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Debt Overhang in the Eurozone: A Spatial Panel Analysis[*]

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Abstract: The debt overhang hypothesis suggests that high debt levels retard prospects for GDP growth. We investigate the impact that debt overhang has had on recent GDP growth in the Eurozone, paying particular attention to the spillover effects that debt has on neighboring countries. We argue that in the Eurozone spatial effects are of crucial importance in modeling regional GDP growth, and find that a Spatial Durbin model is appropriate. We find strong evidence for the debt overhang hypothesis, confirming a concave relationship that has been found in other studies where low levels of debt can have a positive impact on GDP, but at some level a "turning point" occurs. The present study finds that this turning point occurs at a lower Debt/GDP ratio than found in prior studies, and separates out the direct and indirect (spillover) effects on neighboring countries' GDPs.

Keywords: Spatial Panel Data; Debt Overhang
JEL Codes: F43, R15, R12

1. INTRODUCTION

There is a solid cadre of empirical research on the so-called "debt overhang" hypothesis, the idea that a nation's unmanageable level of debt has a detrimental effect on economic growth through its effect on creditor's expected rewards. That is, if a nation's growth is primarily financed by foreign direct investment, high levels of debt would make foreign investors leery about the possibility of higher taxation in the future. Studies on the debt overhang hypothesis probe for the existence and magnitude of the impact that a country's debt load has on GDP growth. Few of these studies acknowledge that the interdependent nature of trade, population and investment flows, and knowledge spillovers strongly suggest that regional interdependence should be explicitly modeled when investigating debt overhang. Failure to do so can cause coefficient estimates to become biased and inconsistent, and cloud our understanding of these macroeconomic relationships. If a country's debt load does have an impact on its own growth, it will undoubtedly affect its neighbors' growth as well, which in turn will cause a secondary feedback effect on the original nation. To date, no study has properly tested for or estimated these spatial interactions of debt overhang. If indeed growth and debt spillovers exist, it can be argued that previous empirical studies have provided an incomplete and possibly misleading assessment of the debt overhang hypothesis.

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The main objective of the present work is to explicitly model these spatial effects in a panel data framework. Additionally, we build upon the non-spatial examination of Checherita-Westphal and Rother (2011) who study the impact of debt on growth for the Euro area. Recent developments in world economies have made evident the need to better understand debt's potential impact in developed nations, especially in the context of the Eurozone crisis. We establish that an interesting spatial dynamic exists between debt levels and growth in the Eurozone, and that spatial spillovers do exist.

2. LITERATURE REVIEW

According to conventional neoclassical growth theory, an increase in the current productive capacity of a nation should lead to higher levels of economic growth (Solow, 1956; Mankiw, Romer, and Weil, 1992). If domestic markets are incapable of financing that investment, then foreign direct investment can act as the necessary vehicle to fund growth. However, governments borrow abroad to smooth domestic consumption or to undertake investment projects that could have been financed by domestic capital (Daud and Podivinsky, 2011). Consequently, negative shocks to the level of investment, especially driven by high levels of debt, will have deleterious effects to a nation's rate of growth if investors believe that the returns to investment will be taxed away when the expected repayment of the debt falls short of the contractual value of the debt (Daud and Podivinsky, 2011). The expectation that a country's debt-service burden will become so heavy that a large portion of current output will accrue to foreign lenders creates a strong disincentive to further investment in the country (Sachs, 1989). Thus, debt overhang can discourage further domestic and foreign investment, harming economic growth (Pattillo, Poirson, and Ricci, 2002; Sen, Kasibhatla, and Stewart, 2006). Additionally, it can worsen economic performance by causing investment myopia if quick-yielding projects become favored over higher-valued long-term investments (Clements, Bhattacharya, and Nguyen 2003). Thus, high levels of debt have a negative impact on the rate of investment and economic growth because of disincentives to invest, cash flow tribulations, and moral hazard effects (Claessens et al., 1990). Intuitively, the negative effects on economic growth will be present in other aspects of the productive capacity of nation through the conduit between investment and physical capital accumulation (Pattillo Poirson, and Ricci, 2004). In this sense, gross capital formation, the value of net additions to fixed assets (excluding financial assets) can be used to establish the impact of debt on long-term investment plans and to minimize the effects of moral hazard on speculation through financial investment.

Whether debt overhang truly has negative influences on economic growth is still being debated, as are several possible mechanisms of action. Whether increased borrowing and debt service crowd out investments, or whether debt discourages investors preoccupied with the prospect of future tax increases and disruptive austerity measures has not yet been satisfactorily established. However, economists are confident that there is some link between debt load and GDP, since the role of external debt in an economy (the incidence of default, low economic growth and high levels of poverty) is an important rationale for debt relief programs (Daud and Podivinsky, 2011).

In one of the earliest empirical investigations of the effect of high levels of debt on a country's rate of growth, Myers (1977) shows that debt overhang leads to underinvestment. Later Pattillo, Poirson, and Ricci (2002) observed that economic growth declined during the 1980s when debt was accumulating, and growth accelerated during the 1990s when debt reduction occurred (the usual argument in favor for debt relief programs). The empirical work of Clements, Bhattacharya, and Nguyen (2003), Chowdhury (2001), and Wijeweera, Dollery, and Pathberiya (2005) has also supported the notion that debt overhang hampers growth. Claessens et al. (1990) found that high level of debt service specifically crowds out investment, leading to lower economic growth.

While Bulow and Rogoff (1991) also find a negative relationship between high levels of debt and underdevelopment, they argue that the borrower's underdevelopment was due more to their own economic mismanagement of their productive resources than to the burden of external debt and thus debt overhang was a symptom, rather than a cause of low economic growth in the indebted countries. Later research by Arslanalp and Henry (2004) and Cordella et al. (2005) support Bulow and Rogoff's hypothesis by showing that either debt overhang does not exist or it does not matter for economic growth.

The fact that studies find conflicting results regarding the sign and the magnitude of the debt-growth relation might thus suggest that the relationship is sample dependent and highly nonlinear. In the latter regard, Cordella, Ricci, and. Arranz (2005, 2010), Pattillo, Poirson, and Ricci. (2002, 2004), and Imbs and Rancière (2005) provide support for a non-linearity in the debt-growth relationship. Reinhart and Rogoff (2010) make a point to establish that this negative relationship is remarkably similar across emerging markets and advanced economies, while ruling out a relationship between debt and inflation. They separate developing from developed nations without focusing specifically on subsets of each group, and find that external debt levels in advanced countries now average about 200 percent of GDP,[1] with external debt levels being particularly high across Europe. However, there is no empirical study that simultaneously addresses the potential problem of debt overhang in the Eurozone taking into account the neighboring effects in a spatial econometric panel data framework.

Nevertheless, in spite of the sizeable empirical literature, most studies have investigated developing countries over the period 1969-1999. There are very few empirical studies that take into account trade and knowledge spillover relationships due to regional interdependence in the debt-growth model, with the exception of Daud and Podivinsky (2011) using a sample of developing countries.[2]

The lack of a sizeable literature on debt overhang in developed countries is troubling, considering that the recent financial crisis has put considerable strains on public finances in the Euro area, particularly with regard to government debt. While the role of debt has been studied, in most studies the impact of debt has been studied in relation to interest rates, government debt itself, and other fiscal variables. According to the CIA's *The World Factbook*, 11 of the top 25 most indebted countries, ranked by their share of external debt to gross domestic product, belong to the Eurozone. The list, which includes Greece, Portugal, and Ireland, also contains well-developed nations like The Netherlands, France, Spain, and Germany.

One notable, recent exception is Checherita-Westphal and Rother (2011) who study the impact of debt on growth for the Euro area. Using four decades of data starting in 1970, they

[1] This figure differs from ours for two reasons: the nations used in their study and the type of debt considered. Their countries included some of the Eurozone countries but also Australia, Canada, Japan, New Zealand, the United Kingdom and the United States. Also, their measure of debt includes both private and public external obligations.

[2] Rey and Montouri (1999) explicitly modeled these relationships when evaluating beta convergence in the United States.

find a negative and highly nonlinear relationship between debt and economic growth. Their study, though non-spatial, finds results similar to debt overhang studies using developing countries. They do a very careful, nonspatial analysis, performing a variety of sensitivity and specification analyses, finding a concave relationship between debt and growth. Checherita-Westphal and Rother (2011, p. 1020) use an interesting instrument in their analysis (italics added for emphasis):

> Thus, we also calculate for every country and year in the sample the average public debt-to-GDP ratio of the other countries and use this variable as an instrument. As such, this instrument has the advantage of not having a direct causation effect on the growth rate, *at least if one assumes that there are no strong spillover effects between debt levels in euro area countries and per-capita GDP growth rate in one specific country*.

An additional advantage of spatial econometrics is that the assumption highlighted above is also a testable hypothesis. We therefore deal with a test of this hypothesis when discussing the empirical results in Section 4.2.

There are two common motivations for the justification of using an explicit spatial modeling framework (see e.g., Elhorst, 2010b). First, a spatial lag model is appropriate if we believe that GDP growth is partly determined by a spatial interaction process with the neighboring countries. This had been clearly demonstrated in theoretical models (López-Bazo, Vayá, and Artis, 2004; Ertur and Koch, 2007) and investigated empirically in the context of convergence (Elhorst, Piras, and Arbia, 2010). In addition, Brueckner (2003) suggests that the actions of neighboring governments (and thus plausibly, policy and GDP) interact through two different types of processes. The first type he calls a *spillover model*, where decisions in one jurisdiction either have cost or benefit spillovers for a neighboring region, or cause some sort of reaction by the neighboring governments (as in yardstick competition (Besley and Case, 1995)). The second type of interaction Brueckner calls a *resource-flow model*, for example as is the case where capital flows between countries seeking the highest returns.

The second common motivation for the use of spatial econometric methods is for the case where the error terms may be thought to be spatially related, causing a nonspherical error covariance matrix (a spatial error model). This could be the case if, for instance, some determinants of GDP (say, culture, terrain, or religious views) are spatially correlated but omitted from the model. In the next section, we will allow for the possibility of both the spatial lag and spatial error models in our specification testing.

3. DATA AND APPROACH

3.1 Data

The data were obtained from the World Economic Outlook Database, produced by the International Monetary Fund, and include the 17 European countries that initiated the Eurozone from 1998 to 2009.[3] The dependent variable is the annual rate of growth (%) of the real gross domestic product per capita (G). The explanatory variables include gross capital formation as a

[3] Austria, Belgium, Cyprus, Germany, Ireland, Italy, Spain, Estonia, France, Greece, Luxembourg, Malta, Portugal, Netherlands, Finland, Slovakia, Slovenia.

Table 1: Descriptive Statistics (Selected Years)

	Variable	Year	Mean	St.Dev.	Min	Max
GDP per Capita (%Δ)	G	1999	3.59	2.18	-0.06	8.42
		2004	2.62	1.77	0.54	7.35
		2009	-5.55	3.12	-14.78	-2.58
Gross Capital Formation (% of GDP)	GCF	1999	22.99	3.49	17.03	28.78
		2004	22.74	4.35	15.91	33.07
		2009	18.95	2.33	14.42	24.42
Population (%Δ)	POP	1999	0.46	0.60	-0.76	1.90
		2004	0.68	0.65	-0.33	1.85
		2009	0.56	0.49	-0.25	1.85
Expenditure/Revenue Ratio	EXPREV	1999	1.03	0.07	0.92	1.18
		2004	1.05	0.06	0.96	1.19
		2009	1.17	0.12	1.02	1.42
Government Debt (% of GDP)	DEBT	1999	46.15	31.02	5.99	113.72
		2004	44.05	28.92	5.03	103.90
		2009	53.27	31.97	7.15	127.10
Exports (% of GDP)	EXPORTS	1999	53.38	29.89	22.54	134.27
		2004	57.01	32.55	23.13	152.33
		2009	55.99	34.98	19.19	160.95
Labor Force Participation Rate	LFP	1999	56.27	4.60	47.60	62.90
		2004	57.25	4.46	49.20	64.30
		2009	58.30	4.79	49.10	66.10

percentage of GDP (*GCF*), the annual rate of growth (%) of the population (*POP*), the share of exports to GDP (%) (*EXPORT*), and the labor force participation rate, as suggested by Sen, Kasibhatla, and Stewart (2006). The fiscal solvency variables include the government expenditure to government revenue ratio (*EXPREV*) and the value of the outstanding government debt as a percent of GDP (*DEBT*). The square of this last variable will be added in the econometric specifications to account for the nonlinear relationship between growth and debt found in the literature[4]. Table 1 provides some descriptive statistics of the data involved.

3.2 Nonspatial Specification

To establish any statistical relationship between debt levels and debt accumulation (indebtedness) to a standard measure of economic growth (percentage change in real GDP per capita), we follow a standard specification framework similar to Checherita-Westphal and Rother (2011) and estimate a country-level panel data model using a conditional growth regression equation of the form,

[4] In the spatial model we also include a slope dummy variable (DEBTCORE) aimed to assess any parameter heterogeneity between the so-called "core" countries (France, Germany, Italy, Netherlands) and the rest of the nations.

(1) $G_{it+1} = \alpha \ln GDPPC_{it} + \gamma_1 Debt_{it} + \gamma_2 Debt_{it}^2 + \delta ExpRev + \mathbf{X}'_{\mathrm{it}}\boldsymbol{\beta} + \upsilon_i + \tau_t + \varepsilon_{it}$

where i indexes countries, t indexes years, G_{it+1} is the growth rate (%) of GDP per capita from t to $t+1$, ln$GDPPC_{it}$ is the natural logarithm of the initial level of GDP per capita, $DEBT_{it}$ is country i's gross government debt as a share (%) of GDP[5], $ExpRev_{it}$ is the ratio of county i's government expenditure to government revenue ratio(%), and $\mathbf{X}_{it}$ is a vector of aggregate socioeconomic and macroeconomic controls that include: Gross Capital Formation as a share (%) of GDP (GCF_{it}), Population Growth rate(%) at time t (POP_{it}), the level of Exports as a share (%) of GDP_{it}, to account for country i's openness level ($EXPORT_{it}$), and the Labor Force Participation Rate (%), to account for country specific labor market conditions (LFP_{it}). Analogous with panel data models terminology, τ_t is the fixed effect for year t, υ_i is the fixed effect for country i, and ε_{it} is a disturbance term.

The fixed effects aim to capture additional country specific economic factors not included in the model, such as fiscal policies, levels of openness and competitiveness, and other market and social characteristics that remain broadly unchanged over time. Year dummies are also included to control for common shocks across countries that occurred over the period of the analysis, as well as for other unobserved economic regime changes (see Checherita-Westphal and Rother, 2011).

In order to ensure a reliable nonspatial estimation and inference of Equation 1, we estimated a two-way fixed effects model correcting for heteroskedasticity. It is important to realize that endogeneity and/or simultaneity might be present in the model if indeed there is reverse causation from GDP growth to Indebtedness. To minimize this potential bias in the estimators, we use lagged values of all the independent variables to explain the dependent variable.

3.3 Spatial Panel Approach

We now discuss our strategy for identifying the proper spatial panel data model. For our methodology, we rely on LeSage and Pace (2009) and Elhorst (2010b). As mentioned in Section 2, because these data are explicitly spatially related, omitting this information may cause estimates to become biased, inconsistent, and/or inefficient. There is a potential for spatial effects because neighboring economies will more than likely affect each other, or there may be unobserved spatial heterogeneity.

We have no strong *a priori* spatial specification model in mind, because little spatial work has been done in this field, and it is likely that spatial lag and/or error processes may be present. Therefore, we will follow a "general to specific" specification search.[6] Following LeSage and Pace's (2009) recommendations, we begin with a spatial Durbin model, which takes the general form

(2) $\mathbf{y} = \rho\mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \mathbf{W}\mathbf{X}\boldsymbol{\theta} + \boldsymbol{\varepsilon}$,

where $\boldsymbol{y}$ is a both a function of explanatory variables ($\mathbf{X}\boldsymbol{\beta}$) as well as a function of the per capita consumption of neighboring areas $\rho\mathbf{W}\mathbf{y}$ and lagged values of the explanatory variables ($\mathbf{W}\mathbf{X}\boldsymbol{\theta}$) .

[5] We also include its square value to capture any additional nonlinearity in the Debt-Growth nexus.

[6] While some prefer the "specific to general approach," i.e., beginning with a non-spatial model and testing using LM tests for the lag and error models, no research to date has shown whether either approach is superior for panel data modeling (Elhorst, 2010b).

Here, ρ (a scalar) describes the "strength" of the spatial dependence of neighbor's per capita GDP growth, and the vector $\boldsymbol{\theta}$ describes the impact of each of the spatially lagged explanatory variables on per capita GDP growth. The spatial Durbin is an attractive starting place for spatial econometric modeling because it nests the more restrictive spatial lag (Equation 3) and error (Equation 4) models as special cases:

(3) $\mathbf{y} = \rho\mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$, if $\boldsymbol{\theta} = 0$.

(4) $\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{u}, \quad \mathbf{u} = \lambda\mathbf{W}\mathbf{u} + \boldsymbol{\varepsilon},\ where\ \varepsilon \sim i.i.d. \quad if\ \boldsymbol{\theta} = -\rho\boldsymbol{\beta},\ because\ \lambda = \rho.$

Testing these restrictions is done with straightforward LR tests. We estimate these models in MATLAB using routines by Elhorst (2010), Lesage and Pace (2009), bias correction methods by Lee and Yu (2010a), and routines for estimating the direct and indirect effects adapted for panel models by Don Lacombe.

When defining the contiguity structure (**W**) for these models we used the k nearest neighbors (*knn*) approach, with *k*=4. A purely geographic approach was used in order to avoid endogeneity issues that can arise if trade relationships are used to construct the matrix. The *knn* approach was used instead of other common options (such as queen or rook contiguity) due to the lack of physical contiguity with several of the Eurozone regions.[7]

4. EMPIRICAL RESULTS

4.1 Nonspatial Estimation

For purposes of comparison with earlier research, non-spatial estimation results are shown in Table 2. Column (1) shows the results for a pooled panel model using Equation 1. Column (2) shows the results of a fixed effects model including the same variables. A joint hypothesis tests of the statistical significance of the fixed effects coefficients indicated that the fixed effects model is more appropriate. In a last iteration, column (3) shows the results of a two-way fixed effect panel data model with the same variables. Again, the appropriateness of model 3 over models 2 and 1 was confirmed through *F* tests. This latter model represents an adequate statistical representation of the data and the estimated residuals do not suffer from significant deviations from the classical assumptions.[8] Additionally, the estimated coefficients are consistent with the current growth-debt literature. In general, and according to standard growth theory, we should expect that the coefficients for fiscal solvency be negative (Sen, Kasibhatla, and Stewart, 2006), and that the relationship between outstanding debt and growth be nonlinear (Cordella, Ricci, and Arranz, 2005) and concave (Checherita-Westphal and Rother, 2011).

Several things are worth mentioning in this preliminary non-spatial modeling of the data with the results of Column (3). Our variables of interest, the indicators variables for indebtedness, have the right signs and are statistically different from zero. In particular, an increase in the expenditures to revenues ratio, a proxy for the current fiscal solvency of the government, has a negative and significant effect in future short-term growth. Likewise, an

[7] In any case, LeSage and Pace (2010) argue that the results of spatial econometric models are fairly insensitive to the specification of the weights matrix.

[8] In particular, skewness = .0003, excess kurtosis = .0018.

Table 2: Nonspatial Panel Data Results

Variables	(1) Pooled Panel	(2) Fixed Effects	(3) Two-Way F.E. Panel
ln*GDPPC*(-1)	-2.129***	4.320***	1.989*
	-4.28	*3.20*	*1.82*
GCF(-1)	-0.112	-0.138	-0.0104
	-1.38	*-1.10*	*-0.08*
POP(-1)	-0.558	-1.918*	-2.169***
	-1.64	*-1.96*	*-3.12*
EXPREV(-1)	-10.84***	-11.52***	-9.358***
	-3.49	*-2.87*	*-3.15*
DEBT(-1)	0.000417	0.260**	0.138*
	0.01	*2.34*	*1.93*
$DEBT^2$(-1)	-3.46e-05	-0.00167**	-0.000962*
	-0.10	*-2.51*	*-1.96*
EXPORT(%Δ)	0.0132	-0.0737	0.0711
	1.25	*-1.47*	*1.49*
LFP	-0.0340	-0.565***	-0.262
	-0.57	*-2.88*	*-1.55*
Observations	204	204	204
R^2	0.146	0.415	0.777
# Cross-sections		17	17

t-stats appear below the estimates. *** p<0.01, ** p<0.05, * p<0.1

increase in the stock of government debt as a percentage of GDP in the previous year has a concave relationship to per-capita GDP growth. In this particular case, the Debt-to-GDP turning point is roughly reached at levels of 72 percent. Debt levels above that threshold would have a negative effect on economic growth. These results give credence to the notion that the relationship between debt and growth is indeed nonlinear. As an additional robustness check, our results are analogous in sign and magnitude to the findings of Checherita-Westphal and Rother (2011), while using a different sample of countries and period.[9] The one important difference is that they found a turning point at a Debt/GDP ratio of around 100 percent that was relatively robust to specification, whereas our turning point is quite a bit lower.[10] As we will see, this difference persists in the spatial estimation as well.

4.2 Spatial Estimation Results

We now turn to estimating models which take regional interdependence into account. In Table 3 we show estimates of the pooled spatial Durbin model.[11] We run two versions of these

[9] They use 12 Eurozone countries from 1970–2011.

[10] However, the lower limit of their turning point confidence intervals did dip down into the 70-80 percent range.

[11] We tested for the possibility that a Random Effects Model is appropriate using a spatial Hausman test (Lee and Yu, 2010b). We found no evidence to support a Random Effects Model (p=.0000, rejecting Random Effects Model in favor of Fixed Effects). We also tested for the appropriateness of using one-way or two-way fixed effects. In either case, the pooled panel data model

Table 3: Dependent Variable: GDP Growth Rate

	Spatial Durbin Model		Core-Periphery Differential Debt Response	
Variable	Coefficient	*t*-stat	Coefficient	*t*-stat
ln*GDPPC*(-1)	-0.6978	-1.51	-1.831***	-2.75
GCF(-1)	0.0503	0.94	0.0379	0.61
POP(-1)	-1.386***	-3.84	-0.876*	-1.74
EXPREV(-1)	-7.962***	-3.10	-9.892***	-3.53
DEBT(-1)	0.073**	2.12	0.087**	2.35
$DEBT^2$(-1)	-0.0008***	-2.58	-0.0007**	-2.33
EXPORT(-1)	0.026***	3.00	0.011	1.03
LFP(-1)	-0.132**	-2.29	-0.174***	-2.93
DEBTCORE(-1)			0.098***	2.58
$DEBTCORE^2$(-1)			-0.0011***	-2.77
W×ln*GDPPC*(-1)	1.579	1.57	1.180	1.09
W×*GCF*(-1)	0.921	0.92	0.010	0.09
W×*POP*(-1)	1.248	1.24	-0.682	-0.58
W×*EXPREV*(-1)	4.218***	4.21	17.955***	2.96
W×*DEBT*(-1)	2.300**	2.30	0.3462***	3.15
$W \times DEBT^2$(-1)	-2.789***	-2.78	-0.002***	-2.86
W×*EXPORT*(-1)	0.117	0.11	-0.042*	-1.74
W×*LFP*(-1)	-1.971**	-1.97	-0.014	-0.05
W×*DEBTCORE*(-1)			0.121	1.16
$W \times DEBTCORE^2$(-1)			-0.0017	-1.49
λ (Spatial Lag Y)	0.754***	20.37	0.722***	17.71
R^2	0.6282		0.6414	

Spatial Studentized Breusch-Pagan Test (Anselin, 1988): for (1) and (2), $p<.05$.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4: LR Tests for Restricting Durbin to Lag and Error Models

Model	log likelihood	LR Stat	Significance
Durbin	-445.97		
Lag	-467.18	42.4297	p = 6.28e-06
Error	-465.99	40.0399	p = 1.66e-05

models; on the right side of Table 3 we test for a differential core-periphery response to debt. It appears from the coefficient estimates that there is a differential response, so we focus on these results in the discussion that follows. In Table 4 we show the results of LR tests to see if the

resulted in a better fit of the data indicating that the variables in question, including the spatial relationships, already capture most of the heterogeneity between the nations ($p \leq .05$).

model should be restricted to the Spatial Lag or Spatial Error models. The *p*-values for both tests are well below 0.05, indicating that the spatial Durbin model is the appropriate specification.

A spatial Breusch-Pagan test revealed that the results in Table 3 do have some residual heteroskedasticity. However, though heteroskedasticity corrections have been determined for some models, such as the Cliff-Ord type model (Piras, 2010; Arraiz et al., 2010), no such correction has been derived and tested for the spatial Durbin model. Even so, this heteroskedasticity should not bias the coefficients, but will bias the standard errors. Therefore, caution should be used in cases where statistical significance is marginal; however, coefficients with very small *p*-values are highly likely to remain statistically significant, even if the standard errors have some bias.

Note that in the spatial Durbin model each independent variable has two coefficient estimates, one for the own effect, and one for the impact of neighboring **X** values on GDP growth. Since the Durbin model also includes spatially lagged GDP growth, we also see in Table 3 that the coefficient of neighbors' growth on our growth is close to 0.72.

It is important to mention that in the Spatial Durbin models the estimated coefficients do not represent the marginal effects of a change in a variable, and extreme caution must be used when interpreting them. In order to easily discuss marginal effects of coefficients, it is necessary to use LeSage and Pace's (2009) method for calculating the average direct and indirect effects for each of the variables of interest (see Table 5).

The direct effect measures the average change in GDP in country *i* caused by a one unit change in that country's explanatory variable. For example, on average if a country's gross capital formation increases by one percentage point of GDP, then GDP growth will expand in that country by .048 percentage points (as an average point estimate). With respect to the indirect effects, they can either be interpreted as:

a) The aggregate impact on y in countries $-i$ of a change in x_j a variable in country i

b) The change in y country i of a one unit change in x_j in all countries $-i$

These effects are identical due to symmetries in the computation. In general, we prefer interpretation a) in this context, since it tells us about the pan-European impact of one "rogue" member who may be a bad neighbor, and/or positive externalities of having a strong member country. However, there is also a good reason to use interpretation b) in this case. As discussed in Section 2, one of several robustness checks Checherita-Westphal and Rother (2011) performed was to use the average levels of Debt in "neighboring" countries (in this case, all of the "other" Eurozone countries) as an instrument, valid under the assumption "that there are no strong spillover effects between debt levels in euro area countries and per-capita GDP growth rate in one specific country." The interpretation in b) allows us to directly test just this hypothesis, and the *p*-values (≤ 0.01)[12] the indirect effects for *DEBT* and $DEBT^2$ strongly suggest

[12] The bias in the standard errors caused by heteroskedasticity will carry over to the simulated standard errors in the direct and indirect effects. Therefore, *p* values at the margin (e.g., the 0.049 for *DEBTCORE*(-1) should be handled with care.

Table 5: Direct and Indirect Marginal Effects
(Core Countries Spatial Durbin Model)

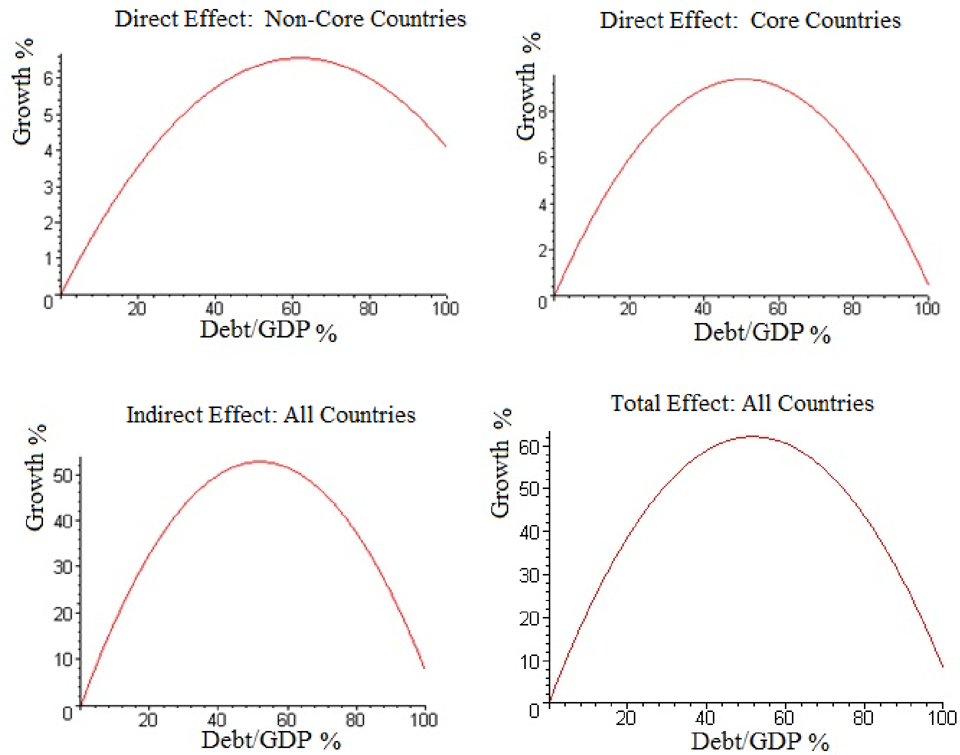
Effects		Coefficient	*t*-stat	prob
Direct	ln*GDPPC*(-1)	-1.895	-1.937	0.070
	GCF(-1)	0.048	0.562	0.581
	POP(-1)	-1.252	-1.685	0.110
	EXPREV(-1)	-6.712	-1.618	0.124
	DEBT(-1)	0.212	3.330	0.004
	$DEBT^2$(-1)	-0.002	-2.951	0.009
	EXPORT(-1)	0.000	-0.025	0.981
	LFP(-1)	-0.212	-1.785	0.092
	DEBTCORE(-1)	0.159	2.125	0.049
	$DEBTCORE^2$(-1)	-0.002	-2.419	0.027
Indirect	ln*GDPPC*(-1)	-0.537	-0.121	0.905
	GCF(-1)	0.123	0.279	0.783
	POP(-1)	-4.327	-1.015	0.324
	EXPREV(-1)	35.629	1.632	0.121
	DEBT(-1)	1.373	3.270	0.005
	$DEBT^2$(-1)	-0.011	-2.890	0.010
	EXPORT(-1)	-0.117	-1.180	0.254
	LFP(-1)	-0.461	-0.515	0.613
	DEBTCORE(-1)	0.654	1.485	0.156
	$DEBTCORE^2$(-1)	-0.009	-1.784	0.092
Total	ln*GDPPC*(-1)	-2.432	-0.466	0.647
	GCF(-1)	0.171	0.338	0.740
	POP(-1)	-5.578	-1.150	0.266
	EXPREV(-1)	28.917	1.152	0.265
	DEBT(-1)	1.585	3.335	0.004
	$DEBT^2$(-1)	-0.012	-2.939	0.009
	EXPORT(-1)	-0.117	-1.026	0.319
	LFP(-1)	-0.673	-0.672	0.510
	DEBTCORE(-1)	0.813	1.592	0.130
	$DEBTCORE^2$(-1)	-0.011	-1.892	0.076

that we should reject it. Indeed, the strength of the spillovers suggests that a heightened awareness of Eurozone interdependence be promoted.

4.3 Discussion of Results

For the direct effects, the polynomial coefficients are different for core versus noncore Euro nations. These can be summarized in graphical form (Panel 1) similar to Checherita-Westphal and Rother (2011). In contrast to their findings of the polynomial's turning point at a debt/GDP ratio of approximately 100 percent, for the direct effect we see the following polynomials for noncore and core countries reached their turning points around 50-60 percent debt levels with the coefficients estimated in the spatial Durbin model.

Panel 1: Graphical Representation of the Debt-Growth Nexus



Additionally, we find a turning point that is slightly lower for Core countries than noncore Eurozone members. Perhaps the turning point is slightly lower for Core countries because the magnitude of debt is larger, and less easily absorbed into the financial system. For the indirect and total effects estimates, it is much more questionable whether there is a difference between the debt/GDP polynomial shapes between core and noncore countries given the high *p*-values. In the figures below we aggregate the coefficients to make one response curve for indirect effects, and one for total.

Here we see the fact that the indirect effects and total effects have a turning point at a similar magnitude, in the neighborhood of 50-60 percent of GDP. Given that the current stock of pan-Euro zone debt is around 87 percent of Eurozone GDP (*The Economist*, 2012); this may help explain some of their woes.

5. CONCLUSION

In this paper we have expanded upon previous literature of the Debt Overhang hypothesis in two main ways. First, we investigate a developed region that currently finds itself in a crisis due to unmanaged levels of debt, in contrast to the bulk of previous research concerning itself primarily with developing nations. Secondly, our empirical technique takes spatial spillovers, heterogeneity, and potential spatially-related missing variables into account. We find strong evidence for the debt overhang hypothesis, confirming the nonlinear, concave relationship found in earlier studies, but the spatially-sensitive estimates find that negative effects of debt may begin to occur at lower debt/GDP ratios than previously thought.

Also importantly, we detected strong spatial spillover relationships regarding debt that can be promulgated in two ways. First, we find a strong spatial relationship between GDP growth and neighbor's GDP growth. Therefore, as a country's growth begins to suffer, this will slow down neighboring growth as well. However, we also find an impact of high debt levels themselves on neighbors' growth, with a very similar nonlinear profile to the direct effect on a country's own growth. We hope that this discovery of multiple vectors through which Debt can infect neighbors' growth will help inform future theoretical and empirical research on the debt hangover hypothesis and the still evolving crisis in the Eurozone.

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