Supplemental Appendix to:

Foreign Direct Investment and Growth Symbiosis: A Semiparametric System of Simultaneous Equations Analysis

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Abstract

This supplemental appendix contains a detailed literature review and additional results from the empirical analysis summarized in the main manuscript.

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1 A Detailed Review of the Literature

We provide a review of the main points of overlap among the existing empirical research on growth, FDI, and institutions. The focus of our review is threefold: (i) to highlight several empirical growth determinants that are generally known to be robust *and* are relevant to the FDI-growth relationship; (ii) to summarize the widely used determinants of FDI; and (iii) to underscore the importance of incorporating both institutional factors and parameter heterogeneity into empirical macroeconomic specifications.[1] Thus, the contribution of this section is to provide a foundation for the empirical model described in the main manuscript, not to provide an exhaustive review of the related literature.

1.1 Determinants of Economic Growth

There is a reasonably well-developed literature that documents the effects of FDI on economic growth rates, with notable contributions including Balasubramanyam, Salisu & Sapsford (1996), Borensztein, De Gregorio & Lee (1998), Alfaro, Chanda, Kalemli-Ozcan & Sayek (2004), Durham (2004), Carkovic & Levine (2005), Kottaridi & Stengos (2010), McCloud & Kumbhakar (2012), and Delgado, McCloud & Kumbhakar (2015), and the relevant references cited therein. Our conditioning set of regressors for our growth equation must be standard in terms of the empirical growth literature, as a whole, as well as be adequate controls and measures for the important interactions identified in the literature on FDI and growth. Consequently, the specification of our growth equation incorporates factors from the following two growth ideologies: neoclassical, and macroeconomic policy.

The neoclassical growth specification is often referenced to Mankiw, Romer & Weil (1992) for the theoretical derivations and empirical specification, and includes initial income, the rate of physical capital investment, and population growth as traditional 'Solow' regressors. Inclusion of initial income provides the impetus for growth rate convergence, and the inclusion of the rate of physical capital investment and population growth are derived from an aggregate production function specification with productivity inputs capital and labor. Recent focus on model uncertainty through the use of linear model averaging (Durlauf, Kourtellos & Tan 2008) and nonparametric techniques that are immune to functional form misspecification (Henderson, Papageorgiou & Parmeter 2012, Delgado, Henderson & Parmeter 2014) have identified each of these 'Solow' variables as robust and important determinants of economic growth.

The macroeconomic policy growth ideology maintains that sound macroeconomic policies are prerequisite for economic growth. Macroeconomic policy is typically measured by trade openness, the inflation rate, and government consumption (Barro 1996, Durlauf et al. 2008), and there is strong empirical support for these variables as correlates of economic growth. Barro (1996) finds that trade openness has a positive and significant effect on growth rates, whereas government consumption has a negative and significant effect on growth rates. Henderson, Papageorgiou & Parmeter (2012), however, find evidence that trade openness is robust *but* has nonlinear effects on economic growth. In addition, Durlauf et al. (2008) and Henderson, Papageorgiou & Parmeter (2012) find evidence that the growth effects of the inflation rate and government consumption are

[1] The literature investigating the determinants of FDI has focused both on macroeconomic and microeconomic (i.e., firm specific) measures of FDI. The focus of our review is primarily on the macroeconomic research, as this relates closest to the focus of our current investigation.

robust to varying forms of model uncertainty.

In essence, these sets of determinants emanate from the general consensus within the empirical and theoretical spheres that – amid the myriad potential growth factors and sources of model uncertainty – the neoclassical and macroeconomic policy variables are generally robust. In addition, FDI has been found to be directly associated with growth-related macroeconomic factors within host countries (Alfaro & Johnson 2013); hence, the omission of such variables from the growth equation may induce a sizeable bias in the estimated relation between growth and FDI.

1.2 Determinants of FDI

The empirical literature investigating determinants of FDI is disproportionately smaller than the empirical growth literature, and is typically motivated by concerns over the locational determinants that can explain the variations in FDI flowing into *particular groups* of countries. The main purported correlates of FDI are the size of the host country, and several macroeconomic policy factors that influence the stability of the host economy as well as the expected risk and return of investment.

The macroeconomic policy factors are typically measured by the joint inclusion of the economic growth rate, the inflation rate, openness to trade, and the foreign exchange rate (see, e.g., Wheeler & Mody 1992). In particular, the economic growth rate is shown to be a statistically significant factor of FDI in the context of developing countries (Schneider & Frey 1985, Culem 1988), Middle Eastern and North African countries (Mohamed & Sidiropoulos 2010), and a sample of South Asian countries (Thangamani, Xu & Zhong 2010). The size of the host country is typically measured by GDP, and is generally found to be robust (Wheeler & Mody 1992, Chakrabarti 2001). Using a *linear* Extreme Bounds Analysis, however, Chakrabarti (2001) finds that the significant effects of the macroeconomic policy factors depend on model specification.

Nevertheless, the size of the host country, the economic growth rate, the inflation rate, openness to trade, and the foreign exchange rate, form a standard set of conditioning variables in the FDI literature (Lim 2001); a larger set of countries, and a more general and flexible model specification than those used by the existing literature, may help to resolve the conflicting findings on the importance of each factor in explaining cross-country variations in FDI levels.

1.3 Institutions and Parameter Heterogeneity

North (1990) defines institutions as "the rules of the game in a society" or "the humanly devised constraints that shape human interaction." The concept of institutions is quite general, reflecting the existence of its many different measures and hence its complexity.[2] In general, because of high collinearity between different measures of institutions, each measure is perhaps more appropriately interpreted as "a measure of institutional quality", rather than measurement of a specific type of institutional quality, such as corruption (Shleifer 2000).

Good institutions have long been thought to be fundamental factors requisite for economic development. Substantial empirical effort has been devoted to establishing the importance of institutions for economic growth. While criticism exists on the direction of causation between institutions and growth (Glaeser, La Porta, Lopez-de Silanes & Shleifer 2004), taken as a whole, this institutions-

[2]In the literature, measures of institutions include, for example, the general level of corruption; the degree of enforcement of property rights, human rights, and the legal system; establishments of banking institutions and financial markets; or constraints on executive branches of government.

growth literature has presented compelling evidence that institutions are fundamental causal factors of growth. See, for example, Acemoglu, Johnson & Robinson (2001, 2002, 2005*a*, 2005*b*), or Alesina, Devleeschauwer, Easterly, Kurlat & Wacziarg (2003) for an excellent review of the evidence.

Different strands of the empirical literature have documented different interactions between measures of institutional quality and economic growth. Corruption has been shown to adversely impact many correlates of economic growth such as domestic investment (Mauro 1995) and government expenditure (Mauro 1998), as well as FDI (Wei & Shleifer 2000) and the composition of capital flows (Wei & Wu 2002). Other measures of institutional quality are also shown to be significant in explaining variations in FDI (Schneider & Frey 1985, Kahai 2004).

It has also been documented that institutions is a source of parameter heterogeneity. Durlauf (2001) argues that 'states of development', which can be thought of generally as institutional quality, induces heterogeneity into growth regression parameters. Minier (2007) parametrically models this hypothesis, and provides compelling evidence of support. Huynh & Jacho-Chávez (2009*a*, 2009*b*) find evidence of significant heterogeneity in the effects of institutions on economic growth using robust nonparametric estimation methods. Through their model averaging exercises, Durlauf et al. (2008) find evidence that institutions may impact growth indirectly through their effects on other regressors. Substantial evidence exists that financial institutions (Hermes & Lensink 2003, Alfaro et al. 2004, Durham 2004) are crucial for identifying a significant link between FDI and growth rates, and McCloud & Kumbhakar (2012) and Delgado et al. (2015) find evidence that corruption induces nontrivial sources of heterogeneity into the growth-enhancing effect of FDI. Further, McCloud & Kumbhakar (2012) identify heterogeneity in the growth effects of FDI using a wide array of institutional measures. These papers argue that for FDI to significantly improve growth rates, host countries must have at least some threshold level of institutional quality, which reflects the absorptive capabilities of the host economy.

Economic growth rates are also influenced by a host of other nontrivial sources of parameter heterogeneity; see, for example, Durlauf & Johnson (1995) for an important early contribution. There exists a host of important empirical papers that employ a wide array of flexible econometric methods and have identified important sources of nonlinearities in growth rates across countries (Liu & Stengos 1999, Durlauf, Kourtellos & Minkin 2001, Maasoumi, Racine & Stengos 2007, Henderson, Papageorgiou & Parmeter 2012). Others provide evidence that failure to model such nonlinearities and heterogeneity leads to inconsistent estimation, and hence erroneous identification of statistically significant growth factors (Temple 2001, Henderson, Papageorgiou & Parmeter 2012, Delgado et al. 2014). In essence, consideration of this research has important implications for the general robustness of econometric growth models, and is perhaps best addressed by modeling parameters as functional coefficients (Brock & Durlauf 2001, Durlauf 2001). Economic policy informed via econometric models that account for such heterogeneity is likely to be more effective at improving growth rates (Burnside & Dollar 2000).

In light of the preceding discussion, we need an empirical model that is a generalization of the standard linear-in-parameters (fully parametric) model of simultaneous equations, and allows us to unify and empirically assess the aforementioned important themes in the empirical macroeconomic and econometric literatures. *First*, we seek to model the types of (joint) interactions between economic growth and FDI. *Second*, we seek to use instrumental variables to mitigate any potential endogeneity embedded in any of the conditioning variables. *Third*, we seek to explore the impact of

economic institutions as direct and indirect fundamental sources of heterogeneity in the coefficient functions in the growth and FDI models. Unlike the growth literature, there appears to be no meaningful analysis on the existence, nature, and sources of parameter heterogeneity in explaining variations in FDI across developed and developing countries. We therefore fill this gap in the FDI literature by allowing for nontrivial sources of parameter heterogeneity in our FDI equation. *Fourth*, we seek to allow for unrestricted (nonparametric) functional form of heterogeneity on the coefficient functions to avoid a potential source of model misspecification.

2 Supplemental Empirical Results

We now provide a detailed discussion of the results from applying our semiparametric instrumental variables systems estimator to our novel empirical model of economic growth and FDI described by (4.1) in the main manuscript. We consider the log of the total area of the country as an instrumental variable for FDI inflows in our growth equation, and both the fertility rate and life expectancy as instruments for growth in our FDI equation. We also explore non-instrumental variables estimates that rely solely on exclusion restrictions implied by the sets of controls X_1 and X_2, while accounting for institutional and non-neutral unobservable effects through Z, for identification. We do not report these non-instrumental variables estimates because (i) these estimates rely on identification assumptions that may not be satisfied and, more important, (ii) the nonparametric density equality test of Li, Maasoumi & Racine (2009) very strongly rejects (with p-value 0.0000) the null hypothesis that the density for each of our non-instrumental variables estimates is equal to that of its instrumental variables counterparts – which points to higher-order differences between the densities from the different estimation methods. We view the latter case as strong statistical evidence in favor of the instrumental variables results. We therefore focus exclusively on the instrumental variables results in our ensuing discussion.

We first discuss our estimated coefficient functions for our bivariate growth-FDI system, and then analyze the marginal effects on these coefficients from a reduction in corruption. Since our semiparametric systems estimator provides observation-specific estimates and standard errors, we summarize these estimates using kernel density plots and 45 degree gradient plots that are depicted by Figures 1 and 2, and the 25th, 50th (median), and 75th percentiles that are in Tables 1 and 2. The 45 degree gradient plots found in the lower panels of the figures show the observation specific function estimates plotted on the 45 degree line, with 95 percent observation specific confidence intervals plotted above and below each point estimate. If the horizontal dotted line at zero lies outside of each observation specific confidence interval, then that point estimate is statistically significant.[3]

2.1 Coefficient Function Estimates

2.1.1 Effects of Economic Growth and FDI

Consider first the system of equations that uses the life expectancy rate as our instrument for the growth rate. It is clear from the kernel density of FDI coefficient estimates in Figure 1 that the effects of FDI on economic growth rates are heterogeneous yet largely positive. The corresponding

[3]See Zhang, Sun, Delgado & Kumbhakar (2012) and Henderson, Kumbhakar & Parmeter (2012) for use of these plots to summarize semiparametric regression results and for more details.

45 degree gradient plot in Figure 1 shows that the majority of these estimates are statistically significant at the 5 percent level. For the FDI equation, Figure 1 reveals that the distribution of growth coefficient estimates is generally positive, and the corresponding 45 degree plot reveals that many of these positive estimates are statistically significant.

We turn to Table 1 for a more detailed analysis of particular point estimates. We find that the effect of FDI on growth (see the growth equation) has an interquartile range of 0.5531, with a median effect of 0.2081. Our point estimates at the quartiles are statistically significant for both the median and upper quartile. More important, there is a clear absence of statistical parity among the estimated quartiles. For example, the 95 percent confidence interval for the estimated upper quartile comfortably excludes the estimated lower quartile and median estimates. These results confirm that for many countries FDI has a significantly positive, heterogeneous and causal effect on economic growth rates. Moreover, at the median a 10 percent increase in FDI inflows relative to GDP causes approximately a 2 percent increase in the economic growth rate.

Turning to the FDI equation, we see that the growth rate has a significantly causal effect on FDI inflows at each reported quartile. These coefficients have an interquartile range of 0.5584 with a median effect of 0.2114. These estimates imply that at the median, a 10 percent increase in the growth rate causes about a 2.1 percent increase in the ratio of FDI inflows to GDP. However, there is statistical parity between the median and upper quartile estimates in that the 95 percent confidence interval for the estimated upper quartile contains the median estimate. Nevertheless, we find strong evidence that for many countries economic growth has a significantly positive, heterogeneous and causal effect on FDI. This empirical evidence of heterogeneity in the effect of economic growth on FDI represents a salient distinction between our work and the existing FDI literature. Further, our goodness of fit measures show that our model has high predictive ability in-sample, and while relatively lower, the out-of-sample predictive ability is acceptable.

In Section 5.1 of the main manuscript, we provide a discussion of the characterization of the types of interactions between economic growth and FDI based on these estimates.

2.1.2 Effects of the Control Variables

Turning to our other coefficient estimates in the growth equation, we see in Table 1 that the standard 'Solow' variables are generally significant at the reported quartiles. In particular, our results show that initial income, population growth, openness, and inflation have negative and significant effects on growth rates at the lower quartile and median, whereas the physical capital investment rate has positive and significant effects at the median and upper quartile. This initial income result is, of course, further evidence of the classic beta-convergence phenomenon that countries with relatively low initial levels of income have faster rates of growth in order to catch up to developed countries. Similarly, we find that government consumption has mixed effects on growth rates, with a negative and significant growth effect at the lower quartile, but a positive and significant growth effect at the upper quartile. That is, in the context of economic growth, government consumption is not productive in all countries. For all the standard 'Solow' variables, there is a clear absence of statistical parity among the corresponding estimated quartiles. These results therefore complement the existing nonlinear growth literature by providing added evidence of sizable heterogeneities within the effects of each of these variables on growth rates.

Considering the effects of our control variables in the FDI equation, we see that foreign exchange

and the log of GDP have a significantly negative effect on FDI at the lower quartile, an insignificant effect at the median, and a positive and significant effect at the upper quartile. Schooling has an insignificant effect on FDI at all quartiles, trade openness has a positive and significant effect on FDI inflows at all quartiles, and inflation has a negative but insignificant effect on FDI flows at the lower and median quartiles. Taking the coefficients on inflation, trade openness, and growth jointly, our results indicate that for many countries the primary attractants of FDI inflows are economic growth and trade openness, but high rates of inflation deter foreign investment. We further emphasize that these findings mark important empirical results for research investigating factors related to macroeconomic factors of FDI flows. In particular, the nature of the heterogeneous effects in the FDI equation partially explains why the previous results from linear models were unable to unearth statistically robust correlates of FDI flows.

In all, we interpret these significant effects in both equations to be robust evidence that our model is flexible enough to significantly capture heterogeneity across countries that might arise because of nonlinearities from interactions of these variables with respect to institutional quality or unobserved country and time effects.

2.2 Effect of Institutional Improvement

Recall that for this paper, an improvement in institutional quality means a reduction in the level of corruption. Turn now to Figure 2 for a set of the results of an improvement in institutional quality on the coefficients in the instrumental variables model. Both distributions are centered around zero, and the associated 45 degree plots show that many of these effects are significant in the FDI coefficient case, but that many of the growth coefficient partials are statistically insignificant. However, it is clear that there are subsets of growth coefficient partials that are negative and positive, and significant.

In Table 2, we find significance of the partial effect of corruption on the FDI coefficient at the lower and upper quartiles. Specifically, an improvement in institutional quality dampens the causal effect of FDI on growth at the lower quartile, but increases the effect at the upper quartile. These results are evidence that for some countries, an improvement in institutional quality weakens, strengthens or has no impact on the effect of FDI on growth. In terms of the effect of a reduction in corruption on the growth coefficient in the FDI equation, we find a significantly positive effect at the upper quartile, but insignificance at the lower and median quartiles. These results suggest that, in general, the effect of growth on FDI does not vary significantly with respect to institutional quality. Nevertheless, improvements in institutional quality reduce the impact of economic growth rates on FDI for some countries, and increase the impact for others.

More important, for each type of the FDI-growth interaction shown in Table 1 in the main manuscript, there is no evidence that countries that exhibit a specific type of interaction respond in the same direction to an improvement in institutional quality. Therefore, an improvement in institutional quality weakens, strengthens, or has no impact on the interactions between FDI and growth.

Turning towards the effects of a reduction in corruption on the rest of the coefficients in the growth equation, we see a reduction in corruption is associated with a weakening of the relationships between most control variables and the growth rate. In the FDI equation, however, we see that improvements in institutional quality is associated with a strengthening of mainly the relationships

between FDI inflows and the foreign exchange rate and trade openness. Overall, our results strongly suggest that corruption is a main source of parameter heterogeneity in the growth equation but not in the FDI equation.

Therefore, although developed countries may have a natural comparative advantage because of their higher level of institutional quality, the magnitudes of their *symbiosis* and *FDI-commensalism* interactions between FDI and economic growth are smaller than those of their developing counterparts.

List of Countries Included in the Analysis

Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Belarus, Belgium, Bolivia, Botswana, Brunei, Bulgaria, Burkina Faso, Canada, Colombia, Congo, Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Finland, France, Gambia, Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, Hong Kong, Hungary, Iceland, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Latvia, Lebanon, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Mali, Malta, Mexico, Moldova, Mongolia, Morocco, Mozambique, Namibia, Netherlands, New Zealand, Nicaragua, Niger, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Saudi Arabia, Senegal, Slovenia, South Africa, Spain, Sri Lanka, Suriname, Sweden, Switzerland, Syria, Tanzania, Thailand, Togo, Trinidad & Tobago, Tunisia, Turkey, Uganda, Ukraine, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.

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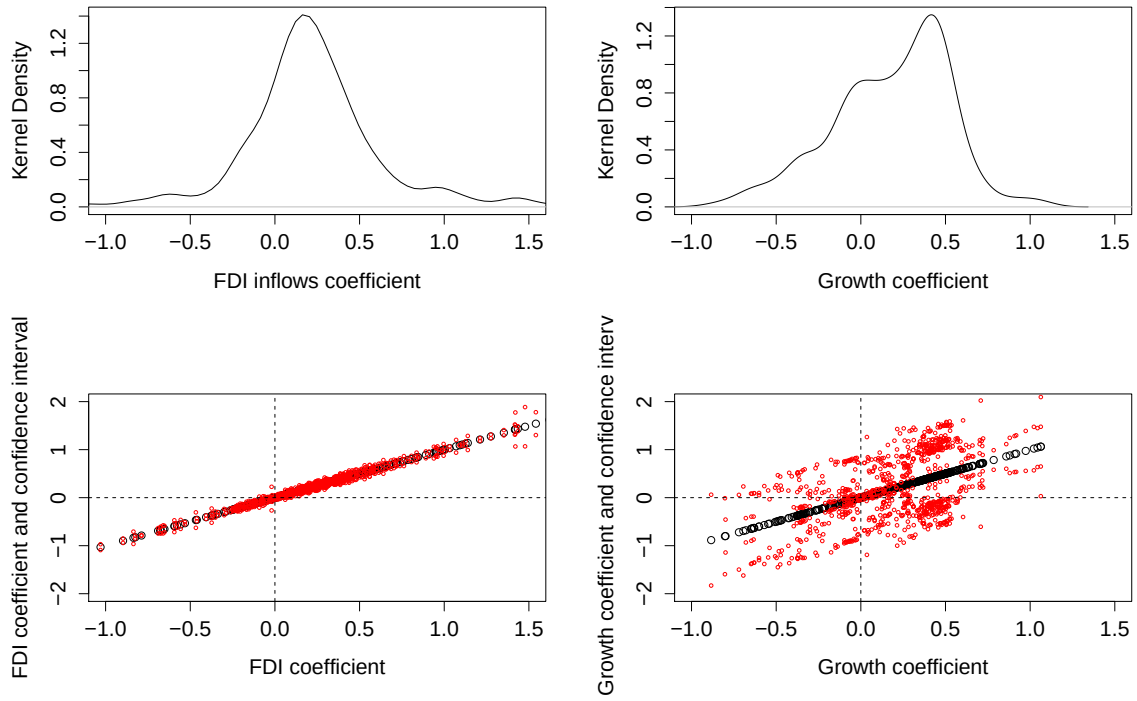

Figure 1: Kernel density plots and significance plots for FDI inflows and growth coefficient functions for the model with instrumental variables.

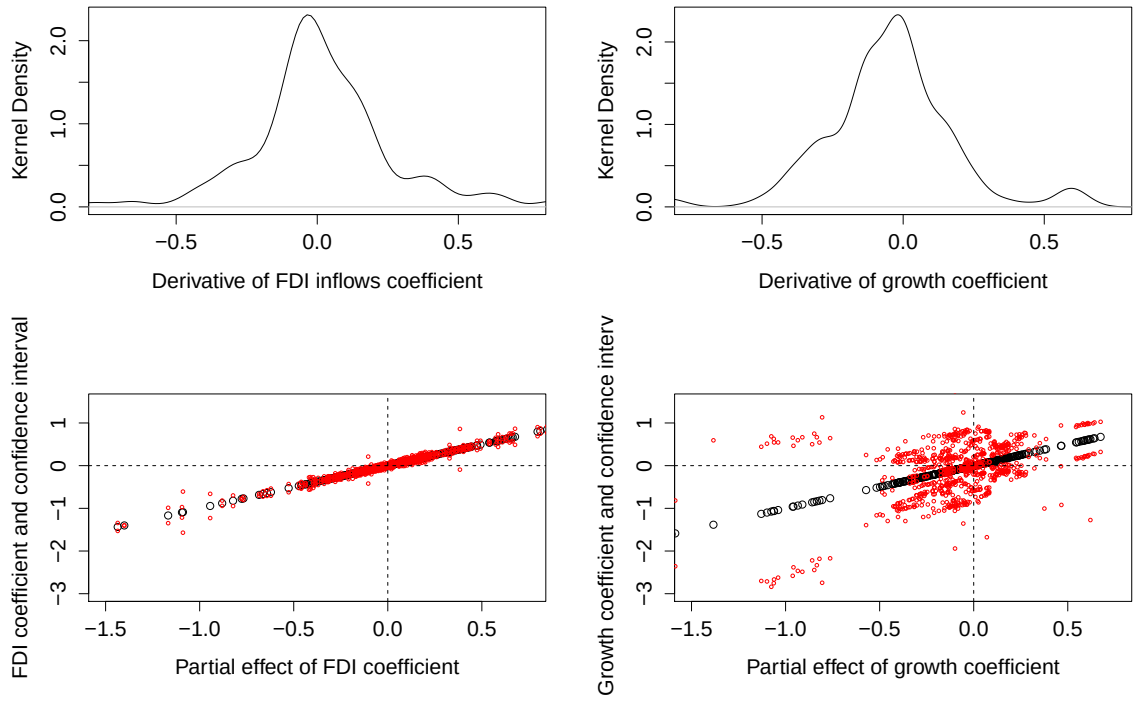

Figure 2: Kernel density plots and significance plots for the partial effect of FDI inflows and growth coefficient functions with respect to corruption for the model with instrumental variables.

Table 1: Summary of estimated coefficients from the system of simultaneous equations model of economic growth and FDI for the instrumental variables model.

Growth Equation				FDI Equation			
Variable	25th	50th	75th	Variable	25th	50th	75th
Intercept	**-0.0362**	**0.0086**	**0.0779**	Intercept	**-0.0452**	0.0193	0.1324
	0.0009	0.0021	0.0183		0.0181	0.0232	0.0919
FDI inflows	0.0087	**0.2081**	**0.5618**	Growth	**0.0167**	**0.2114**	**0.5751**
	0.0210	0.0314	0.0067		0.0020	0.0733	0.2485
Initial income	**-0.0071**	**-0.0011**	**0.0034**	Foreign Exchange	**-0.0003**	-0.0001	**0.0006**
	0.0002	0.0001	0.0000		0.0001	0.0001	0.0003
Population growth	**-0.5209**	**-0.1068**	**0.0407**	Log GDP	**-0.0053**	-0.0005	**0.0018**
	0.0100	0.0020	0.0014		0.0025	0.0013	0.0004
Investment	**-0.0313**	**0.0936**	**0.2054**	Schooling	-0.0146	0.0107	0.0380
	0.0066	0.0049	0.0038		0.0185	0.0113	0.0270
Openness	**-0.0279**	**-0.0028**	**0.0162**	Openness	**0.0167**	**0.0313**	**0.0494**
	0.0007	0.0003	0.0005		0.0044	0.0100	0.0170
Inflation	**-0.0956**	**-0.0205**	**0.0675**	Inflation	**-0.0221**	**-0.0052**	0.0172
	0.0002	0.0025	0.0069		0.0045	0.0017	0.0115
Government consumption	**-0.1316**	-0.0063	**0.0758**				
	0.0022	0.0043	0.0095				
Sample size		463		Sample size		463	
In-sample R^2		0.9999		In-sample R^2		0.9322	
Out-sample R^2		0.1681		Out-sample R^2		0.2084	
Out-sample $ASPE$		0.0012		Out-sample $ASPE$		0.0059	

1. 25th, 50th, 75th refer to percentiles.
2. Estimate-specific bootstrapped standard errors are reported below each estimate. Coefficients in bold are significant at the 5% nominal significance level.
3. R^2 is calculated as the square of the correlation between $(y, \widehat{y})$.
4. $ASPE$ is the average of the squared difference between $(y, \widehat{y})$.
5. Out-of-sample prediction measures are the mean of 1000 out-of-sample replication exercises (see text for details).

Table 2: Summary of estimated partial effects of corruption on the coefficients from the system of simultaneous equations model of economic growth and FDI for the instrumental variables model.

Growth Equation				FDI Equation			
Variable	25th	50th	75th	Variable	25th	50th	75th
Intercept	**-0.0452**	-0.0010	**0.0660**	Intercept	-0.0388	0.0164	**0.0639**
	0.0020	0.0066	0.0023		0.0500	0.0238	0.0171
FDI inflows	**-0.1371**	0.0000	**0.1523**	Growth	-0.2242	0.0112	**0.1345**
	0.0073	0.0000	0.0151		0.2096	0.1681	0.0155
Initial income	**-0.0058**	0.0002	**0.0061**	Foreign Exchange	0.0000	**0.0002**	**0.0007**
	0.0003	0.0011	0.0003		0.0001	0.0001	0.0003
Population growth	**-0.0477**	**0.0207**	**0.1511**	Log GDP	-0.0024	-0.0005	0.0021
	0.0025	0.0043	0.0010		0.0021	0.0012	0.0013
Investment	**-0.1981**	**-0.0614**	**0.0477**	Schooling	**-0.0126**	0.0090	0.0239
	0.0166	0.0065	0.0061		0.0013	0.0143	0.0261
Openness	**-0.0272**	**-0.0009**	**0.0259**	Openness	-0.0086	**0.0138**	**0.0274**
	0.0009	0.0003	0.0008		0.0044	0.0037	0.0050
Inflation	**-0.0662**	**0.0230**	**0.0844**	Inflation	-0.0077	-0.0006	**0.0161**
	0.0146	0.0011	0.0078		0.0052	0.0006	0.0014
Government consumption	**-0.1029**	**0.0095**	**0.1087**				
	0.0019	0.0020	0.0124				

1. 25th, 50th, 75th refer to percentiles.
2. Estimate-specific bootstrapped standard errors are reported below each estimate.