Techniques for dealing with reverse causality between institutions and economic performance

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This working paper is part of the research programme on 'Institutions, Governance and Long-term Economic Growth', a partnership between the French Development Agency (AFD) and the Maastricht Graduate School of Governance (Maastricht University – UNU-Merit). The research builds on the Institutional Profiles Database IPD, jointly developed by AFD and the French Ministry of the Economy since 2001.

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AFD-MGSoG/UNU-Merit Working Paper Series on
« Institutions, Governance and Long term Growth »

In 2010, the French Development Agency (AFD) initiated a partnership with the Maastricht Graduate School of Governance (Maastricht University - UNU-Merit) with a view to exploring the conceptual and econometric relationships between institutions and long-term growth. As a development bank with a long-term lending horizon, AFD is particularly interested in better understanding the determinants of countries' long term economic, social, and political trajectory.

AFD has thus developed a programme on "Institutions, Governance, and Long-term Growth" dealing with the five following dimensions:

(i) Measuring institutions and discussing the meaning of such measures, notably through the Institutional Profiles Database;
(ii) Testing the econometric relationship between institutional measures and long term growth;
(iii) Exploring through a series of country case studies the historical relationship between processes of economic accumulation, forms of political organisation, and social cohesion;
(iv) Discussing conceptual frameworks for making sense of the interaction between political, social and economic forces in the process of development;
(v) Developing methodologies for political economy analyses.

The MGSoG/UNU-Merit team is involved in the five dimensions with a particular focus on the first two. Its primary objective is to explore the Institutional Profiles Database jointly developed by AFD and the French Ministry of the Economy since 2001. Institutional Profiles Database is unique by its scope (about 350 elementary questions pertaining to all institutional dimensions covering 148 countries in 2012), its entirely free access, and its ambition to incorporate the most recent theoretical advances in the field of political economy.

The present series intends to convey the results of our ongoing research, and in so doing to reflect the wealth of issues that can be fruitfully addressed from an "institutionalist" perspective. We hope that readers will find these papers stimulating and useful to develop their own understanding and research.

Nicolas Meisel (AFD)
Adam Szirmai (MGSoG/UNU-Merit)

For more information on the programme, please visit our websites:
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Techniques for Dealing with Reverse Causality between Institutions and Economic Performance

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Abstract

This article provides a succinct review of the arguments stressing the mutual relationship between institutions and economic performance, and a scholarly account of some of the most popular econometric strategies used to minimize reversed causality problems in impact estimation. Among the techniques revisited we find the instrumental variables (IV) approach, distributed lags and vector autoregressions (VAR), quasi-experiments, and identification by heteroskedasticity (IH). Ultimately, the review is conceived as a methodological aide to researchers seeking to explore causal relationships through the use of the Institutional Profiles Database (IPD) produced by the Agence Française de Développement (AFD).

1 Introduction

The way interactions occur between the economic and the institutional domains in societies has been the subject of extensive research and debate[1]. The quest for finding causation mechanisms that link one to the other has propelled a burgeoning literature of theoretical and empirical nature, which often acknowledged the difficulties in assigning causes and effects. Yet, the importance that policymakers

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[1]For an overview of the debates see Aron (2000), Jütting (2003), Shirley (2005), deHaan (2007), Kohn (2009).

and scholars have granted to isolating the impacts of political decisions and institutional incentives, as well as to finding precise determinants of high economic performance, turned into a priority the development of methodological techniques designed to overcome endogeneity problems arising from different sources. These techniques have become more refined as the debate on institutions and economic performance evolved, and as data availability increased significantly.

The aim of the present work is to provide a succinct review of the debate on the mutually-determined relationship between institutions and economic performance, and to provide a scholarly account of some of the most frequently used strategies to measure the impact of institutions on GDP levels or GDP growth[2], while minimizing endogeneity problems. Ultimately, the review is conceived as a methodological aide to researchers making use of the Institutional Profiles Database (IPD) produced by the Agence Française de Développement (AFD).

The following section will present a brief overview of the main theoretical arguments put forward in the literature to try and understand channels of causality linking institutions and economic performance. The case is made that causality is likely to run both ways, so that institutions and growth are both part of a simultaneous system of mutual determination. Acknowledging this possibility has severe consequences for statistical inference on the interrelationships. Section 3 introduces some of the main techniques used to account for such endogeneity: (a) the instrumental variables approach (IV), (b) the use of lagged variables, (c) quasi-experimental designs, and (d) vector autoregressions (VARs). Some key articles resorting to these different methods are outlined. The dominant method in the literature is, easily, instrumental variables. Section 4 takes "the proof of the pudding" by testing the usefulness of a number of the available instrumental variables for institutions in the context of the Institutional Profiles Database (IPD). The fifth and final section concludes.

[2]Within the concept of economic performance, it is importante to draw attention towards the distinction between output levels and output growth. Although the academic debates are mostly framed around the relationship between institutions and growth, in reality different authors refer to different independent variables (regarding this, see the complementary paper by Meisel and Ould Aoudia (2008) "Is Good Governance a Good Development Strategy?"). In order to cover both options, we choose the more encompassing concept of 'economic performance', even at the risk of it being too encompassing.

2 Channels of causality between institutions and economic performance

The early nineties marked the start of a renewed era for institutions in all corners of the developing world. The transition from soviet regimes to market economies fostered a fervent interest in knowing which liberal institutions were the most suitable for boosting the economic performance of the new partners coming into the globalized economy. In Latin America, the initial excitement for the Washington consensus policies was buffered by the realization that these policies would only be successful where good institutions pre-existed. In Africa, it became more and more clear that traditional growth models relying on capital, labour and technology endowments failed to predict the continent's long and persisting frail performance.

Against this rather deceptive backdrop, scholars brought institutions back to light in different forms: as civil liberties and political rights, as different forms of governance, as property rights, as trade and fiscal policy, as political instability proxied by *coups d'état*, regime duration, social revolts and violence (Aron 2000). By and large, a general consensus about the definition of institution was never achieved, but empirical literature has tended to resort to two main types of proxies: rule of law, mostly in terms of property rights, and democracy levels. The reason is twofold: influential theories have linked these two concepts with economic performance since early on, and -not coincidentally- data availability has slanted research in the same direction. As a consequence, a plethora of works have put the spotlight on the relationship between institutions and economic performance[3]. A few studies have shown skepticism and vowed for a cautious interpretation of this relationship, claiming that findings prove the relationship insignificant or difficult to substantiate empirically (Glaeser et al. 2004; Rodrik 2008). In particular, several works raise doubts about a positive association between democratic regimes and growth (Sirowy and Inkeles 1990; Przeworski and Limongi 1993, Helliwell 1994 and Alesina et al. 1996; Brunetti 1997 and Minier 1998). Moreover, several authors have even claimed the relationship between these two is negative (Levine and Renelt 1992; Tavares and Wacziarg 2001; Dollar and Kraay 2003).

However, mainstream academic works show a positive relationship between some measure of institutional quality and growth (e. g. Knack and Keefer 1995; Borner et al. 1995; Sala-i-Martin 1997; Barro 1998; Rodrik 2000; Acemoglu et al. 2001;

[3]An insightful literature review on the topic is found in Bluhm and Szirmai (2011). For a deeper exploration of the relationship between good governance and development, see Meisel and Ould Aoudia (2008). For a discussion on the proximate and ultimate causes of growth see Szirmai (2011).

Kaufmann and Kraay 2002; Rodrik et al. 2004; Persson and Tabellini 2005).[4]

Regarding the causal mechanisms that lie underneath this relationship, however, scholarship continues to turn to classic theories. In these theories it is possible to find equally appealing arguments for both parts of the simultaneous causation problem: arguments that explain why growth has been a historic prerequisite of institutional development, and inversely, why institutional maturity has been a prerequisite for growth and affluence.

One famous argument of why and how growth brings about institutional development was motivated in the late fifties by Seymour Lipset, an exponent of the modernization theory: increasing wealth results in changes in political culture, and this, in turn, in political systems. In that sense, wealth is a facilitating condition for democracy, and at the same time higher economic development means higher chances for democracies to become self-legitimizing in the long run. Lipset argued that several modernization variables existed: wealth, industrialization, urbanization and education. At the same time, the effect of these modernization factors worked through additional intervening variables, such as democratic culture, class structure changes and state-society relationships. The conditions that propelled democratic demands and institutional change were deemed to be the *social requisites for democracy*. Democracy would only survive for longer periods when it proved well performing, legitimate and economically efficient (Lipset 1959). Another argument behind the idea that growth brings more and better institutions suggests that as countries become wealthier, they can afford to dedicate more resources to institution building (Butkiewicz and Yanikkaya 2006).

Others, however, have proposed a somewhat different view on the directionality of the growth-institutions relationship. The idea that institutions are mainly responsible for first setting the conditions for prosperity was the start of a fertile stream of literature, later known as new institutionalism. Taking a historical economy approach, North and Thomas (1973) resort to the notion of institutions as legal constraints to government expropriation, and place the focus on the importance that property rights have in fostering economic development. This view is linked to the transaction costs economics approach previously made famous by Robert Coase (1937), according to which it is believed that uncertainty about property rights and contracts increases the transaction costs that need to be internalized by investors. Therefore, institutions understood as constraints reduce the uncertainty present in economic exchanges, and provide the incentives that structure behaviour in societies, which in turn determines the economic path followed by a

[4]For comprehensive reviews on the empirical findings and debates, see Sirowy and Inkeles 1990; Alesina and Perotti 1994, Brunetti 1997; Minier 1998; Aron 2000; Jütting et al. 2003; Ménard and Shirley 2008.

country (North 1990).

Although these exponents take slightly different angles on the directionality, they both conceive an interdependent relationship. Lipset recognizes democratic attitudes as an explanation of economic modernization, and North acknowledges that institutions change incrementally according to different factors, including relative costs and prices in the economy. A rather well-established consent arising from this complexity is that the two factors are mutually reinforcing, in a cycle where expectations of better institutions propel economic growth, and contexts of affluence provide the most suitable setting for the sustainability of high-quality institutions in the long run (Przeworski et al. 2000; Persson and Tabellini 2006).[5]

In sum, as Rodrik, Subramanian and Trebbi (2004) formulate it: *"problems of endogeneity and reverse causality plague any empirical researcher trying to make sense of the relationships among these causal factors."* (p. 133) If reverse causality problems are not dealt with, the result is the incapability of knowing how the interactions between development and institutional advancements take place, and how interventions should be managed. In the following section, we provide a technical overview of different techniques to minimize biases, and how they have been applied.

3 Methods for dealing with simultaneity

On a broad definition, a regressor is endogenous when it is correlated to the error term. This correlation can have different sources: omitted variable bias, measurement error, sample selection bias, misspecification of the functional form, serial correlation combined with lagged dependent variables, and/or simultaneity. The focus of this article is on the problem of simultaneity, a situation in which two variables are co-determined, like the variables x_i and y_i in the following system:

$$y_i = \beta x_i + u_i \tag{1}$$
$$x_i = \gamma y_i + v_i \tag{2}$$

where the subscript i indexes the observations; u_i and v_i are unobserved disturbance or error terms; and β and γ are parameter measuring the respective causal effects.

[5]This general consensus is not undisputed, however, as authors like Kaufmann and Kraay argue that evidence shows a strong positive relationship going from better governance to higher per capita income, and a negative relationship running from per capita income to governance (Kaufmann and Kraay 2002).

As a consequence of this co-determination, none of the equations can be estimated consistently by standard OLS techniques.

The first empirical studies assessing the relationship between institutions and economic performance did not pay much attention to the problem of simultaneity, and suggested only statistically significant associations between institutions and growth on the basis of cross-sectional data (see Aron 2000 for a rather comprehensive review of these early works). Later on, as more data became available and more sophisticated methods became feasible, simultaneity problems were taken more seriously, and specific techniques started to be applied in the field to alleviate these problems.

3.1 Instrumental variables

The instrumental variables approach (IV) is without doubt the most widely used technique to deal with simultaneity problems in econometric specifications. For illustration, let us consider a linear model in its simplest static form:

$$y_i = \beta x_i + u_i \tag{3}$$

where the subscript i is an index for observations; y_i is the dependent variable and x_i is an explanatory variable; u_i is an unobserved disturbance or error term comprising all other determinants of y_i; and β is a parameter measuring the causal effect of x_i on y_i. For the sake of simplicity, all variables are expressed in deviations from their population means. If it holds that $E(x_i u_i) = 0$ then the standard OLS estimator is consistent. However, when $E(x_i u_i) \neq 0$ due to simultaneity (or for any other reason), the OLS estimator of the impact of x_i on y_i is biased and inconsistent because even in large samples it converges to the wrong probability limit:

$$p\lim \hat{\beta}_{OLS} = \frac{E(x_i y_i)}{E(x_i^2)} = \beta + \frac{E(x_i u_i)}{E(x_i^2)} \neq \beta\,.$$

A valid instrumental variable z_i is one that meets two conditions, called relevance and exogeneity.

1. Relevance: z_i is substantially correlated with the causal variable of interest x_i, so that
$$E(z_i x_i) \neq 0$$

2. Exogeneity: z_i is uncorrelated with the unexplained part of y_i, so that
$$E(z_i u_i) = 0\,.$$

The IV model, therefore, implies that the instrument is correlated with the dependent variable, but exclusively through the endogenous explanatory variable. The rationale for these conditions is that they guarantee that the probability limit of the IV estimator (to which it converges in large samples) is

$$p\lim \hat{\beta}_{IV} = \frac{E\left(z_i y_i\right)}{E(z_i x_i)} = \beta + \frac{E(z_i u_i)}{E(z_i x_i)}$$

which equals β if and only if both these conditions hold. In these expressions, the instrumental variable z_i (like y_i and x_i) is expressed in deviations from its mean.

A well-known way to obtain and understand the IV estimator is via two-stage least squares (2SLS). The first stage consists of regressing the endogenous explanatory variable (x_i) on the instrument (z_i), as well as any other exogenous covariates appearing in the model. One then obtains the predictions (in our illustration)

$$\hat{x_i} = z_i \hat{\pi} \tag{4}$$

where $\hat{\pi}$ is the resulting OLS estimate (often called a reduced-form coefficient). These predicted values $\hat{x_i}$ can be interpreted as a version of the explanatory variable x_i from which the endogenous variation (the dependence on u_i) has been "cleaned out", as only the exogenous variation (explained by z_i) has been kept in. The second stage consists of regressing the dependent variable y_i on the predicted series $\hat{x_i}$ from the first stage regression. That is, one estimates

$$y_i = \hat{x_i}\beta + \left(x_i - \hat{x_i}\right)\beta + u_i = \hat{x_i}\beta + w_i\,.$$

Given the validity of the instrumental variable z_i, the composite disturbance $w_i = \left(x_i - \hat{x_i}\right)\beta + u_i$ that we find in this second-stage regression is uncorrelated with the instrumental regressor $\hat{x_i}$. Therefore, OLS will estimate β consistently or "free of simultaneity bias".

With divergences in terms of techniques, samples and conceptualizations, numerous empirical studies have attempted to identify exogenous sources of variation providing instrumental variables for institutional quality. In the remainder of this subsection, we will review a selection of those empirical studies that have provoked discussion or achieved some prominence in the literature.

In their 2001 article published in the *American Economic Review*, Acemoglu, Johnson and Robinson (henceforth AJR) present the novel idea of using European settler mortality rates during three centuries as an instrument for institutions. The argument behind this, is that different types of colonization led to different institutions, depending on the incentives Europeans had to reside permanently on the

colonies. In the colonies where settler mortality expectations were high, settlers set up extractive states, without great protection of property rights or guarantees against government expropriation. On the contrary, where settler mortality levels were lower, they had incentives to reside in the colonies, and fostered institutions that envisioned limits to the executive powers and their expropriation potential.

Within this framework, the authors argue that European mortality levels can be used to instrument institutions and, subsequently, find out the partial effect of the latter on economic growth levels. In order to comply with the exclusion restriction (the assumption that the regression error has zero conditional mean, conditionally on the instrument), they put forward the argument that settlers' mortality rates more than 100 years ago are unlikely to have an impact on today's economic performance, other than through institutions. Parallel to this, they address the threat to the exclusion restriction posed by factors that are potentially correlated with settler mortality and also determine income levels, such as identity of the main colonizer, legal origin, climate, religion, geography, natural resources, soil quality and ethnolinguistic fragmentation, as well as controls for current disease levels. They find that none of the estimates changes substantially once controlling for these covariates.

The impact of the work by AJR has been huge, yet some weaknesses have also been pointed out. First, their narrow definition of "institutions": this refers to guarantees against expropriation risk and is proxied by the expropriation risk index of the Political Risk Services. Secondly, settler mortality information is available for only a small set of countries (the 64 countries that were ex-colonies), and even so it is constructed from very partial sources concerning those countries (see Albouy 2008).[6] Thirdly, Khan (2012 forthcoming) advances a profound critique of AJR's interpretation of history, by questioning the alleged stability brought by white settlers.

Tracing further back the use of instrumental variables, AJR refer to two previous widely cited works: Mauro (1995) and Hall and Jones (1999). In order to asses the effects of bureaucratic corruption, Mauro (1995) instruments corruption using an index of ethnolinguistic fragmentation. His research makes use of the Business International (BI) database[7], comprising information on BI correspondents' perceived measures of corruption, red tape, and the efficiency of the judicial system for the years 1980 until 1983, for a total of 70 countries. The index of ethnolinguistic fragmentation he uses as an instrument measures the probability that

[6]For a follow-up on the latest works by Acemoglu and others on the same topic and a detailed critique of their work, see the complementary paper by Bluhm and Szirmai (2011).

[7]Which is part of the Economist Intelligence Unit.

two individuals drawn randomly in a country belong to different ethnolinguistic groups.[8] Ethnolinguistic fragmentation is assumed "exogenous" to both economic performance and institutional quality. As additional instruments, Mauro (1995) also constructs dummies of whether the country was ever a colony, and whether the country was still a colony in 1945. The results show that institutional inefficiency proxied by bureaucratic corruption is strongly associated with lower levels of private investment, also after controlling for other determinants of investment.

Hall and Jones (1999) choose distance from the equator as an instrument for social infrastructure, based on the argument that latitude is correlated with Western influence, and this influence, in turn, affects institutions. They also use the share of the population speaking English and the share speaking a major European language as instruments for institutional quality. Acemoglu et al. (2004) argue that in the work of both Mauro (1995) and Hall and Jones (1999), the instruments may easily have a direct influence on growth and therefore fail the exogeneity condition.

Another largely cited instrument is that of Frankel and Romer (1999), who calculate the fitted values of trade predicted by a gravity model, in order to instrument for actual trade/GDP ratios. Their gravity equation accounts for bilateral trade as a function of country mass, distance between partners, and a few geographical measures. The resulting aggregate index of trade is used to instrument actual trade, as a determinant of income levels.

Rodrik, Subramanian and Trebbi (2004) estimate the independent effect of institutions, geography and trade on income levels. By resorting to the IV approach, they aim to identify the impact of the two endogenous variables (institutional quality and international trade levels), while also measuring the impact of geography on incomes, both directly and through each of the other two as intermediary channels. For this purpose they choose to simultaneously include geography, integration (levels of international trade) and institutions among the determinants of income levels. They resort to the Frankel and Romer (1999) instrument for integration, and the Acemoglu et al. (2001) instrument for institutions. Their results show a significant impact of institutions, which "trump" both trade and geography, once they are controlled for. They test the robustness of their results against different sample sizes, extending the original sample of 64 countries used by Acemoglu et al. (2001). In order to enlarge the sample, they must replace the Acemoglu et al. (2001) settler mortality instrument with the more accessible instruments of Hall and Jones (1999): fraction of English and Western-European languages speakers within a country.

[8] This index refers to 1960 and was calculated by Taylor and Hudson (1972).

Glaeser et al. (2004) pay close attention to the definition of institutions used in the growth and institutions literature. They explore it in different forms: risk of expropriation, government effectiveness and constraints to the executive. They argue that the first two result in outcomes that do not distinguish between constraints and choices (e.g. they do not distinguish between a dictator choosing property rights, and a democratic leader which has no other choice than supporting property rights). In the third case, they contend that these constraints on the government reflect only the outcome of the most recent elections, which are for the most part volatile in developing countries, instead of durable rules (as institutions should be). Regarding the instrumental variables model of Acemoglu et al. (2001), they argue that rather than institutions, settlers brought human capital to the colonies, and that the latter is the better predictor for growth. Furthermore, because settlement patterns may affect growth through other channels than institutions, they do not consider them as valid instruments for institutions (Glaeser et al. 2004, p.21).

Eicher and Leukert (2009) seek to examine parameter heterogeneity in the relationship between institutions and per capita incomes, by contrasting institutional impacts on a subset of developed economies versus a subset of developing ones. They depart from the work by Hall and Jones (1999) using instrumental variables, arguing that the instruments these authors use are no longer valid when accounting for parameter heterogeneity. In order to account for this heterogeneity, Eicher and Leukert split the sample into OECD and non-OECD countries. They construct new instruments on the conceptual basis of the hierarchy of institutions hypothesis (Acemoglu et al. 2005b; Persson 2004; Eicher and Schreiber 2010), which contends that a sequential three-link causal chain exists between constitutional/political institutions, economic institutions, and economic outputs. Given this sequentiality, the authors argue that constitutional and political institutions can be a valid instrument for economic institutions, and these, in turn, have a direct impact on growth. Their results suggest that the effect of institutions varies across the two subsets, having three times larger impact in developing countries.

3.2 Dynamics

3.2.1 Distributed lags and state dependence

The aim of models with lagged variables is to allow for causal effects that are lingering over some period of time rather than instantaneous.[9] Some of these

[9]It may be pointed out here that dynamic models may help to identify causal chains (or at least minimize reverse causation) through time sequencing; we will return to this possibility in

models resort to distributed lag regressions, in which Y_t is expressed as a function of current and past values of X_t. The set of past values of interest are included among the explanatory variables in the specification, in order to avoid the omitted variable bias that would be caused by delayed effects. For example, the relationship might be expressed as

$$Y_t = \beta_0 + \beta_1 x_t + \beta_2 x_{t-1} + \beta_3 x_{t-2} + u_t. \tag{5}$$

Other dynamic specifications address state dependence (y_t being determined by y_{t-1}) by including lagged values of the dependent variable:

$$y_t = \gamma y_{t-1} + \beta x_t + \epsilon_t \tag{6}$$

or, in a panel context relevant for our purposes,

$$y_{it} = \gamma y_{i,t-1} + \beta x_{it} + \alpha_i + \epsilon_{it}. \tag{7}$$

Dollar and Kraay (2003), while using the instrumental variables approach, estimate causal effects at different points in time. They seek to assess the partial effect of both institutions and trade on growth, by regressing ten-year ("decadal") growth rates on instrumented changes in trade and instrumented changes in institutional quality. They argue that a close interaction exists between trade and institutions, and as a consequence, existing literature tends to fail when trying to apply an identification strategy to isolate the partial effects of each in the long run. They argue that previous specifications are weakly identified, as both sets of instruments have a strong explanatory power for both endogenous variables. The result is high multicollinearity in the second-stage regressions.

In order to overcome the multicollinearity problem associated with static estimates, Dollar and Kraay (2003) propose to exploit time variation in the data through a dynamic analysis. In a model in first differences, decadal changes in real per capita GDP growth are regressed on their lagged values and on contemporaneous changes in trade and in institutional quality, instrumented by their respective lags. Formally, their estimating equation is of the type

$$y_{ct} - y_{c,t-k} = \beta_1 (y_{c,t-k} - y_{c,t-2k}) + \beta_2' (X_{ct} - X_{c,t-k}) + (\gamma_t - \gamma_{t-k}) + (v_{ct} - v_{c,t-k}) \tag{8}$$

where y_{ct} is the log of GDP per capita in country c at time t; $y_{c,t-k}$ is its lag k years ago; and X_{ct} is a set of regressor variables (possibly measured as decadal averages) including trade volumes and institutional quality measures.

Subsection 3.2.3.

Dollar and Kraay's measure of institutional quality is based on a composite indicator of rule of law constructed by Kaufmann et al. (2002), measuring the period 2000-2001. They argue that their first-difference model has several advantages in terms of measurement error, omitted variables and endogeneity. Regarding the first, it corrects for some biases that arise from measuring cross-sectional levels of the variables instead of differences. It avoids omitted variable bias by controlling for constant (or almost constant) factors such as colonial history or geographic characteristics. In terms of endogeneity, Dollar and Kraay argue that the set of instruments is more natural than the alternatives previously proposed. The underlying assumption of the model is that, whereas trade volumes and institutional quality measures may be correlated with current and lagged shocks to GDP growth, they are uncorrelated with future shocks to GDP growth. Their results suggest that the long-term partial effects of both trade and institutions on growth are substantial, but the role of trade is more important in the short run.

Butkiewicz and Yanikkaya (2006) focus on the role of democracy and the rule of law in promoting growth. They challenge the conventional notion that while rule of law exerts a significant influence on growth, democracy is innocuous to it. Since measures of democracy and rule of law tend to be highly correlated, yet are important to distinguish, they make an effort to isolate the impact of each. Based on a comprehensive sample and a three-stage least squares (3SLS) technique, the authors conclude that both variables exert a significant effect on growth, and moreover that the impact of democracy is higher in developing countries.

It is worthwhile to mention some details of the approach of Butkiewicz and Yanikkaya (2006). The overall sample comprises a hundred countries, from 1970 to 1999. Five different measures of democracy are included, as well as five measures of rule of law. As dependent variables, the authors use the average annual growth rates of real per capita GDP during three decades: the 70s, the 80s, and the 90s. The model they estimate is of the type

$$\gamma_{yt} = F(y_t, k_t, h_t; Z_t) \tag{9}$$

where γ_{yt} is a country's average per capita growth rate in period t, y_t is the country's initial GDP per capita, k_t is the initial stock of physical capital per person, h_t is initial human capital per person, and Z_t is a vector of control and environmental variables, including various measures of democracy and rule of law. The authors first estimate the effects of rule of law and of democracy in two separate specifications, using the seemingly unrelated regression (SUR) technique, as in Barro (1997). Here, up to three different equations are estimated (one for each decade[10]), allowing for correlation of the error term across equations, a condition

[10]Only two for the specification including rule of law.

that arises from including initial GDP levels in each decade. According to these estimates, three out of five of the rule of law measures have an impact on GDP per capita growth, while none of the democracy measures exert a similar impact. Later on, the authors propose an alternative technique, also used by Barro (1997), involving 3SLS estimation and instrumenting rule of law and democracy. As an instrument for rule of law they resort to the index of ethnic fragmentation previously used by Mauro (1995); and for democracy to secondary school enrollment rates. The authors' findings demonstrate that once controlling for endogeneity through instrumental variables, it is possible to find large and significant effects of both democracy and rule of law measures on growth.

3.2.2 Vector autoregression (VAR)

Vector autoregressive (VAR) models seek to capture the interrelations of a set of endogenous variables over a certain period of time, by describing each variable as a linear function of its lagged values. A VAR of order 1 (with one lagged value), for example, can be specified as the two-equation system:

$$y_t = c_1 + \beta_1 y_{t-1} + \beta_2 x_{t-1} + \epsilon_t \tag{10}$$

$$x_t = c_2 + \gamma_1 y_{t-1} + \gamma_2 x_{t-1} + u_t \tag{11}$$

The work by Hsiao and Shen (2003) is concerned with the way foreign direct investment (FDI) contributes to the growth prospects of developing countries. Within this framework, the authors seek to unravel two sequential relationships: on one hand, which intangible factors (such as bureaucracy, degree of openness, institutional stability and urbanization) affect FDI levels, and on the other, how strong are the feedback relations between FDI and real gross domestic product (GDP). For the latter purpose, they use two data sources: time-series data for China 1982-1998, and panel data on 23 developing countries between 1976 and 1997. As simultaneity is likely between FDI and GDP, they lay out a simultaneous equations model with the recursive form:

$$y_{1,t} = c_1 + a_1(L)y_{1,t-1} + a_2(L)y_{2,t} + u_{1,t} \tag{12}$$

$$y_{2,t} = c_2 + b_1(L)y_{1,t-1} + b_2(L)y_{2,t-1} + u_{2,t} \tag{13}$$

where $y_{1,t}$ is the log of real GDP; $y_{2,t}$ is the log of FDI levels; c_1 and c_2 are constants; L is the lag operator; $a_i(L)$ and $b_i(L)$ are lag polynomials (autoregressive operators) of the form $a_i(L) = a_{i1} + a_{i2}L + ... + a_{ip_i}L^{p_i}$ and $b_i(L) = b_{i1} + b_{i2}L + ... + b_{iq_i}L^{q_i}$; and $u_{1,t}$ and $u_{2,t}$ represent independent error terms. Therefore, the model assumes that FDI is a component of real GDP, and at the same time, that FDI levels are

determined by lagged GDP. As a way to determine the polynomial orders p_i and q_i, Hsiao and Shen resort to a methodology proposed by Hsiao (1979). The resulting equations for the Chinese time series data are:

$$log(GDP_t) = c_1 + a_{11}log(GDP_{t-1}) + a_{21}log(FDI_t) + u_{1,t} \quad (14)$$

$$log(FDI_t) = c_2 + b_{11}log(GDP_{t-1}) + b_{21}log(FDI_{t-1}) + b_{22}log(FDI_{t-2}) + u_{2,t} \quad (15)$$

where $log(GDP_t) = y_{1,t}$ and $log(FDI_t) = y_{2,t}$. Three-stage least squares estimation for the Chinese data yields the result that a 1 % increase in FDI raises GDP by barely 0.0005% in the short run; in the long run however, direct and indirect effects accumulate to raise GDP by 5.45%. On the other hand, an increase of 1% in GDP raises FDI by 2.12% in the short run, and 34.45% after 10 years.

The results of a similar assessment based on data from 23 developing countries between 1976 and 1997 show estimates that are consistent with the results from China [11]. In this sense, Hsiao and Shen are able to establish with some degree of precision the existence and extent of feedback relations between FDI and GDP.

3.2.3 Time sequencing

It may be worth emphasizing here that dynamic models may help to identify causal chains (or at least minimize reverse causation) through time sequencing. Suppose it takes some time for institutions to affect growth performance, and for growth performance to feed back into institutions; and that the implied time lags are not shorter than a period of observation. Although both causal relationships involve explanatory variables that are not strictly exogenous, these are predetermined rather than contemporaneously endogenous. It is then possible to specify the model as a recursive rather than a simultaneous system of relationships, in effect a VAR.[12] Standard estimation methods will not be affected by simultaneity biases; OLS will be consistent. The paper of Hsiao and Shen (2003) discussed above is a case in point. The main reason why this possibility is used so little in the context of the growth-institutions nexus is probably not that sufficient time lags are unlikely, but rather that data are too limited. Historical series on institutional aspects measured over time in a consistent way are rare and, where they exist, they may contain very little time variation, since institutions do not usually change fast in a peaceful context.

[11] Data on GDP for China and the 23 developing countries comes from the World Development Indicators, while FDI levels are from the International Monetary Fund, International Finance Statistics (IFS).

[12] This requires that structural shocks or disturbance terms are uncorrelated across equations.

3.3 Quasi-experimental designs

There is a growing trend among researchers on institutions to make use of techniques that emulate the conditions of randomized controlled experiments. Such experiments have three characteristics: a) experimental subjects are exposed to a "treatment" and later contrasted to a "control" group, where the treatment is absent; b) there is random assignment of the subjects to either treatment or control groups, which guarantees the absence of confounders explaining resulting differences between the groups; and c) the administration of the treatment is exclusively done by the researcher (Dunning 2008). These conditions have the advantage of allowing for inference regarding causal relations on the variables of interest.

In quasi-experimental designs, the level of exogeneity of the treatment variable is sometimes at stake. The treatment is usually the consequence of an event of some kind, for which randomness is often more difficult to argue for. Yet, this randomness remains the underlying assumption of these models.

3.3.1 Difference-in-differences models

The difference-in-differences technique can be applied when there is information available on the same observations before and after the experiment. The estimation of the impact of an intervention (treatment) on a certain population, is done by comparing pre and post treatment values of the variable of interest in both treated and non treated groups. As mentioned earlier, one condition is that the treatment variable is randomly assigned within the population of interest, and thus, can be claimed to be an exogenous source of variation. The estimation principle can be formalized as follows:

$$\hat{\beta}_{did} = (\bar{Y}_{ta} - \bar{Y}_{tb}) - (\bar{Y}_{ca} - \bar{Y}_{cb}) = \triangle \bar{Y}_{treatment} - \triangle \bar{Y}_{control} \tag{16}$$

where $\hat{\beta}_{did}$ is the difference-in-differences estimator; Y is the variable of interest; $\bar{Y}_{ta}$ is the treatment group average of Y after the treatment and $\bar{Y}_{tb}$ is the treatment group average of Y before the treatment; $\bar{Y}_{ca}$ is the average of Y in the control group after the treatment and $\bar{Y}_{cb}$ is the average value of Y in the control group before the treatment.

Papaioannou and Siourounis (2008) resort to a difference-in-difference design to assess the effect of democratization on short and long term growth. They point out that in contrast to cross country analyses, the relationship becomes significant when using time-series information. For this design to work, there needs to be strict exogeneity of the reform variable (change of regime) by random assignment. In this respect, they cite the work by Acemoglu et al. 2005a showing

that the correlation between income and democracy almost vanishes when using differences instead of levels. This finding would make reversed causation a lesser concern. Within the control group, Papaioannou and Siourounis include countries where regime change is absent, representing three different categories: democratic, autocratic and intermediate governments. In order to overcome the assumption that democratization is conditionally uncorrelated with other time-varying factors, they add the proper controls for these factors. Although they manage to minimize the concern of reversed causation, the authors acknowledge that it is difficult to establish causality.

3.3.2 Natural experiments

When arguing that economic institutions are the fundamental cause of differences in per capita income, Acemoglu et al. (2005b) resort to two quasi-experiments to document their findings: (1) the partition of Korea into North and South Korea after World War II, and (2) the colonization pattern followed by European settlers starting in the fifteenth century, already mentioned in section 3.1.

Acemoglu et al. (2005b) characterize the Korean case as *one of the clearest natural experiments for institutions*. The reason for this is that while Korea shared a unified history under Japanese domination prior to 1945, the Soviet occupation of North Korea after the end of the war was a purely exogenous shock that determined quasi-randomly the establishment a different set of institutions on each side.[13] While the North turned to Soviet socialism and abolished property rights, the South preserved property rights and successfully developed a market economy. In terms of both culture and geography, the authors argue that nearly all aspects were similar between the two countries at the moment of the division, or, if anything, benefited the North (Acemoglu et al. 2005b: 405). Drawing inferences from this natural experiment, the authors conclude that the dramatically different paths undertaken in terms of economic performance can be attributed to the different institutions established.

Eicher and Schreiber (2010) also resort to a natural experiment to measure the short term effects of structural policies on annual growth. They make use of time-series data on 26 East-European transition countries over a period of eleven years (1991-2001). The set-up and adequacy of the natural experiment is given by the authors' contention that the fall of the iron curtain provides an ideal source of exogenous institutional change, from communist to capitalist institutions. The proxies for structural policies are built through a composite structural policy index,

[13]The Republic of Korea was established to the South of the 38th parallel.

with measures of market-supporting institutions -such as price liberalization, trade openness, privatization, competition policy, etc.- taken from the European Bank for Reconstruction and Development (EBRD) transition reports. An additional proxy for structural policies is the ICRG Rule of Law measure. Proxies for political institutions are democracy measures from Polity IV. System GMM (Generalized Method of Moments) is used to estimate transformed relationships of the following type:

$$Y_{i,t} - Y_{i,t-1} = \beta \triangle I_{i,t} + \gamma Y_{i,t-1} + \triangle \nu_t + \triangle \epsilon_{i,t} \tag{17}$$

where $Y_{i,t}$ denotes per capita income growth in country i at time t; $I_{i,t}$ is a structural policy index; v_t is a time-fixed effect; and $\epsilon_{i,t}$ is white noise. In order to construct instruments with panel data, Eicher and Schreiber proceed in two different ways. Following the standard GMM approach, they include the third, fourth and fifth lags of the per capita income growth as instruments. As an alternative, they resort to the hierarchy of institutions theory in order to use a country's constitutional features as instruments for structural policies (see Section 3.1 above). As both strategies show similar results, the authors conclude that the short term contemporaneous effects of structural policies on growth are substantial: a ten percent increase in the quality of institutions raises annual growth rates by 2.7 per cent.

3.4 Identification through Heteroskedasticity (IH)

A final approach to be mentioned here is identification through heteroskedasticity, a method advocated recently by Rigobon (2003) and Rigobon and Rodrik (2005). Suppose a plausible argument can be made that the world consists of two (or more) groups of countries that differ in the degree of "tightness" of the institutions-growth relationships. The groups are known so the data can be split accordingly, and the tightness of the relationships will be measured by the respective variances of the structural disturbance terms. For instance, Rigobon and Rodrik (2005) split the world in countries that have been colonized by European powers and countries that have not. They argue that colonization had a homogenizing influence, reducing the variance of shocks to which countries have been subjected, yet leaving the impact of institutions on income or growth unaltered. Another split they propose relates more directly to geography, distinguishing between countries in continents extending on a North-South axis (Africa and the Americas) versus countries in continents extending on an East-West axis (Eurasia). Because the diffusion of agricultural technologies is easier on an East-West axis (mainly for climatic reasons), they expect the variance of income shocks to be larger in the North-South sample.

How do such splits help identification? The basic idea is (as in 2SLS methods) to start by estimating the reduced form rather than the structural form of the model. The reduced form is a system of equations from which endogenous regressors have been substituted out. Since it contains only exogenous (or, more generally, predetermined) regressors, the reduced form is easy to estimate without running into the problem of simultaneity bias. In general (as in standard simultaneous equations models), there are too few reduced-form coefficients to identify all the structural coefficients. However, a split in the sample that shifts the variances without affecting the structural coefficients generates additional information, in the form of identifying moment equations. From the reduced form, apart from the coefficients, not one but two (or more if the split is multiple) variance-covariance matrices can be estimated consistently (assuming the split is sufficiently balanced). Each reduced-form covariance provides an additional restriction or "moment equation" that can (in principle) be exploited in the recovery of structural parameters. The additional moment equations will only be useful provided the number of structural-form parameters is not increasing in parallel with the number of reduced-form parameters. This is achieved by a relatively standard identifying assumption, namely, that structural shocks or disturbance terms are uncorrelated across structural equations. So, on the one hand, splitting the world in two groups of countries doubles the number of structural as well as reduced-form error variances to be estimated. On the other hand, the split does not create any unknown structural covariances (correlations across equations), whereas it *doubles* the number of estimable reduced-form covariances. The increasing number of reduced-form moments helps identify the structural coefficients of interest, and easily tilts the balance from an underidentified to an overidentified structural form.

The exploitation of the moment equations to recover the structural parameters is not an ordinary linear regression problem. The state-of-the art way to deal with it as efficiently as possible is found in the same family as "minimum distance" estimators and the "Generalised Method of Moments" (GMM). An increasing number of econometric and statistical softwares, including Stata (from version 11), proposes advanced GMM procedures.

4 Testing instruments on IPD 2009

Section 3.1 has shown that the use of instrumental variables has been legitimized as a valid option to minimize simultaneity bias in the context of the growth and institutions literature. The present section is dedicated to testing the validity of the instruments reviewed in this article, and to estimate the impact of institutions

on growth making use of this tool. In order to do this, we resort to the measures of institutions that have been reported in de Crombrugghe and Farla (2009). These measures consist of two main principal components (PCs) that arise from an exploratory analysis of the 3-digit variables in IPD 2009. The first PC refers to the formalization of regulation and depersonalization, while PC2 refers to rule and degree of State intervention. Our dependent variable of interest is the mean rate of per capita growth over the period 2000 - 2007 taken from the Penn World Tables.

Table 1 presents the results of the estimations including a large set of instruments. The first type of instruments refers to settler mortality rates, where *mort*, expresses settler mortality rates as computed in Acemoglu et. al. (2001); *mort2* is Albouy's (2008) corrected settler mortality rates; *logmort0* is the log of settler mortality as computed in Acemoglu et. al. (2001); and *logmort2* is the log of settler mortality corrected by Albouy (2008). Second, it presents the measures proposed by Mauro (1995) to instrument corruption: *avelf*, the average of the five ethnolinguistic fragmentation indexes reported in La Porta, Lopez-de-Silanes, Schleifer and Vishny (1999), plus two additional dummies: *ex2col*, whether a country was ever a colony, and *ex2col45*, whether the country was still a colony in 1945[14]. A third set of instruments put to test is that of Hall and Jones (1999). They use distance from the Equator (*disteq*) to instrument institutions, as well as two other variables: *engfrac*, the share of the population speaking English and *eurfrac*, the share of the population speaking a major European language. Finally, Eicher and Leukert (2009) use constitutional and political institutions to instrument economic institutions. In order to avoid multicollinearity, their two baseline political institutions are *xconst1990*: constraints to the executive in 1990, and *xrreg1990*: executive recruitment regulation also in 1990, and taken from the Polity IV database.

The estimation of the impact of institutions on growth also includes a few covariates of relevance: the level of economic openness in 2007 (chain series 2005, from PWT 6.3); the log of GDP per capita in 1995 from Rodrik, Subramanian and Trebbi (2004); the investment share of real GDP per capita in 2007, from PWT 6.3; and the population in 2007 from Maddison databases 2010.

In each of the specifications we report the coefficients of both the first and the second stage IV regressions, as well as the F statistic of the Stock and Yogo (2005) strong instrument test (instrument validity) and the p value of the Hansen J test of overidentifying restrictions (instrument exogeneity).

Table 1 presents the results of the estimation including the AJR instruments.

[14]Given the countries included in the samples, *ex2col* had to be dropped due to perfect multicollinearity.

Table 1: *Impact of Institutions on Growth with IV technique (AJR instruments included)*

	pc1	*pc2*	*Per Capita Growth (log)*
Settler mortality rates (mort)	0.000 (0.000)	–0.001 (0.000)	–
Settler mortality rates corrected (mort2)	0.000 (0.000)	0.001 (0.000)	–
Log of settler mortality (logmort0)	–0.415 (0.441)	0.714 (0.599)	–
Log of settler mortality corrected (logmort2)	0.033 (0.235)	–0.07 (0.334)	–
Ethnolinguistic fragmentation (avelf)	1.06 (0.849)	0.807 (1.286)	–
Colony in 1945? (ex2col45)	1.32*** (0.484)	–1.394 (0.989)	–
Distance to the Equator (disteq)	0.027 (0.027)	0.005 (0.023)	–
Fraction of English speakers (engfrac)	2.353** (1.121)	0.647 (0.884)	–
Fraction of Eur language speakers (eurfrac)	3.137*** (1.778)	-0.975 (1.409)	–
Constraint to the executive in 1990 (xconst1990)	0.084 (0.1)	0.096 (0.14)	–
Executive recruitment regulation (xrreg1990)	0.004 (0.01)	–0.004 (0.012)	–
First PC (pc1)	–	–	0.001 (0.002)
Second PC (pc2)	–	–	–0.003 (0.008)
Economic Openness in 2007 (pw_openk2007)	–	–	–0.000 (0.000)
Log of GDP per capita 1995 (lcgdp95)	–	–	–0.006 (0.004)
Investment share (pw_ki2007)	–	–	0.0006** (0.0003)
Population in 2007 (mill)	–	–	0.021 (0.015)
N	50	50	50
R^2	0.80	0.58	0.23
F statistic	8.51	1.72	–
Stock Yogo F	–	–	1.893
Hansen p	–	–	0.35

Notes: significance levels reported as *** p<0.01; ** p<0.05; * p<0.1; two tailed. Intercept not reported, standard errors in parenthesis. Stock Yogo is the F statistic test for weak identification, with significance thresholds according to Stock and Watson (2002). Hansen p is the p-value of the Hansen J test of over-identifying restrictions of all but one instrument, the joint null being that the instruments are valid.

When this happens, the sample is left with a total of 55 countries. The first two columns report the results of the first-stage estimations of the impact of the instruments on the two principal components.

The dummy taken from Mauro (1995) measuring whether the country was a colony in 1945, as well as the two Hall and Jones (1999) language dummies are significant when explaining the variance in the first principal component. For the second principal component, however, none of the instruments are significant. The Stock Yogo F test is well below the critical values, and it is therefore not possible to reject the weak instruments hypothesis[15]. The last column reports the estimated coefficients of the two instrumented institutional measures, as well as the small set of covariates chosen to explain growth. It does not find significance in any of the the two principal components. Of all covariates, only the share of investment in 2007 results significant at the 5% level. The p-value of the Hansen J statistic passes the overidentification test, meaning that it cannot be rejected that the instruments are exogenous.

Table 2 presents a similar estimation, but excluding the instruments of AJR, in order to maximize the number of observations, which amounts to 88 in this regression. It is easy to observe that now all of the instruments except for regulation of executive recruitment are significant in explaining the variance of the first PC. For the second PC, the situation has changed only marginally from the previous estimation, as now ethnolinguistic fragmentation has become significant. When estimating the impact of institutions on growth, the situation remains is very similar to the previous table, where only investment share is significantly associated with growth. Regarding the instrument validity tests, it occurs once more that the Stock-Yogo test is failed, whereas the overidentification test is passed.

5 Conclusions

As Rodrik et al. (2004) rightly pointed out, endogeneity problems abound in the study of the interactions between institutions and growth. The literature on the subject has acknowledged the limitations and challenges inherent to the empirical analysis of data aiming at unveiling the precise impact of different institutions on growth. These challenges arise not only from potential biases in econometric

[15]In any case, this is expected to happen when several instruments are tested jointly. When each set of instruments is tested individually on each PC, we find that all sets (*logmort0 logmort2; avelf; ex2col ex2col45; disteq; engfrac eurfrac; xconst1990 xrreg1990*) but *mort* and *mort2* pass the test for PC1, and only *avelf* passes the test for PC2.

Table 2: *Impact of Institutions on Growth with IV technique (AJR instruments excluded)*

	pc1	*pc2*	*Per Capita Growth (log)*
Ethnolinguistic fragmentation (avelf)	1.64*** (0.55)	1.977** (0.869)	–
Colony in 1945? (ex2col45)	–1.55** (0.47)	–0.44 (0.571)	–
Distance to the Equator (disteq)	0.048*** (0.015)	0.015 (0.015)	–
Fraction of English speakers (engfrac)	1.064** (0.52)	–0.208 (0.454)	–
Fraction of Eur language speakers (eurfrac)	1.171*** (1.36)	0.472 (1.45)	–
Constraint to the executive in 1990 (xconst1990)	0.308*** (0.086)	0.166 (0.131)	–
Executive recruitment regulation (xrreg1990)	–0.000 (0.004)	0.002 (0.007)	–
First PC (pc1)	–	–	0.001 (0.002)
Second PC (pc2)	–	–	0.002 (0.005)
Economic Openness in 2007 (pw openk2007)	–	–	0.000 (0.000)
Log of GDP per capita 1995 (lcgdp95)	–	–	–0.007 (0.006)
Investment share (pw ki2007)	–	–	0.0006** (0.0003)
Population in 2007 (mill)	–	–	0.043 (0.019)
N	88	88	88
R^2	0.85	0.44	0.09
F statistic	8.78	1.21	–
Stock Yogo F	–	–	1.071
Hansen p	–	–	0.49

Notes: significance levels reported as *** p<0.01; ** p<0.05; * p<0.1; two tailed. Intercept not reported, standard errors in parenthesis. Stock Yogo is the F statistic test for weak identification, with significance thresholds according to Stock and Watson (2002). Hansen p is the p-value of the Hansen J test of over-identifying restrictions of all but one instrument, the joint null being that the instruments are valid.

specifications, but also from conceptual discussions about how to conceptualize and measure different institutions.

In this article we have reviewed some of the most frequently used techniques to account for reversed causality problems in the institutions and economic performance literature. For the full methodological details on each, the reader should be referred to the corresponding original articles and seek support from the econometric literature. Overall, we have been able to see that several alternatives are available, but the pertinence of each depends ultimately on the type of data the researcher uses and the purpose of the analyses. Mathematically, they are all suitable for minimizing biases as long as the assumptions behind each are met. At the same time, all of them are perfectible and subject to some level of controversy that should be taken into account.

The nature of the Institutional Profiles Database (IPD) entails features that provide an advantage for certain analyses, while at the same time the researcher should be warned about some limitations.

IPD has a great level of detail in terms of both the formal policies as well as the *de facto* practices that countries pursue. In this sense, IPD offers the possibility to control for numerous meso-level institutions, such as labor market institutions, fiscal federalism and state organization, all essential intervening factors in the relationship between institutions and growth (Durham, 2004). IPD, therefore, has the potential of providing a great richness of variation in institutions across countries, and insights into their interactions. At the same time, the same richness of the database serves the purpose of testing hypotheses with different conceptualizations of institutions, an aspect that has been greatly emphasized as a potential source of bias.

The cross-sectional nature of the database allows for the implementation of identification strategies that are feasible for a cross sectional setting, such as IV estimation in its simplest form. One section of this article was dedicated to provide an empirical confrontation of the relative strengths and weaknesses of some of the different proposed instruments and alternative estimators.

In order to apply any of the other techniques, however, IPD needs to be complemented with alternative databases, or else systematize its panel data components, in order to retain information of the countries included during previous points in time. Part of these challenges are undertaken in the complementary paper by Cingolani and de Crombrugghe (2012), on the panel component of IPD. The richer the historical depth of the data, the more sophisticated the techniques available become.

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