compare the probability density function for economic growth using the original data and the distribution of the forecasted level of growth that emerges when the trade variable is increased or decreased by its standard error.[8]

1.2. Selection of the control variables

The study of socioeconomic phenomena is typically plagued by inconsistent empirical estimates and model uncertainty. The first usually arises from omitted specific effects which, if correlated with other regressors, may lead to misspecification of the underlying dynamic structure or from endogenous variables that may be incorrectly treated as exogenous. The second case of model uncertainty—initially pointed out by Leamer (1978) and later

[8] This technique allows the examination of how a uniform change in trade openness can affect the dispersion of economic growth. For surveys of quantile regression methods, see Buchinsky (1998), Koenker and Hallock (2001), and Koenker (2005).

elaborated by Durlauf and Quah (1999) and Brock and Durlauf (2001)—arises because the lack of clear theoretical guidance and tradeoffs on the choice of regressors results in a broad number of possible specifications and often contradictory conclusions. A coherent mechanism to address the problem of model uncertainty is provided by Bayesian Model Averaging (BMA).[9] Briefly, BMA is a complete Bayesian solution to the problem of model uncertainty, which involves averaging over all possible combinations of predictors when making inferences about the quantities of interest. Unlike the classical approach which conditions on a single model and thus underestimates uncertainty when making inferences, in BMA no single model is assumed to be the "true" model. Instead, all possible models are assigned different probabilities based on the researcher's prior beliefs using the posterior model probabilities as weights.[10] By averaging over all the considered models, BMA provides an attractive tool to deal with model uncertainty, an issue that is potentially important in growth analysis.

Despite the vast number of cross-country growth studies that followed the seminal papers of Barro (1991), and Mankiw, Romer, and Weil (1992), the mechanics of economic growth are still not fully understood. In the years that followed, several determinants were used to explain economic performance categorized into those arising from policy (macroeconomic fiscal, exchange rate and trade policies, high inflation, and poorly functioning financial markets), those arising from politics and institutions, and those due to exogenous factors beyond the influence of the domestic domain. Evidence of the importance of these variables is mixed, and the lack of consensus on the key determinants of growth has recently led some scholars to formally incorporate model uncertainty through the use of BMA in the empirical growth analysis. Fernández, Ley and Steel (2001a) (henceforth, FLS), Brock and Durlauf (2001), Sala-i-Martin, Doppelhofer, and Miller (2004) (henceforth, SDM), and Tsangarides (2005) have used BMA techniques to investigate growth determinants.

We apply both the FLS and SDM techniques to identify robust growth determinants $\boldsymbol{Z}$ for (1).[11] Roughly speaking, FLS give an equal probability to each model, while SDM assume different probabilities. To identify a variable as a robust determinant, we consider two criteria. Following the first criterion, we compute the posterior inclusion probability of a variable which should be higher than 50% for selecting this variable. The second criterion relies on the probability of sign certainty. Using the dataset of Tsangarides (2005) which covers a cross section of 149 countries over the period of 1960-2000, we consider 22-24 potential determinants to arrive to a set of robust growth determinants.

Table A1 in Appendix A presents the results of our robustness simulations, which can be summarized as follows. First, we identify a robust effect of the "Solow determinants", namely, population growth and investment, and the initial level of per capita GDP capturing conditional convergence, as well as a few policy variables, such as trade openness and the

[9] Seminal contributions to BMA include those of Raftery (1995), and Raftery, Madigan and Hoeting (1997).

[10] Appendix A provides some BMA background and outlines our methodology.

[11] See Appendix A for details of the FLS and SDM techniques. Appendix B provides a description of the determinants used and their sources.

government's balance as share of GDP. It is indeed re-assuring that the openness variable (our key variable of interest) is identified as a robust determinant, which further underlines its importance. In addition, our exercise identifies a few other variables as robust: these are life expectancy, the tropical area dummy, and ethnicity. In the end, we drop these three variables because some represent fixed effects and also for data availability problems. Finally, for inflation rate and terms of trade there is tentative robustness evidence (as in some cases conclusions vary with the choice of the prior), but we chose to keep them in the list of robust variables.[12] In the end, we retain seven variables, namely initial per capita GDP, log of real investment as share of GDP, government's balance in percentage of GDP, openness, population growth, terms of trade growth, and inflation rate.

1.3. Endogeneity of the explanatory variables

A typical concern in growth regressions is the issue of endogeneity. Indeed, some of the explanatory variables identified in Section 1.2 (namely, openness, investment, and government balance) could potentially be endogenous, and ignoring this potential endogeneity may bias the results. Earlier work in the quantile regression literature has examined situations where the explanatory variables were potentially endogenous. For example, Amemiya (1982), Powell (1983), and Chen and Portnoy (1996) propose two-stage quantile estimators. Other approaches rely on IV and GMM quantile estimators (Abadie et al. (2002), Honoré and Hu (2004), Chernozhukov and Hansen (2005 and 2006), Chernohukov et al. (2007), and Sakata (2007)), and control functions (Lee (2007)).

To deal with this issue of endogeneity, we apply a two-stage quantile approach, where a quantile regression is implemented in both the first-stage estimation of the explanatory variables that are potentially endogenous (openness, investment, and government balance) using the least absolute deviation, and in the second stage for the initial equation after plugging in the fitted values of the variables using first stage estimates. For our special variable of interest, openness, we get the required fitted values from a gravity model which we run separately. In particular, for the period of our analysis (1980-2006) we regress countries' bilateral trade on a vector consisting of various gravity variables: distance, land border, membership of regional trade agreement, and dummies variables indicating bilateral free trade agreements, historical ties, sharing of a common currency.[13] Specifically, we estimate:

$$\log(T_{ijt}) = a_0 + \sum b_k^{'} W_{ijt} + u_{ijt} \quad (7)$$

[12] As discussed later excluding them from the list of robust variables does not make a difference to the quantile regression results.

[13] For a complete description of the model structure, please refer to Tsangarides et al. (2008).

where T_{ijt} stands for the value of bilateral trade between countries *i* and *j* at time *t*, W_{ijt} is a vector of *k* gravity variables and u_{ijt} is an error term. Appendix C presents the results of the gravity regressions. Following the literature, we consider several estimators (pooled OLS, pooled OLS with country effects à la Anderson and van Wincoop, panel country-pair fixed effects, and Hausman-Taylor), to examine the robustness of the results. Estimated coefficients are in line with results in the literature, and underline the importance of the "gravity variables" like GDP and distance, as well as the currency union and free-trade area dummies, on bilateral trade. Both OLS and country-fixed effects are likely to be biased, so we focus our attention on the country-pair-fixed-effects and the Hausman-Taylor estimates. While the Hausman-Taylor estimates are able to identify the effect of time-invariant determinants (which drop out with the country-pair fixed, effects) and can potentially control for the endogeneity of certain determinants, the estimated coefficients are sensitive to the choice of instruments, and vary significantly. In the end, we derive our fitted values for openness from the country-pair fixed effects.[14]

2. EMPIRICAL RESULTS FROM QUANTILE REGRESSIONS

The dataset for the quantile regressions includes annual data for 1980-2006 from a sample of 75 developing countries: 27 from Africa, 11 from Asia and Pacific, 25 from Central and Latin America, 9 Middle East and Arab countries and 3 from Europe (see Appendix D). To summarize, the explanatory variables are those selected from the robustness analysis described in Section 1.2. Also, as described in Section 1.3, to control for the possible endogeneity of trade openness we retain the fitted values of bilateral trade obtained from the gravity estimates, while for the two other endogenous variables, we consider the first-stage quantile fitted values of government balance and investment.

2.1. Estimation results

Our growth equation is estimated as an error-correction model in order to allow for both short- and long-run impacts. The short-run effects are measured by the coefficients of the contemporaneous exogenous variables. The long-run impact is measured by the sum of the coefficients related to the contemporaneous and lagged variables divided by the coefficient of the real GDP. Table 1 reports the estimation results for the whole period, with the 25th quantile of growth distribution representing countries with low growth rates and the 75th quantile those with high growth rates. First, the impact of openness on the per capita GDP growth rate in the two-stage quantile regressions is very different between low-growth and high-growth countries, as the estimated 25th quantile coefficient is at least twice that of the 75th quantile. In addition, openness is associated with a 3-8 percent increase in growth in the short-run, while in the long-run growth varies less than proportionally in the high-growth countries (0.75), but more than proportionally in the low-growth countries (1.6). In other

[14] The predicted values from country-pair fixed effects and Hausman-Taylor estimates were very highly correlated (0.95-0.98), so the choice between the two estimators has virtually no impact on the quantile regression results.

words, in the short-run, a 1% increase in openness leads to a 0.03% increase in the real GDP in the high-growth countries, and this effect is more than doubled in the low-growth countries (the elasticity being equal to 0.08%). A similar conclusion holds for the long-run impact where the elasticities fall in between 0.75 (high-growth countries) and 1.6 (low-growth countries). These results suggest that the effect of openness is stronger for low-growth countries, both in the short- and long-run. Furthermore, comparing the two-stage least-sum of absolute deviations (LAD) regression (50th quantile) with GMM, it seems that the latter over-estimates the influence of trade in the short-run, but under-estimates its impact in the long-run. The other coefficients tend to be fairly similar across quantiles, with the notable difference of the variables capturing economic policies, namely inflation and government balance. Inflation is not-significant for high-growth countries, while it significantly affects growth in low-growth countries. Like trade, the effect of fiscal policy is roughly doubled when we compare the high- and low- growth countries. This would mean that the trade-growth nexus is stronger in those countries where the economic policies also drive the economic growth. Trade per se is not a factor of growth, but it is complementary to the effects played by the other determinants.

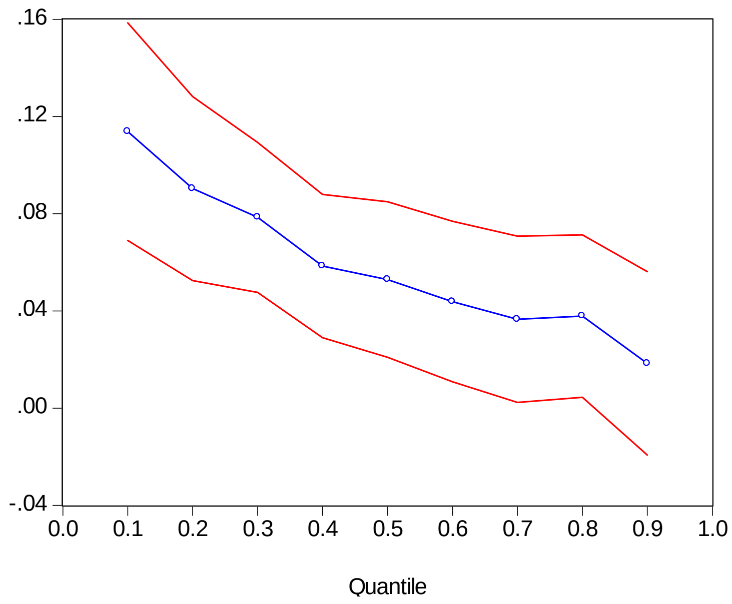
Figure 1 reports the impact of trade at different quantiles, showing graphically how the impact of openness falls in size as we move to higher quantiles, with the coefficient dropping by about 60 percent until the 40th percentile and falling less slowly there after as growth increases. Interestingly, we see that the decline in the impact of openness on growth is steeper for the lowest quantiles and less strong for the highest ones. This would mean that the impact of trade on growth is stronger in the very poor countries, suggesting that the benefits from openness are the strongest for countries that have the smallest growth rates.

Table 1. GMM and Two-Stage Quantile Regressions 1980-2006
Dependent variable: per-capita real GDP growth

	(1)	(2)	(3)	(4)
	GMM	Two-stage quantile regressions		
		0.5	*0.25*	*0.75*
Real GDP(-1)	-0.21	-0.03 ***	-0.05 ***	-0.04 ***
	-	(-4.20)	(-6.03)	(-3.95)
Investment share	0.06 ***	0.05 ***	0.05 **	0.06 ***
	(4.71)	(4.64)	(2.47)	(3.67)
Government balance	-0.03	0.23 ***	0.28 **	0.15
	(-0.79)	(2.82)	(2.50)	(1.18)
Population growth	-0.006	-0.04 ***	-0.04 ***	-0.04 ***
	(-0.50)	(-2.95)	(-9.71)	(-3.70)
Terms of trade growth	-0.008	0.005	0.01	0.002
	(-0.84)	(1.56)	(1.30)	(0.96)
Inflation	0.005	-0.01 **	-0.02 ***	-0.02
	(0.78)	(-2.38)	(-4.02)	(-1.59)
Trade				
Openness	0.09 ***	-	-	-
	(3.64)			
Gravity	-	0.04 ***	0.08 ***	0.03 **
		(2.90)	(5.02)	(1.96)
Investment share(-1)	0.01	-0.01	-0.005	-0.02
	(0.98)	(-0.80)	(-0.25)	(-1.07)
Government balance(-1)	0.28 ***	-0.04	-0.001	-0.01
	(12.83)	(-0.38)	(-0.01)	(-0.15)
Population growth(-1)	-0.06 ***	0.01	0.003	0.014 **
	(-4.20)	-0.91	(0.43)	(2.14)
Terms of trade growth(-1)	-0.02 **	0.009 ***	0.02 ***	0.014
	(-2.22)	(2.75)	(5.69)	(1.26)
Inflation(-1)	-0.02 ***	0.004	0.008 **	0.01
	(-2.69)	(0.99)	(2.18)	(0.99)
Trade				
Openness(-1)	-0.004	-	-	-
	(-0.25)			
Gravity(-1)	-	-0.01	-0.03	-0.004
		(-0.93)	(-1.55)	(-0.29)
Pseudo R^2	-	0.23	0.26	0.25
Impact of trade on growth				
Short-run	0.09	0.04	0.08	0.03
Long-run	0.43	1.33	1.6	0.75

Notes:
1. GMM estimations in column (1), and two-stage quantile estimations in columns (2)-(4). All regressions include country dummies; t-statistics in brackets. ***: p<0.01, **: p<0.05, *: p<0.1.
2. The sparsity function is computed using a Kernel method (the results are robusts to other methods such as bootstrap or Siddiqui).
3. The short-run impact is given by the openness coefficient; the long-run impact is given by the absolute value of the ratio of openness to the lagged value of per-capita GDP growth rate.
4. Instruments used both for GMM and in the first-stage quantile regressions are lagged values of the endogenous and explanatory variables as well as lagged values of their first-difference.

Figure 1: Impact of trade on growth at different quantiles and 95% confidence interval



Next, we repeat the analysis of quantile regressions on two sub-periods, namely 1980-1995 and 1996-2006. We justify the breaking of the sample period in this fashion for the following reason. The first sub-period was characterized by a change in the economic philosophy in favor of market-oriented development, particularly in the field of international trade. During this period, policies of trade and liberalization took place in many developing countries under structural adjustment programs supported by international financial institutions and the so-called "Washington consensus". However, up until the first half of the 1990s, these policies led to only short-lived recoveries in the Latin American countries and a few take-offs in Africa. As a consequence, from the mid-nineties onwards there was a shift in the approach: trade policies were complemented by reforms putting a stronger focus on other macroeconomic and social policies including productivity-boosting reforms, spending on social programs, improving the investment climate, and the strengthening of institutions. The results reported in Tables 2 and 3 show that the conclusions obtained for the whole period (1980-2006) are explained by those of the second sub-period 1996-2006 (Table 3). For the sub-period 1980-1995, we find little evidence of any statistically significant correlation between trade openness and growth (Table 2). These results are in line with the stylized facts and empirical studies showing that trade openness based on first generation market-oriented policies have not lead to any economic boom in the developing countries (see Rodrik (1998), Easterly (2001), and World Bank (2005)).

Table 2. GMM and Two-Stage Quantile Regressions 1980-1995
Dependent variable: per-capita real GDP growth

	(1)	(2)	(3)	(4)
	GMM	Two-stage quantile regressions		
		0.5	*0.25*	*0.75*
Real GDP(-1)	-0.21	-0.04 **	-0.02	-0.06 ***
	-	(-2.44)	(-1.08)	(-3.82)
Investment share	0.08 ***	0.04	0.04	0.04
	(8.38)	(1.33)	(1.18)	(1.01)
Government balance	-0.1 ***	0.48 **	0.53 **	0.28
	(-3.99)	(2.20)	(2.44)	(0.91)
Population growth	-0.001	-0.02 **	-0.02 *	-0.03
	(-0.26)	(-2.18)	(-1.91)	(-0.98)
Terms of trade growth	-0.009	0.01 **	0.01 **	0.005
	(-1.44)	(2.14)	(1.98)	(0.26)
Inflation	0.005	-0.02 **	-0.02 ***	_0.01
	(1.21)	(-2.18)	(-4.06)	(-1.22)
Trade				
Openness	0.10 ***	-	-	-
	(7.58)			
Gravity	-	0.03	0.04 *	0.03
		(1.32)	(1.60)	(1.16)
Investment share(-1)	0.01	-0.04	-0.04	-0.07 *
	(1.51)	(-1.52)	(-1.50)	(-1.69)
Government balance(-1)	0.29 ***	-0.146	-0.03	-0.06
	(15.74)	(-0.64)	(-0.17)	(-0.25)
Population growth(-1)	-0.06 ***	0.02 **	0.003	0.03
	(-6.20)	(2.34)	(0.26)	(1.44)
Terms of trade growth(-1)	-0.02 **	0.02 ***	0.02 ***	0.007
	(-3.13)	(2.99)	(2.7)	(0.26)
Inflation(-1)	-0.009	0.003	0.0002	-0.0002
	(-1.41)	(0.36)	(0.05)	(-0.01)
Trade				
Openness(-1)	-0.02 *	-	-	-
	(-1.89)			
Gravity(-1)	-	-0.003	-0.006	0.01
		(-0.12)	(-0.19)	(0.35)
Pseudo R^2	-	0.28	0.32	0.31
Impact of trade on growth				
Short-run	0.10	0.0	0.0	0.0
Long-run	0.36	0.0	0.0	0.0

Notes:
See notes for Table 1.

Table 3. GMM and Two-Stage Quantile Regressions 1996-2006
Dependent variable: per-capita real GDP growth

	(1)	(2)	(3)	(4)
	GMM	Two-stage quantile regressions		
		0.5	*0.25*	*0.75*
Real GDP(-1)	-0.12	-0.16 **	-0.09 **	-0.15 ***
	-	(-3.79)	(-2.25)	(-3.68)
Investment share	0.06 ***	0.06 *	0.06	0.04
	(3.14)	(1.92)	(1.63)	(1.51)
Government balance	0.03	-0.01	0.15	-0.03
	(1.18)	(-0.06)	(0.72)	(-0.29)
Population growth	-0.08 ***	-0.03 *	-0.04 ***	-0.03 ***
	(-3.82)	(-1.78)	(-2.72)	(-2.96)
Terms of trade growth	-0.12 ***	0.006	0.007	0.009
	(-6.93)	(0.45)	(0.76)	(0.607)
Inflation	-0.16 ***	-0.06	-0.124 ***	0.05 **
	(-3.74)	(-0.98)	(-3.83)	(2.27)
Trade				
Openness	0.11 ***	-	-	-
	(3.93)			
Gravity	-	0.09 ***	0.107 ***	0.05 **
		(3.16)	(4.21)	(2.27)
Investment share(-1)	0.09 ***	-	-	-
	(6.45)			
Government balance(-1)	0.15 ***	-0.001	0.04	-0.04
	(3.70)	(-0.01)	(0.29)	(-0.43)
Population growth(-1)	-0.103 ***	0.01	0.001	-0.0054
	(-7.59)	(1.14)	(0.08)	(-0.16)
Terms of trade growth(-1)	-0.01 *	-0.007	0.002	-0.008
	(-1.76)	(-0.50)	(0.13)	(-0.29)
Inflation(-1)	-0.18	0.03	0.07 *	0.003
	(-5.29)	(0.98)	(1.68)	-0.09
Trade				
Openness(-1)	0.04 *	-	-	-
	(1.90)			
Gravity(-1)	-	0.02	-0.012	0.04
		(0.72)	(-0.38)	(1.34)
Pseudo R^2	-	0.42	0.41	0.46
Impact of trade on growth				
Short-run	0.11	0.09	0,11	0.05
Long-run	1.25	0.56	1.18	0.33

Notes:
See notes for Table 1.

Overall, our finding that openness affects low-growth countries more than high-growth ones challenges the conclusions of most of the earlier cross-section and time series studies that reveal either very little evidence of any statistical impact of trade on growth in the recent decades, or in some cases, a negative influence.[15] We believe there are two possible reasons for the difference. *First*, most of the earlier studies focus on trade liberalization and its effect on developing countries, essentially testing the validity of the "Washington consensus" while our focus is on openness rather than liberalization. Also, failure to find a statistical link between liberalization and growth may not be that surprising given that it is now a rather well-established fact that trade policies have not played a significant role in growth performance of many developing countries in Africa, Latin America and even Asia (for a review of the arguments, see Stiglitz (2005)). One notable exception is Foster (2008), who uses quantile regressions to study the impact of trade liberalization on the per capita GDP growth rate in developing countries between 1960 and 2003. He finds a positive and varying impact of such policies across quantiles and explains his findings by the fact that the liberalization-growth relationship is affected by third factors (in his case, crises). *Second*, in our approach we use the growth determinants to explore whether openness conditional on other policies (the robust growth determinants) affects growth. We are essentially exploring the complementarity of openness with other policies to affect growth, rather than just the link between liberalization and growth.

2.2. Explaining the differences between low- and high-growth countries

Our results show a different impact of openness on growth, depending on whether the countries are low- or high-growth economies. The former belong to the lower tail of the growth distribution (left), while the latter are located in the upper tail of the distribution (right). To identify these countries in our sample we proceed as follows. For each country, we compute the number of growth rates below the 25th or 30th quantile of growth distribution and the number of growth rates above the 70th or 75th quantile of the distribution. A country with more than 40 percent of its growth rates below the 30th quantile is referred as a low-growth country, while one with more than 40 percent of its growth rates above the 70th quantile is referred as a high-growth country. Using this criterion, we find 44 countries that are low-growth economies and 25 countries that are high-growth economies. The first group accounts for 59 percent of our sample and the second group represents 33 percent of the sample.[16]

Differences between the low- and high-growth countries are related to their differences in trade dependency. The group of low-growth economies includes countries like Albania,

[15] See Rodrik and Rodriguez (1999), UNDP (2003), and Wacziarg and Welch (2003).

[16] The former includes countries from all the continents, but a majority is in Africa and Latin America (for instance, Argentina, Benin, Bolivia, Côte d'Ivoire, Brazil, Madagascar, Ecuador, Honduras, Malawi, Nicaragua, Paraguay, Peru, Zambia, etc). The second group is made of countries essentially from Latin America and Asia and very few from Africa. Examples of countries are Egypt, Ethiopia, Korea, Pakistan, Panama, Thailand, Tunisia, Singapore, Uruguay and Vietnam.

Bolivia, Côte d'Ivoire, Colombia, Dominican Republic, Mali, Malawi, Niger, Paraguay, Senegal, Venezuela, Zambia, and Yemen. It is current wisdom that these countries' dependency ratio on imports is higher relative to that of the countries with a mature manufacturing sector. Historical data show that their economies rely on imports of raw materials, machines, capital goods, intermediate producer goods and consumer goods. These countries also have high export concentration ratios, with their exports concentrated on a few commodities. In addition, historically, these countries' rapid trade expansion was not accompanied by fast expansion of their production capacity. The share of their manufacturing sector in GDP has remained relatively low due to the lack of viable productive infrastructure, supply capacity constraints, and "de-industrialization" facing them during the 1980s and 1990s when they were forced to adopt trade liberalization policies (see Noorbakhsh and Paloni (2000), and Shafaeddin (2006)). Another possible explanation for which a strengthened trade-growth nexus characterizes the low-growth countries may be that these countries' structure of production and exports are locked in primary products and simple processing (see Laird and Fernandez de Cordoba (2006)). Indeed, countries which depend on exports of primary commodities often rely on trade more than those with a diversified export structure. Finally, a third possible explanation is that the outward-oriented strategies during the 1980s and 1990s discouraged private investment due to its reduced profit margin resulting from large import openness. On the whole, for the low-growth countries, the observed higher correlation between growth and trade openness reflects the strong dependence of their economies on foreign trade.

We now consider the case of the highest growth countries which includes countries like Botswana, Chile, Guyana, Pakistan, Panama, Thailand, and Vietnam. One of the reasons why the link between openness and growth is smaller for the higher quantiles may be that their exposure to and dependence on international trade has been smaller in comparison with the low-growth countries. These countries have been able to reduce their dependency on developed countries by upgrading their production structure through imported technology, resulting in a more mature industrial base. A mature industrial sector coupled with the fact that these countries have a competitive advantage in the export of high-tech finished goods implies that they have a higher growth rate relative to the economies of the 25th quantile. On the whole, for these countries, growth is more closely linked to domestic industries and, accordingly, the correlation with exports and imports is lower compared to countries belonging to the first group.

2.3. Consequences of a trade shock on growth

To study the consequences of the heterogeneous response of growth to trade openness, we examine how the growth distribution changes when all countries in the sample are hit by the same trade shock. Such shocks are exogenous and can be either positive or negative. They can be of various types: changes in the prices of goods, suppression of trade barriers, increase of the size of a considered zone compared to another one, training effects, etc. We proceed as follows. We first compute the conditional probability density function for the growth rate of per capita GDP, using the estimated coefficients of (1) for different quantiles from the 10th up to the 90th. Then, the obtained distribution is "shocked" by one standard error of the trade openness variable (the fitted variable from our gravity model). We consider both positive and negative shocks.

Figures 2 and 3 show the growth conditional distribution corresponding to a situation with no shock on trade (solid lines) and the corresponding conditional distributions when the economies are "perturbed" with an exogenous shock to openness (darker lines), first for a positive shock and then a negative shock. The analysis reveals that a negative openness shock is associated with a more pronounced dispersion of the growth distribution, and a reduction in the mean as the conditional distribution moves to the left, with countries in the lower tail affected more, the latter effect reflecting the higher vulnerability of low-growth countries to negative trade shocks. In addition, the relative position of the countries relative to each other widens. In contrast, a positive shock induces an increase in the mean and a reduction in the dispersion of the distribution, as the conditional distribution becomes leptokurtic. This suggests a catching-up effect between low- and high-growth countries and as a consequence, low-growth countries become closer to high-growth countries, which can be interpreted as a convergence phenomenon.

Figure 2: Growth conditional distribution (positive trade shock)

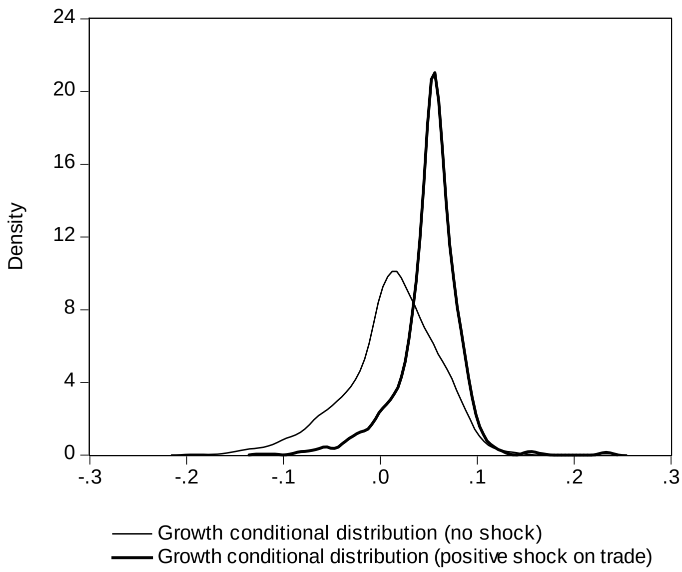
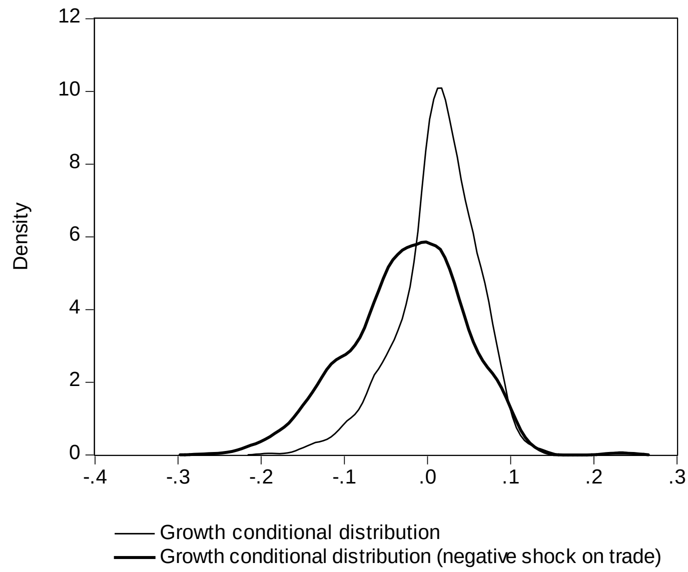


Figure 3: Growth conditional distribution (negative trade shock)



An exposure to *symmetric* trade shocks (meaning that all the countries face the same shock with equal magnitude) thus causally affects countries' growth in a heterogeneous manner. With regard to the current international crisis, a negative shock could come from a shift in the demand from the developed countries. Less access to the industrialized countries' markets may penalize the low-growth countries more importantly than the high-growth ones. One reason for this could be that a shift in the demand from the world market discourages factor accumulation in the poorest countries by decreasing factor prices (see Acemoglu and Ventura (2001)). Another reason can be found in the economic geography literature. Reduced market access induces a decline in the agglomeration benefits leading to lower income levels (see Amiti and Cameron (2004)). So, our finding of a more dispersed distribution following a negative shock can be sustained by economic arguments. When facing a negative trade shock, the developing countries could decide to reduce their openness to trade. For instance, in order to avoid too huge trade deficits, governments could decide to respond to a reduction in the export volume by reducing their imports. Doing this, the low-growth countries would increase the likelihood to deter their growth further while the high-growth countries would be more immunized (since we found in our regressions that the impact of trade on growth is, at least, twice as high in the low-growth countries as in the high-growth ones).

3. CONCLUSION

The "heterogeneity" hypothesis in the literature investigating the trade-growth nexus has recently re-opened the debate on this association. In this context, the empirical literature follows two strands. One is related to the question of omitted conditional variables in the classical regressions linking trade to growth. Another focuses on the application of more appropriate econometric tools to investigate the possibility of heterogeneous responses. In this paper, we attempt to control for both of these criticisms, by applying quantile regression analysis, while controlling for identified robust growth determinants.

This paper shows that the response of growth performance to trade openness varies among the developing countries, providing empirical evidence of parameter heterogeneity. These results are in contrast to some earlier literature relying on mean-based approaches which mask the real effect and may sometimes lead to contradictory conclusions. Our results suggest that after conditioning on the robust growth determinants, openness has a higher impact on growth among low-growth countries relative to high-growth countries, with significantly larger short-run and long-run effects. We also show that trade openness shocks have an impact on the dispersion of international distribution of growth: we identify significant changes in the conditional growth distribution as a response to openness shocks, with positive shocks resulting in improvements in the distribution (higher mean income and smaller dispersion) and convergence effects and negative shocks resulting in lower growth and wider dispersion around the mean. In terms of policy implications, our findings suggest that, on the one hand, low-growth countries could benefit the most from increasing trade openness, which would also help their convergence to the highest growth economies in the long-run. On the other hand, increased trade dependency may raise vulnerability in situations of decreasing trade. As a result, in this case, countries that stand to gain the most from increased trade in the long-run are also in danger of being hurt the most in the short-run.

Our paper challenges the empirical results usually obtained in the literature in several manners. We find a positive impact of openness (using as a proxy an indicator of bilateral trade from a gravity model) on the growth rates of all the developing countries in our sample. This contradicts the idea that restrictions to trade can promote growth, an argument that has sometimes been put forward to motivate the protectionist measures undertaken in some emerging economies. Our estimates suggest that such restrictions would have less impact on the countries which are already growing faster, but in any case, the latter would still experience a decrease in their real per-capita GDP. Neither can we assert that the most open economies grow faster than the less open ones, another argument that has frequently been evoked to encourage the adoption of liberalization policies by the developing countries. In our sample, high-growth countries—for which we obtain a lower trade coefficient—have been less open to trade than the low-growth ones (over many years their ratio of imports in percentage of GDP remain lower and the ratio of the value-added in the manufacturing sector as share of GDP is higher). Our results are in line with the arguments provided by Dani Rodrik[17] that, over the 1980s and the 1990s, fast-growth developing countries have undertaken more trade restrictions in order to create domestic capacity.

[17] See Rodrik (1998) and Rodrik and Rodriguez (1999).

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APPENDIX A: SELECTION OF THE CONTROL VARIABLES

This Appendix provides a summary of the BMA approach and presents briefly the calculated quantities and summary statistics used. Further details of the FLS and SDM can be found in the original papers.[18]

Suppose that the parameter space can be divided into K regions (models) where θ is the quantity of interest. Let D denote the data. Then Bayesian inference about θ is constructed using Bayesian Model Averaging, based on the posterior distribution:

$$p(\theta \mid D) = \sum_{j=1}^{K} p(\theta \mid D, M_j) p(M_j \mid D) \quad (1.1)$$

which follows by the law of total probability. Therefore, the full posterior distribution of θ is a weighted average of the posterior distributions under each model ($M_1,...,M_K$), where the weights are the posterior model probabilities $p(M_j \mid D)$.

Using Bayes' theorem, the posterior model probabilities are obtained using:

$$p(M_j \mid D) = \frac{p(D \mid M_j) p(M_j)}{\sum_{l=1}^{K} p(D \mid M_l) p(M_l)} \quad (1.2)$$

In the spirit of Bayesian inference, prior distributions need to be specified for the parameters θ_k, and the models M_j, the specification of which differs between FLS and SDM. Assuming that we have k^* variables, there are $K = 2^{k^*}$ possible sampling models, so the space of all possible models is $\mathrm{M} = \left\{ M_j : j = 1,...,2^{k^*} \right\}$. When there is no preference for a specific model $p(M_1) = p(M_2) = ... = p(M_K) = \frac{1}{K}$, which is the specification in FLS. However, SDM assume that the model probabilities are not equal: assuming that each variable has an equal inclusion probability, the prior probability for model M_j is:

$$p\left(M_j\right) = \left(\frac{\bar{k}}{k^*}\right)^{k_j} \left(1 - \frac{\bar{k}}{k^*}\right)^{k^* - k_j} \quad (1.3)$$

[18] We thank the authors for making their Fortran and Gauss codes available. See the *Journal of Applied Econometrics* Data Archive for FLS, and http://www.econ.cam.ac.uk/faculty/doppelhofer/ for SDM.

where k^* is the total number of regressors, $\bar{k}$ is the researcher's prior about the size of the model, k_j is the number of included variables in model M_j, and $\frac{\bar{k}}{k^*}$ is the prior inclusion probability for each variable.

Defining parameter priors in the case of SDM reduces to defining only $\bar{k}$. That is the only prior that is arbitrarily specified in the simulations, so robustness checks of the results are estimated by changing the value of this parameter. For this reason, we estimate our simulations with values of $\bar{k} = 5, 8, 11, 15$. On the other hand, FLS define priors for the parameters that are common to all models, namely the intercept, the scale parameter, and the slope coefficients. For the intercept and the scale parameter improper priors are assumed, while for the slope parameters we experiment with a variety of g-priors (specifically 1-9) as discussed in Fernández, Ley and Steel (2001b).

Posterior densities can be calculated for θ using (1.1). Further, using (1.2) we can estimate the posterior inclusion probability of a variable. It is the sum of all posterior probabilities of all the regressions including the specific variable (regressor), and it serves as a ranking measure to see how much the data favors the inclusion of a variable in the regression. It is calculated as:

$$P(\text{inclusion}) = p(\theta_k \neq 0 \mid D) = \sum_{\theta_k \neq 0} p(M_j \mid D) \tag{1.4}$$

If $p(\theta_k \neq 0 \mid D) > p(\theta_k \neq 0) = \frac{\bar{k}}{k^*}$ then the variable has high marginal contribution to the regression model.

Next, conditional on a variable's inclusion, we compute the sign certainty probability, a measure of the robustness of the sign of the coefficient. It estimates the probability that (conditional on inclusion) the coefficient is on the same side of zero as its mean and is calculated as:

$$\begin{aligned} P(\text{sign certainty}) &= p\left[sgn\left(\theta_k\right) = sgnE\left(\theta_k \mid D\right) \mid D, \theta_k \neq 0\right] \\ &= \sum_{j=1}^{2^{k^*}} p\left(M_j \mid D\right)\left\{p\left[sgn\left(\theta_k\right) = sgnE\left(\theta_k \mid D\right) \mid M_j, D\right]\right\} \end{aligned} \tag{1.5}$$

We base our robustness estimations on the inclusion probability and the sign certainty.[19]

In particular, we proceed as follows. From a set of 22 or 24 potential regressors we apply both the FLS and SDM estimations to derive $P(\text{inclusion})$ and $P(\text{sign certainty})$. This is repeated

[19] In addition, conditional means and variances may be computed, as discussed in FLS and SDM. We are not interested in inference based on BMA *per se*, so we only focus on these two measures.

for nine values of g-priors for FLS and five values of $\bar{k}$ ($\bar{k} = 5, 8, 11, 15$) in the case of SDM. Then results are "aggregated" from both simulations and then summarized using our specified rule where a variable is identified as "robust" if $P(\text{inclusion}) \geq 0.50$ and $P(\text{sign}) \geq 0.90$. Finally, we combine results from all three simulations to arrive at the set of robust growth determinants used in (1).

Appendix A, Table A1: List of Variables Used in the Growth Regressions
Possible Simulations Using 22-24 Regressors

Simulation 1: 24 regressors				
	FLS		SDM	
	prior=1-9		kbar=5,8,11,15	
	P(incl.)	*P(sign)*	*P(incl.)*	*P(sign)*
lny0	0.88	1.00	0.70	0.98
lni	0.98	1.00	0.95	1.00
lnpopgr	0.25	0.73	0.17	0.88
lninfl	0.31	1.00	0.26	1.00
baly	0.91	1.00	0.73	1.00
lng	0.24	0.96	0.19	0.76
brmy	0.24	0.98	0.17	0.79
open	0.45	1.00	0.37	0.99
totgr	0.30	1.00	0.23	0.92
lpyr	0.41	1.00	0.35	0.89
lsyr	0.29	0.99	0.25	0.87
lfexp	0.66	1.00	0.51	1.00
ehet	0.64	1.00	0.46	0.90
democ	0.23	0.87	0.17	0.66
change	0.27	0.99	0.20	0.84
pw10	0.26	0.90	0.18	0.65
tropicar	1.00	1.00	0.95	1.00
infrapc	0.31	0.96	0.24	0.68
infraq	0.32	0.96	0.24	0.60
overval	0.33	1.00	0.27	0.99
regime	0.23	0.81	0.16	0.56
relipr	0.85	1.00	0.71	0.59
lland	1.00	1.00	0.99	1.00
SSA	0.31	0.93	0.22	0.46

Simulation 1: 22 regressors				
	FLS		SDM	
	prior=1-9		kbar=5,8,11,15	
	P(incl.)	*P(sign)*	*P(incl.)*	*P(sign)*
lny0	0.97	1.00	0.86	0.99
lni	0.74	1.00	0.83	1.00
lnpopgr	0.29	1.00	0.25	0.93
lninfl	0.42	1.00	0.38	1.00
baly	0.86	1.00	0.71	1.00
lng	0.36	1.00	0.33	0.76
brmy	0.26	1.00	0.21	0.98
open	0.96	1.00	0.86	1.00
totgr	0.27	1.00	0.23	0.89
lpyr	0.31	1.00	0.27	0.89
lsyr	0.34	1.00	0.31	0.84
lfexp	0.88	1.00	0.75	1.00
ehet	0.49	1.00	0.40	0.91
democ	0.30	0.94	0.25	0.64
change	0.29	1.00	0.27	0.94
pw10	0.24	0.97	0.21	0.48
tropicar	0.96	1.00	0.85	1.00
infrapc	0.32	0.98	0.28	0.67
infraq	0.25	0.96	0.22	0.57
overval	0.46	1.00	0.42	1.00
regime	0.23	1.00	0.21	0.67
SSA	0.27	0.97	0.22	0.72

Simulation 1: 22 regressors				
	FLS		SDM	
	prior=1-9		kbar=5,8,11,15	
	P(incl.)	*P(sign)*	*P(incl.)*	*P(sign)*
lny0	0.99	1.00	0.91	0.96
lni	0.62	1.00	0.83	1.00
lnpopgr	0.29	1.00	0.23	0.89
lninfl	0.34	1.00	0.31	0.99
baly	0.92	1.00	0.76	1.00
lng	0.43	1.00	0.37	0.73
brmy	0.36	1.00	0.32	0.99
open	0.98	1.00	0.90	1.00
totgr	0.33	1.00	0.28	0.95
ltoted	0.33	1.00	0.30	0.98
lfexp	0.93	1.00	0.82	1.00
blk	0.79	1.00	0.64	1.00
ehet	0.49	1.00	0.42	0.86
democ	0.27	0.76	0.22	0.77
change	0.32	1.00	0.28	0.97
pw10	0.26	0.97	0.22	0.52
tropicar	0.99	1.00	0.91	1.00
infrapc	0.40	1.00	0.37	0.75
infraq	0.27	0.87	0.22	0.53
overval	0.45	1.00	0.43	1.00
fixed	0.24	0.96	0.22	0.48
interm	0.27	1.00	0.24	0.98

Notes:
1. For a list of regressors and their definitions and sources see Appendix B.
2. Highlighed variables are classified as "robust" using the authors' defined criterion for robustness: P(sign)≥0.90 and P(inclusion)≥0.50.
3. Each of the simulations 1-3 were estimated using several priors. For FLS, priors 1 through 9 were used as defined in Fernandez, Ley, and Steel (2001b). For SDM, priors of kbar=5, 8, 11, 15 with kbar as defined in Sala-i-Martin, Doppelhoffer and Miller (2004).

Appendix B: List of Variables Used in the Growth Regressions

Variable	Definition	Source
Dependent Variable		
DIFFY	Logarithm of real GDP per capita (1996 US dollars at PPP)	Penn World Table 6.1
Explanatory Variables		
LNY0	Logarithm of initial real GDP per capita (1996 US dollars at PPP)	Penn World Table 6.1
Solow determinants		
LNI	Logarithm of real investment as ratio to GDP (1996 US dollars at PPP)	Penn World Table 6.1
LNNPOPGR	Logarithm of annual population growth rate plus 0.05	Penn World Table 6.1
Human capital (Augmented Solow)		
LPYR	Logarithm of average stock of years of primary education	Barro and Lee
LSYR	Logarithm of average stock of years of secondary education	Barro and Lee
Macroeconomic stability		
LNINFL	Logarithm of one plus the inflation rate.	IFS
BALY	Government balance as share of GDP, current LCU	World Economic Outlook
LNG	Logarithm of real government consumption as ratio to GDP	Penn World Table 6.1
Financial development		
BRMY	Ratio of broad money to GDP.	World Economic Outlook
Trade regime		
OPEN	Exports plus Imports as share of GDP (1996 US dollars at PPP)	Penn World Table 6.1
External environment		
TOTGR	Terms of trade (goods and services) growth	World Economic Outlook
Health		
LFEXP	Life expectancy at birth (total)	World Development Indicators
Internal environment/resources		
LLAND	Logarithm of arable land per capita, hectares, average over five years	World Development Indicators
EHET	Ethnic heterogeneity	Sambanis
ELFO	Updated index of ethnolinguistics fractionalization	Sambanis
INFRAQ	Indicator of infrastructure quality	Calderon and Serven
INFRAPC	Indicator of infrastructure stock	Calderon and Serven
RELIPR	Relative investment price level (PI/PC) (1996 US dollars at PPP)	Penn World Table 6.1
Corruption/War		
BLK	Ratio of black market rate and official exchange rate minus one	Easterly and Sewadeh
PW10	Incidence of civil war in the last 10 years	Sambanis
Institutions/governance		
DEMOC	Aggregate index of democracy	Polity IV
CHANGE	Annual change in the Polity index	Polity IV
Geography/Physical Factors		
TROPICAR	% Land area in geographical tropics	Gallup, Mellinger, Sachs
Dummy variables		
SSA	Sub-Saharan Africa Dummy	IMF classification
Exchange rate regime		
OVERVAL	Index of overvaluation/undervaluation based on ppp	Author's calculation
REGIME	IMF de facto fine classification	Author's calculation
FIXED	IMF de facto fine classification	Author's calculation
INTERM	IMF de facto fine classification	Author's calculation
FLOAT	IMF de facto fine classification	Author's calculation

Appendix C: Gravity Model Estimations

Estimation:	OLS		CFE		CPFE		HT1		HT2	
Specification:	(1)		(2)		(3)		(4)		(5)	
Currency union	0.36	**	0.42	***	0.09	*	0.14	**	0.10	
	(0.15)		(0.15)		(0.06)		(0.07)		(0.07)	
Log distance	-1.28	***	-1.56	***			-2.33	***	-3.58	***
	(0.02)		(0.02)				(0.08)		(0.50)	
Log product real GDP	1.12	***	0.34	***	0.85	***	1.18	***	0.92	***
	(0.01)		(0.07)		(0.07)		(0.02)		(0.02)	
Log product real GDP/capita	0.00		0.53	***	0.14	**	-0.06	***	0.10	***
	(0.01)		(0.07)		(0.06)		(0.02)		(0.02)	
Common language	0.49	***	0.48	***			0.48	***	0.31	
	(0.05)		(0.05)				(0.07)		(0.28)	
Common land border	0.69	***	0.47	***			-0.81	***	-3.25	***
	(0.12)		(0.12)				(0.23)		(1.18)	
Free trade agreement (FTA)	1.25	***	0.59	***	0.25	***	0.26	***	0.26	***
	(0.10)		(0.09)		(0.05)		(0.04)		(0.03)	
Number landlocked in the pair	-0.32	***	-3.49	***			-0.40	***	-0.69	***
	(0.03)		(0.37)				(0.05)		(0.18)	
Number islands in the pair	0.13	***	-0.58				0.61	***	0.93	***
	(0.04)		(518.20)				(0.06)		(0.28)	
Log product of areas	-0.07	***	0.39	***			-0.03	*	0.15	***
	(0.01)		(0.03)				(0.02)		(0.04)	
Common colonizer	0.85	***	0.83	***			0.73	***	0.24	
	(0.07)		(0.07)				(0.09)		(0.37)	
Current colony	0.26		0.71		0.18		0.16		0.17	
	(0.26)		(0.74)		(0.39)		(0.27)		(0.27)	
Ever colony	1.32	***	1.38	***			1.41	***	1.85	**
	(0.13)		(0.13)				(0.24)		(0.92)	
Same nation	1.95	***	1.64				2.69		3.43	
	(0.43)		(0.85)				(1.73)		(6.60)	
Constant	-26.07	***	-5.03	**	-28.01	***	-20.79	***	-4.89	
	(0.32)		(2.02)		(2.30)		(0.83)		(3.79)	
Observations	221 269		221 269		221 269		221 269		221 269	
Number of pairid					13 431		13 431		13 431	
R-squared	0.70		0.75		0.10		.		.	
Hausman HT1 vs RE (p-value)									0.00	
Hausman FE vs HT1 (p-value)									0.76	
Hausman HT2 vs RE (p-value)							0.00			
Hausman FE vs HT2 (p-value)							0.63			
Hausman FE vs RE (p-value)							0.00		0.00	

Notes: Authors' calculations.
1. Robust standard errors in parentheses. ***: p<0.01, **: p<0.05, *: p<0.1.
2. Instuments for HT estimation are: for HT1: endogenous (cu ldist lrgdp lrgdppc) and HT1: endogenous (cu fta ldist).
3. Time effects included in the regressions. CFE, CPFE, and HT stand for country fixed effects, country pair fixed effects, and Hausman-Taylor, respectively.
4. Hausman p-values represent test p-values from sequential testing to select among FE vs. RE vs. HT based on pre-test estimator of Baltagi et al (2003).

Appendix D: List of countries

Region	**Counties**
Africa (27)	Algeria, Benin, Botswana, Burkina Faso, Cameroon, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Mauritius, Kenya, Madagascar, Malawi, Mali, Morocco, Mozambique, Namibia, Niger, Nigeria, Senegal, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia.
Asia and Pacific (14)	Bangladesh, China, South Korea, India, Indonesia, Malaysia, Nepal, Pakistan, Papua New Guinea, Philippines, Singapore, Sri-Lanka, Thailand, Vietnam.
Central and Latin America (22)	Argentina, Bahamas, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Ecuador, Guatemala, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela.
Arab and Middle East (9)	Bahrain, Iran Islamic Republic, Jordan, Kuwait, Lebanon, Oman, Saudi Arabia, Syrian Arab Republic, Yemen.
Europe (3)	Albania, Armenia, Republic of Moldova.

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