Regional Output Differences in International Perspective

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Abstract

Accurate regional estimates of output are desired as an indicator of level of development and as a variable used to explain internal migration, demand patterns, fertility and other aspects of behavior. This paper explores one often neglected aspect of regional income differences, namely that due to price differences or regional purchasing power parities. When nominal regional income measures are adjusted for these price level differences they are termed real regional incomes. The preferred method of estimating regional purchasing power parities by detailed price comparisons is discussed for Brazil, the United States and the European Union. The empirical thrust of the paper is an investigation of different methods for estimating regional real incomes based on PPP data[1] for 167 countries and nominal regional incomes and other data for about 870 administrative areas at the sub-national level. Even in their present form we believe the real income estimates provided for the geographical units present opportunities for understanding the world economic structure.

A. Introduction

The political economy of countries revolves upon leaders gaining support from different constituencies within an administrative boundary, be it a city ward, a province, or a regional configuration in larger countries. Conflicts within countries frequently center on differences in income between regions and the extent to which these represent one area receiving more public expenditures, projects or subsidies than another. Within and between countries resources are often allocated inversely to a small degree to the level of per-capita income, for example the social fund in the European Union (EU). Since perceptions of regional neglect are partly based on objective estimates of income, it is important to have good estimates. To understand the distribution of world income, and concentrations of the very poor, it is important to have regional income estimates that can be compared within and between countries, and this is the focus of our paper. We make a first step towards developing a comparable set of inter-area real income comparisons for a world of about 800 sub-national administrative units and countries. Some of the sub-units are larger than most countries, such as Uttar Pradesh in India with 159 million or Sichuan in China with 115 million. We use the smallest administrative unit that is available from official sources (see Sources of Regional Data in the Appendix), except in the case of Chile, where we used the second smallest unit since their smallest units totaled 300 plus areas. Geographically, more disaggregation is desirable for many of the large countries.

What distinguishes this paper from other studies such as Gallup, Sachs and Mellinger (1998) is that we also ask what difference it makes to take into account price

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[1]Authors' estimates available from PWT 6.1 at http://pwt.econ.upenn.edu

differences within countries. We begin with nominal estimates of regional incomes based on production or other methods of estimation, aware that the concept of income and quality of estimates of nominal levels and growth vary widely across countries.[2] Clearly there is much work to be done to get good nominal income estimates, important research that is not attempted in this paper. As a first step we correct the nominal incomes for differences in purchasing power parities (PPPs) across countries and as a second step, across regions within countries. Unfortunately, there is only limited direct data on price differences within countries so much of the paper addresses the problem of finding an indirect way to satisfactorily estimate differences in regional price levels. We undertake this estimation because we believe these regional price differences are important, and after going through the exercise, we ask whether this correction would alter our perception of the world compared to what we obtain from step one above.

The preferred method of directly estimating regional price differences is discussed in section B of the paper. Because few countries collect price data appropriate for directly estimating regional price levels, we discuss in section C indirect methods that might be used to estimate price levels and real incomes within countries. Models are developed of how location and trade may influence price levels. We estimate two versions of this model, one that assumes spatial heterogeneity among countries or regions and a second that explicitly includes spatial autocorrelation effects from neighbouring and nearby units.

B. Regional Price Levels

1. Methodology

Just as national PPPs are used to convert GDPs in national currencies to a common unit, it is desirable for making quantity comparisons to take account of price differences across regions of a country using the same currency. The creation of a Euro area or the use of the U.S.$ in Ecuador does not lessen the need for price comparisons. Many commercial enterprises in the United States and Europe sell information on regional price levels to employers setting salaries or employees considering relocation. Accra in the United States and Employment Conditions Abroad in London are two such organizations. The methods used in most commercial ventures grew out of the binary comparisons between countries, especially those carried out by Gilbert and Kravis (1954), who used the United States as the center of a star involving the UK, France, Germany and Italy. Direct binary comparisons among the European countries were not carried out. The direct method is used by governments and international organizations such as the United States State Department and the International Civil Service Commission.

Multilateral comparisons grew out of binary beginnings, as methods were developed to deal with the fact that binary comparisons between A/B, A/C, and B/C do

[2] For example the Statistical Yearbook for China for 2000 reports growth in income in all provinces but one as higher than reported for all of China.

not lead to transitive results; the direct comparison of B/C does not generally equal the indirect comparison obtained by dividing A/C by A/B. The United Nations International Comparison Programme (ICP) begun in 1968 experimented with several different multilateral methods (Kravis, Kenessey, Heston and Summers, 1975). Many investigations of multilateral methods resulted; commonly used methods are discussed by Irwin Diewert (1999) and Rao (2001). The broad results of all the methods support the most important finding of the ICP, namely that the price level (purchasing power divided by the exchange rate) of GDP rises systematically with per capita GDP; this is sometimes referred to as the Balassa-Samuelson effect (Heston, Summers and Nuxoll, 1994).

This basic finding, when extended to regions within a country, implies that higher income regions would have higher prices than low-income regions. Whether one is making purchasing power comparisons between or within countries, the information required to carry out a full benchmark comparison are prices of comparable goods and services. In many countries substantial price information is available, especially for foods. In the 1960's, the CPI in the United States had enough common items across cities, collected each month within each city, to put together spatial price comparisons. However, the BLS did not believe these spatial comparisons were of very good quality, and neither business nor labor was keen on having official estimates of regional price levels within the United States. Official intercity comparisons were discontinued in 1968.

The framework for the CPI that the BLS introduced in the 1970s also did not seem to readily lend itself to comparisons across space because collectors were not asked to price the same item in different outlets. The sampling frame is such that the price collector checks off, for each entry-level item (ELI), the outlet, size, packaging and other information about the volume seller as indicated by an outlet employee. Since the CPI only required the price change for the same item from the previous period, it was not known whether the same items were priced in Los Angeles and Minneapolis.

However, it turned out that the ELI approach to the CPI may be the model of what price data should be for making regional or international comparisons. A short discussion of the BLS experiments for the United States illustrates this point. Regional price differences remained a research subject for the BLS, and a hedonic approach was examined in the work of Kokoski, Cardiff and Moulton (1994) and Kokoski, Moulton and Zieschang (1999).

In fact, Kokoski *et al* began experimenting with the hedonic approach that had also been part of the early international PPP comparison work. In the ICP, the method was termed the Country Product Dummy method (CPD) by Robert Summers (1973), to deal with fact that not all countries collected prices for all items. The version that Summers used was a very straightforward hedonic regression model akin to those used for temporal studies (Griliches, 1990, Triplett, 1990, Berndt, Griliches and Rappaport 1995). In equation (1) below, $j = 1,2,...,m$ countries, $i = 1,2,\ldots n$ items in a basic heading, and p_{ij} is the price of item i in country j, and å$_j$ is the error term. The prices are regressed against two sets of dummy-variables, D_j for each country other than the numeraire country (country 1), and the second set with a dummy for each item specification, z_i.

$$(1)\ \ln p_{ij} = \sum_{i=1}^{n} b_i z_i + \sum_{j=2}^{m} a_j D_j + e_{ij}$$

The transitive price parity, a_j, is the logarithm of the estimated country parity for the heading relative to the numeraire country. The item coefficient, â$_i$, is the logarithm of the estimates of the average item price in the currency of the numeraire country (which could be a regional currency).

The innovation of Kokoski and colleagues was to apply this data to the estimation of internal price parities by BLS city using the Entry Level Item (ELI) characteristics of the prices being collected. The basic idea was similar to the CPD procedure. For example, if Apple is the ELI, we may not be able to match the specific apple(s) priced in Philadelphia with those priced in Los Angeles. But across all the BLS cities, as long as there is overlap of specific apples priced in some cities, then a parity can be obtained for all apples between any pair of cities. Given the unit of measurement of a kilogram, there would be a code for outlet type, city, and dummies for Fuji, Rome, Granny Smith, Delicious, McIntosh, and so forth. In the CPD equation, the â$_i$'s would provide an average price per kilogram for types of apples, and the a_j*'s* yield the price level of apples in each city.

A formulation of this hedonic framework that seems appropriate for regional comparisons is set out in (2) below. In equation (2) the subscript *j* refers to regions within a country, the subscript *(i)* refers to item characteristics, such as brand or product identification, and *(k)* refers to the outlet type. The brand characteristics (B_i) and outlets (O_k) are expressed as dummy variables, so that one characteristic or outlet must be omitted to avoid perfect multicollinearity in the estimating equation. This omitted characteristic becomes the base, and â or γ is the (log) price parity relative to this base. As in equation (1), the ás yield the price level relative to each region.

$$(2)\ \ln p_{ikj} = \sum_{i=1}^{n} b_i B_i + \sum_{k=2}^{l} g_k O_k + \sum_{j=2}^{m} a_j D_j + e_{ijk}$$

In the example below, the regions are districts into which São Paulo is divided for the purpose of collecting prices for the city CPI.[3] Although, the geographical dispersion of São Paulo is not as great as in a typical country, there are significant differences in prices across its districts, so the example simulates how the framework might be applied across regions at the country level. The three items used for illustration are dentists'

[3] We thank Professor Heron do Carmo, Coordinator of the CPI for the Fundação Instituto de Pesquisas Economicas (FIPE), who was kind enough to provide illustrative prices for several items that could be readily collated from the December 2001 survey. FIPE estimates a weekly consumer price index for São Paulo, as do several other institutions in Brazil. This survey covers over 80 districts with a range of outlets, brands and varieties of goods and services.

charges for a filling, milk and lightbulbs. For all three items there are different characteristics, namely type of outlet and brand or product, as well as various districts where the prices are collected.

Table 1 presents the results of the estimated equations for the three items. For lightbulbs and milk, a base price in a supermarket is provided in Brazilian Reais (R$) for a particular brand. Some further remarks will be made about the districts below. The factors to modify the base price are indicated for the highest and lowest districts for that item, for the different outlets, and for different types of fillings (dentist) or brands (milk and lightbulbs). The value of hedonic estimation is that it holds constant price-determining characteristics of the markets for products, such as outlet type, allowing the estimation of the regional, or district effects in this example. This point is made especially clear in Table 1 by the wide variety of prices that are observed for what is thought to be a fairly homogeneous item, namely a liter of milk. In terms of the main purpose of this illustration, an analysis of variance suggests there is a statistically significant district effect for all three items. The price in the highest district is 340% above the lowest for dentists, 30% for milk and 22% for lightbulbs. So it certainly makes sense to take district into account for a large city, and certainly for larger geographical units, such as countries.

Table 1		
Item:		**Lightbulbs**
Base price	*60W GE transparent bulb (1 unit)*	*R$1.04*
Price level relative to base:		
Outlet type	- Supermarket	1.00
	- Hardware	0.90
Brand/Product	- 60W Phillips	1.17
	- 100W GE	1.33
	- 100W Phillips	1.50
	- Fluorescent 15W 3-pack	16.83
District: highest	- Vila Prado	1.48
lowest	- Aricanduva	0.65
	N=247, R^2=98.5 RMSE=0.133	
Item		**Dentists**
Base price	*Porcelain filling 1-face*	*R$32.24*
Brand/Product type	- Amalgama type B	1.31
	- Amalgama type C	0.42
	- Resin type B	1.48
	- Resin type C	0.47
	- Silicate typeC	0.27
District: highest	- Jabaquara	2.39
lowest	- Saude	0.70
	N=72, R^2=97.1 RMSE=0.138	
Item		**Milk**
Base price	*Grade A Milk 1 liter*	*R$1.57*

Outlet type	Supermarket	1.00
	Bakery	1.18
Brand/Product type	Skim	
	- Special	0.60
	- Paulista	0.69
	- Parmalat	0.66
	Grade B Milk	
	- Special	0.72
	- Paulista	0.82
	- Parmalat	0.81
	Long Life Milk	
	- Parmalat	0.69
	- Paulista	0.72
	- Leco	0.70
District: highest	Raposo Tavares	1.11
lowest	Vila Formosa	0.86
	N=524, R^2=79.7 RMSE=0.162	

2. The European Union

The European Union (EU) publishes nominal income differences by sub-national units of their member countries. Income differences have been converted to Euros by use of PPPs, but within each country, the relative incomes of regions have simply been scaled to the average GDP per capita in Euros on a PPP basis. The Economic Commission of the EU has made it an action item to also adjust these nominal regional incomes to real regional incomes by taking account of the differing price levels within countries. Clearly real regional incomes are an important statistic for the EU because of the social funds made available for poorer regions.

Eurostat, which would have responsibility for such estimates, has not been able to carry out the task because it would require a significant expenditure of resources. However with increasing pressures from the Commission, Eurostat is considering a method that would build upon existing price collection within countries, perhaps augmented by some special collection. For example, across the Departments of France, comparisons would be made of CPI item prices of comparable items in Paris and Lyon to obtain price levels to put Department nominal incomes on a real income basis.

3. Other experiences

Japan does carry out a special survey every 5 years using the same survey framework as the CPI. The purpose of this survey is to obtain prefecture price levels for the purpose of adjustment of government salaries for regional cost of living differences. Korea carries out a similar survey. In connection with the early ICP estimates for India, an attempt was made to use the prices from city and rural temporal price indexes to estimate regional differences in price levels by expenditure groups. India has a price index for rural workers, additional urban indexes for industrial workers and white-collar workers (Heston, 1971). These indexes provide enough overlap to allow estimates of price level differences by rural-urban and various states of India. Angus Deaton and Alessandro Tarozzi (2000) used the National Sample Survey in India to investigate regional price levels based upon unit values, not transactions prices.

The United States has a COLA program aimed at adjusting salaries for federal employees working outside the continental U.S. for differences in cost of living compared to Washington, D.C. This adjustment is done each year based upon special surveys and has become a matter of considerable litigation. Much criticism has also been attached to the U.S. poverty line because it does not take into account regional price differences. When just regional price differences are taken into account in the United States, Aten (1986) found that the cost of the poverty bundle was 40% less in the Dakotas than in New York or San Francisco. It can be quantitatively important to systematically take into account regional differences in purchasing power

For most purposes we want real regional incomes. At least one of the conference papers has moved in this direction, namely Azzoni and colleagues (2001) who are working on convergence of state incomes in Brazil. In this paper, there is not enough information to generate real regional incomes for our world using preferred methods of estimation based on detailed price comparisons. This has led us to consider alternative methods that we believe have considerable interest, especially for those interested in how geographical factors and trade enter into the formulation.

C. A Model of Regional Price Levels

1. Penn World Table estimates

We begin with the estimates of real GDP per capita for 1996 for 167 countries in PWT 6.1 (Heston, Summers and Aten 2002). As a first step, for each sub-national unit with available data, the nominal national currency income estimate is converted to 1996 international dollars ($I) at the PPP for the country from PWT 6.1.[4] This procedure provides us with a set of nominal regional incomes that are quite interesting per se, suggesting the wide geographical variation around the world. Altogether there are 36 countries with 740 sub-national units and an additional 131 countries[5] with no sub-

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[4] An $I has the purchasing power of a US $ over all of GDP, but not its components.

[5] Albania, Armenia, Antigua, Australia, Azerbaijan, Burundi, Benin, Burkina Faso, Bulgaria, Bahrain, Bahamas, Belarus, Belize, Bermuda, Barbados, Bhutan, Botswana, Central African, Switzerland, Cote d'Ivoire, Cameroon, Congo, Republic, Comoros, Cape Verde, Costa Rica, Cyprus, Czech Republic, Djibouti, Dominica, Denmark, Dominican Republic, Algeria, Ecuador, Eritrea, Estonia, Ethiopia, Fiji, Gabon, Georgia, Ghana, Guinea, Gambia, The, Guinea-Bissau, Equatorial Guinea, Grenada, Guatemala, Guyana, Hong Kong, Honduras, Croatia, Haiti, Hungary, Ireland, Iran, Iceland, Israel, Jamaica, Jordan, Kenya, Kyrgyzstan, Cambodia, St. Kitts & Nevis, Kuwait, Laos, Lebanon, St. Lucia, Sri Lanka, Lesotho, Lithuania, Luxembourg, Latvia, Macao, Morocco, Moldova, Madagascar, Mexico, Macedonia, Mali, Malta, Mongolia, Mozambique, Mauritania, Mauritius, Malawi, Namibia, Niger, Nicaragua, Nepal, New Zealand, Oman, Panama, Peru, Papua New Guinea, Poland, Puerto Rico, Paraguay, Qatar, Romania, Russia, Rwanda, Saudi Arabia, Sudan, Senegal, Singapore, Sierra Leone, El Salvador, Sao Tome and

national breakdown, for a total of 871 observations. Table 2 provides the list of countries with regional breakdowns. Where possible, per capita personal income data were used, such as those computed by the Department of Commerce and published in the Survey of Current Business for the United States. In a few countries - Brazil, Chile, Indonesia, and South Korea, only gross regional product data were available for recent years, and these are labeled 'P' in Table 2[6].

Table 2	Code	Country	Units	P/I	Year
1	ARG	Argentina	24	I	1991
2	AUT	Austria	9	I	1993
3	BEL	Belgium	9	I	1993
4	BGD	Bangladesh	5	I	1991
5	BOL	Bolivia	9	I	1992
6	BRA	Brazil	27	P	1991
7	CAN	Canada	12	I	1996
8	CHL	Chile	12	P	1992
9	CHN	China	30	I	1994
10	COL	Colombia	23	I	1990
11	DEU	Germany	37	I	1993
12	EGY	Egypt	21	I	1990
13	ESP	Spain	17	I	1993
14	FIN	Finland	3	I	1992
15	FRA	France	22	I	1993
16	GBR	United Kingdom	35	I	1993
17	GRC	Greece	12	I	1993
18	IDN	Indonesia	27	P	1996
19	IND	India	25	I	1991
20	ITA	Italy	20	I	1993
21	JPN	Japan	47	I	1993
22	KAZ	Kazakstan	18	I	1994
23	KOR	Korea South	14	P	1995
24	MYS	Malaysia	13	I	1991
25	NGA	Nigeria	17	I	1992
26	NLD	Netherlands	12	I	1993
27	NOR	Norway	19	I	1992
28	PAK	Pakistan	4	I	1988
29	PHL	Philippine	13	I	1991
30	PRT	Portugal	7	I	1993
31	SWE	Sweden	21	I	1993
32	TUR	Turkey	69	I	1995

Principe, Slovak Republic, Slovenia, Swaziland, Seychelles, Syria, Chad, Togo, Thailand, Tajikistan, Turkmenistan, Trinidad , Tobago, Tunisia, Taiwan, Tanzania, Uganda, Uruguay, Uzbekistan, St.Vincent & Grenadines, Vietnam, Yemen ,Congo, Dem. Republic, Zambia, Zimbabwe.

[6] We included a dummy variable for these four countries, but it was not significant in the models that we tested.

Table 2	Code	Country	Units	P/I	Year
33	UKR	Ukraine	24	I	1994
34	USA	USA	51	I	1996
35	VEN	Venezuela	22	I	1994
36	ZAF	South Africa	9	I	1985

How should we think about the relationship of these nominal regional incomes to real incomes? We develop two approaches that take into account geographic and trade variables. In the first, we test whether the relationship between income and price levels is stable or whether it changes based on the latitude or the level of openness of a region. The second approach explicitly takes into account the spatial autocorrelation or 'spillover' effects that neighboring regions or countries might have on one another.

2. The usual suspects

Income

Much work has been done on the determinants of price levels at the country level using structural and nonstructural factors as explanatory variables (Balassa 1964; Clague and Tanzi 1972; Kravis and Lipsey 1983; Heston, Nuxoll, and Summers 1994) including the explicit modeling of a spatial component (Aten 1997). Clearly the first variable to come to mind is income. Any explanation of the variation of price levels across countries begins with income, and nominal income is where one would begin in moving from national to regional price levels.

Openness and Human Capital

Openness of the economy, as measured by the sum of exports and imports to total GDP, is a commonly used variable in explaining how price levels differ across countries. One view is that PPPs will be closer to the exchange rate, everything else the same, the more open is the economy. Our dependent variable, price level, is the ratio of the PPP to the exchange rate, and is generally greater than one for high-income countries and less than one for low-income countries. If openness brings PPPs closer to the exchange rate, we would expect its sign to be negative for high-income countries and positive for low-income countries, but factors other than the level of per capita income appear to interact with openness so that its effect is less straightforward.

A number of researchers have also used a human capital variable to explain price levels. The idea is that where human capital is scarce, the price of non-tradables, particularly professional services in health, education and general government will be high. Thus a negative correlation between human capital and price levels across countries is expected. This relationship is not examined in this paper but will be a subject of future research.

Geographic Variables

Gallup, Sachs and Mellinger (1998), among others, explored the role of geographical factors in socio-economic progress across countries. Similar geographical variables such as proximity to water are examined here. We classified each geographical unit into a climate zone, following the modified Koppen classification system described in McKnight and Hess (2002: 207-211). Latitude was used to 'explain' income differences (Gavin and Haussman 1998; Haussman 2001), an approach that has revived a debate on the relationship between economic development and geographical and cultural factors. While our emphasis is on geographical factors, note should be made of a literature of dissent as illustrated by Rodrick, Subramanian and Trebbi (2002). The debate expanded to the realm of physioeconomics - "the economics of physics based physiology, as affected by physiography (climate and terrain)" in Parker (2000:33). Parker's starting point is the strong positive correlation between income levels and latitude, but he conjectures that countries in colder climates require a higher level of consumption than warmer countries to maintain the same 'homeostatic utility level' (2000: 198). Thus, a single measure of per capita income can be interpreted as endogenous to climatic variation as manifested in latitude differences. That is, the relationship between income levels and latitude may exist, but it tells us more about physiological and psychological balance (homeostasis) than about economic well-being and performance (Parker 2000).

In recent work, Aten (2001) considered two models that contrast the significance of latitude as a direct explanatory variable for price level differences versus an indirect measure that captures income variations and only indirectly explains price level differences[7]. In either case, the interpretation of latitude is that it is a proxy for a host of unknown geographic variables such as climate, topology and soil productivity. We find that when climate is taken into account, the role of latitude in explaining variations declines significantly.

In addition, Aten (1997) found that international prices are spatially autocorrelated at given income levels, particularly when trade flows rather than distances represent the interaction among countries. Parker (2000) argued that measures of distance across the sphere are asymmetric – neighboring countries may be more similar across latitudes than by longitude - and a measure of climate distance would be more meaningful. Since trade flows across regions within countries are difficult to obtain, and climate 'distance' is not a well-defined measure, we use instead 19 climate zones dummy variables as well as a matrix of proximity weights between each possible pair of regions and countries. This matrix representing the degree of spatial interaction enables us to test for residual variation that may persist after latitude, proximity to water, and climate are taken into account.

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[7] The two models used by Aten followed Casetti's (1997) grouping of conventional versus expansion equations. The initial specification was conventional, using income, openness of the economy and latitude as independent variables in the model. The second approach hypothesizes that the economic variables are primary, but their coefficients vary geographically. In other words, the parameters of the economic variables are allowed to drift in geographic space. This approach emphasized the two-stage structure of the model and suggests that "the variables in the initial model carry a higher priority than the expansion variables." (Casetti 1997:15).

3. Model with expansion variables

In this first specification outlined in (3) below, the price levels of countries and regions are assumed to be spatially independent. That is, there is no *a priori* expectation that values in one geographic unit are more similar (or dissimilar) to another because of their spatial proximity.

$$(3)\quad PL_j = a_1 Y_j + \sum_{i=1}^{n} b_i C_{ij} + \sum_{i=1}^{m} g_i D_{ij} + e_j$$

PL_j is the price level in country or region (*j*), relative to the United States, Y_j is the per capita GDP in I$, C_j is a continuous variable such as latitude, or openness, and D_j is a dummy variable such as climate zone. The dummy variables include indicators of spatial heterogeneity, such as access to water, or a political-economic grouping like former Soviet republics, or Caribbean Islands. Non-linear versions of the model are also tested. The error terms (å) are assumed to be uncorrelated, with mean zero and constant variance. As a variation of (3), we relax the assumption of an invariant income parameter, suggesting instead that it may change with latitude or openness. That is described in (4) below, where we hypothesize that the parameter a_1 is determined by the variable(s) C_i.

$$(4a)\quad PL_j = a_{1j} Y_j + \sum_{i=1}^{m} g_i D_{ij} + e_j \quad \text{and}$$

$$(4b)\quad a_{1j} = d_0 + \sum_{i=1}^{n} d_i C_{ij}$$

Substituting (4b) into (4a) yields:

$$(4c)\quad PL_j = d_0 Y_j + \sum_{i=1}^{n} d_i C_{ij} Y_j + \sum_{i=1}^{m} g_i D_{ij} + e_j$$

In other words, we assume that latitude and/or openness may affect price levels, but their effect depends on the per capita income levels. The coefficients on the dummy variables represent the intercept or initial level of the dependent variable, and each one is tested alone and in combination with other dummy variables such as climate, water access, regional grouping and data type. Data type refers to the fact that four out of the 36 countries with regional data had regional product rather than income data. We also try to capture differences that may arise because countries have participated in the 1996 benchmark study that is the basis for the PPP estimates of PWT 6.1. There are 115 countries in the 1996 benchmark, and out of the remaining 52 non-benchmark countries in PWT, only China, Colombia, India, Malaysia, and South Africa had sub-national data. The regional groupings consist of 15 world regions (West, Central, Eastern and Southern Africa, North Africa and the Middle East, North and South America, the Caribbean, Central, Eastern, Southeastern and Southwestern Asia, East and West Europe and Oceania).

4. Model with spatial interaction

The expansion model in (4c) and the various geographic dummy variables capture the effects of levels of income, openness and geography on the price levels, that is the spatial heterogeneity of the data, but do not tell us anything about the pair-wise relationships between geographic units. For example, is there a ripple or spillover effect such that regions with high price levels can be expected to be closer to each other, even after latitude, region and climate are taken into account? We look at the residual maps and also test for autocorrelation[8] and try to specify the nature of this autocorrelation in the models below.

The weights matrix W is added to our previous equations as a spatial autoregressive error term, so that the original error term å in specification (3 and 4c) is no longer homoskedastic and uncorrelated:

$$(5a) e_j = lWe_j + x_j$$

î now has mean zero and constant variance (if our specification of the weights matrix does indeed capture the residual autocorrelation). Substituting into (3) we obtain the spatial error model (5b):

$$(5b)\ PL_j = a_1 Y_j + \sum_{i=1}^{n} b_i C_{ij} + \sum_{i=1}^{m} g_i D_{ij} + lWe_j + x_j$$

Similarly, substituting into (4c) we obtain the expansion model with a spatially autoregressive term (6):

$$(6)\ PL_j = d_0 Y_j + \sum_{i=1}^{n} d_i C_{ij} Y_j + \sum_{i=1}^{m} g_i D_{ij} + lWe_j + x_j$$

Spatial interaction is represented by the W matrix of bilateral weights representing the arc distance (great circle distance, in miles) between each possible pair of geographic units defined by the latitude and longitude of the capital city of each region. The weights are inversely proportional to the square of the distance. In other words, units that are near have a greater weight than those that are far apart. There is a growing literature on the choice of weights and the sensitivity of the chosen matrix to capturing spatial interaction, and we test a set of contiguity and nearest neighbour matrices in addition to the distance matrices[9]. Contiguity is equivalent to a dummy

[8] Spatial autocorrelation diagnostics include Moran's I, the Lagrange Multiplier test and the Kelejian-Robinson statistic, implemented in SpaceStat© v. 1.90© 1999.
[9] Two inverse distance matrices (the linear and quadratic versions), nine contiguity matrices (based on distances of 100, 200, 300, 400, 500, 1000, 2000, 3000 and 5000 miles) and eleven nearest neighbour matrices (k=1-10 and 15) were tested.

weight – that is, the weight between a pair of units is one if the units are within a certain distance (ranging from 100 miles to 5000 miles) of each other and equal to zero otherwise. Nearest neighbour matrices also contain zeroes if an observation is not a k-nearest neighbour (with k ranging from 1 to 15), and one otherwise.

D. Results

We report results for the expansion equation (4c) and the expansion with a spatial autoregressive term (6) in log form. Table 3 shows the estimated coefficients and some diagnostics[10]. The traditional R^2 is not a good measure-of-fit for the spatial lag models, although a pseudo-R^2 based on the ratio of the variance of the predicted values to the variance of the observed values of the dependent variable is shown. The correct measure of fit is the log likelihood, and the models with the highest log-likelihood are preferred (Anselin 1999).

The independent variable is the price level (*PL*), with the U.S. equal to 100. *Y* is the nominal per capita GDP in dollars at purchasing power parities (or International $), *Open* is the sum of exports and imports as a percentage of GDP, and *Latitude* is the absolute latitude in decimal degrees. The log transformation of each variable is denoted by the prefix *Ln*. The set of dummy variables are for climate, benchmark, water proximity and regional grouping.

Table 3. **Model Results** (N=871) Dependent = Ln of Price Level	Expansion (4c)	Spatial Error (6)
Ln Y	0.16* (.06)	0.29** (.04)
Ln Latitude	-0.53* (.17)	0.15 (.12)
Ln Open	-0.88** (.24)	-0.57* (.20)
Ln Latitude * Ln Y	0.06* (.02)	-0.01 (.01)
Ln Open * Ln Y	0.08* (.03)	0.05* (.02)
Wå (autoregressive term)	-	0.83** (.02)
Dummy variables[a] (climate-water-benchmark-region)		
Bsh-0-1-1	1.87** (.41)	3.65** (.52)
Aw-0-1-1	1.97** (.41)	3.89** (.50)
Cfa-1-1-8	2.09** (.43)	3.19** (.59)
Adjusted R^2	0.89	0.81
Mean Square Error ML (ó^2)	.039	.023
Log-Likelihood	175	407

**p<0.001; *p< 0.005 (Standard errors in parentheses)
[a] Shows only the largest 3 coefficients that are common to both specifications. Detailed model results are available from the authors.

[10] Model results are obtained from SpaceStat version 1.90© 1999, Luc Anselin.

Both models imply that price levels rise with income as expected. Openness has an apparent dampening effect but at given income levels it raises the price level. Similarly, the latitude coefficient is significantly negative but its effect is positive when expanded from the income variable. The significance of the expansion variables suggests that there is an intermediate influence of trade and geography on the relationship between income levels and price levels. Casetti (1992) describes a Bayesian regression to determine the stability of the initial income parameter but such an exercise is not attempted here. An interesting interpretation of the expansion variables is that they indicate how geography and trade (as measured by latitude and openness) change the effects of income levels on the price levels, and alternatively, how the effectiveness of income levels as determinants of price levels depends on geography and trade.

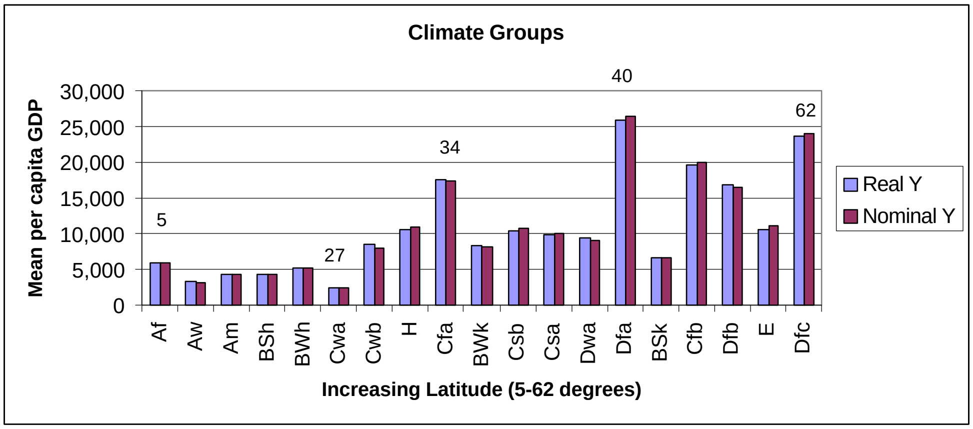
When we divide the data into two groups, above and below median per capita GDP, the coefficients on the low-income group change signs, but are much less significant. One interpretation of the changing sign on the openness variable is that it does bring the PPPs closer to the exchange rate, and hence is positive for high income countries that have a price level above one (PPP greater than exchange rate) and negative for low income countries with price levels below one (PPPs less than the exchange rate). Due to the instability of the coefficients for the low-income grouping, and an analysis of the pooled versus separate model variances, the pooled model is preferred.

The dummy variables combine climate, water proximity, benchmark participation and regional grouping. For example, the Bsh-0-1-1 dummy indicates regions in the Hot, Dry, Low-latitude Steppe climate classification, without water access, with participation in the 1996 benchmark comparison and located in West Africa.

In the spatial error model, the latitude coefficients are no longer significant but the coefficient on the W matrix is large, positive and very significant (0.83). This result suggests that the spatial variation that was previously attributed to latitude is now captured by the spatial proximity matrix. Various W matrices were tested, and the one reported here (because it resulted in the highest likelihood function) is the k-nearest neighbour matrix with k=5. That is, for each observation, only the 5 nearest observations, measured by the arc distance between them in miles, are considered neighbors. Another difference between the spatial error (6) and the simple expansion (4c) model results is that that the income coefficient is higher (0.29 versus 0.16), and openness has less of a dampening effect (-0.57 versus –0.88). The dummy variable levels are also higher, and the residuals tend to be smaller for the low-income countries.

Figure 1 is the breakdown of mean nominal and predicted real per capita GDPs by the climate groups. The groups are ordered by increasing latitude, and it can be seen that the distribution of incomes is not simple, with clusters of low-income regions in mid-latitude climates (BWk, Csb, Csa, Dwa and Bsk) and a downward trend between 40 and 60 degrees latitude.

Figure 1



A description of the climate types and the observed and predicted price levels and estimated real incomes (based on Equation 6) are shown in Table 4. The highest price levels are found in Cfa, Cfb, Dfa and Dfc, representing mid-latitude and severe mid-latitude climates, a pattern that follows the one shown in Figure 1 for income levels. Climates Cfa and Cfb have the highest number of observations (110 and 139 respectively), corresponding to 34 and 51 degrees of latitude on average. Also, the sub-tropical latitudes below 22 degrees of latitude (Af, Aw, Am, BSh, BWh) have lower incomes than the higher latitude regions, but latitude *per se* does not appear to be the determining factor. The relationship between latitude and price levels disappears altogether when we take into account proximity (as measured by their interaction with their nearest neighbors), and more detailed geographic variables such as climate.

Table 4

Climate Group	**Sub-type**	***N***	**PL**	***Predicted PL***	***Real Y (I$)***	**Koppen**
A: Tropical Humid	Af	*62*	47.6	*45.8*	*5938*	Tropical Rainforest
	Am	*42*	36.5	*36.2*	*4297*	Tropical Monsoon
	Aw	*67*	50.4	*50.9*	*3258*	Tropical Savanna
B: Dry	BSh	*51*	48.2	*49.2*	*4183*	Steppe, Low-latitude, hot
	BSk	*68*	42.8	*42.2*	*6602*	Steppe, Mid-latitude, cold
	BWh	*41*	35.6	*35.8*	*5148*	Desert, Low-latitude, hot
	BWk	*13*	41.1	*39.5*	*8378*	Desert, Mid-latitude, cold
C: Mid Latitude	Cfa	*110*	103.4	*102.3*	*17679*	Humid Subtropical w/o dry season, hot summers
	Cfb	*139*	118.7	*120.2*	*19694*	Marine West Coast w/o dry season, warm to cool summers
	Cfc	*N/A*	-	-	-	Marine West Coast w/o dry season, warm to cool summers
	Csa	*95*	67.8	*68.8*	*9725*	Mediterranean, dry, hot summers
	Csb	*14*	74.9	*76.5*	*10435*	Mediterranean, dry warm

Table 4						
Climate Group	**Sub-type**	***N***	**PL**	***Predicted Real Y*** ***PL***	***(I$)***	**Koppen**
						summers
	Cwa	*16*	20.5	*19.5*	*2370*	Humid Subtropical, dry winters, hot summers
	Cwb	*3*	38.4	*35.7*	*8499*	Humid Subtropical, dry winter, warm summers
D: Severe Midlatitude	Dfa	*18*	123.6	*127.2*	*25952*	Humid Continental w/o dry season, hot summers
	Dfb	*70*	87.1	*84*	*16907*	Humid Continental w/o dry season, warm summers
	Dfc	*7*	109.3	*108.7*	*23765*	Subarctic w/o dry season, cool summers
	Dfd	*N/A*	-	-	-	Subarctic w/o dry season, very cold winters
	Dwa	*8*	51.4	*49.5*	*9370*	Humid Continental, dry winters, hot summers
	Dwb	*N/A*	-	-	-	Humid Continental, dry winters, warm summers
	Dwc	*N/A*	-	-	-	Subarctic, dry winters, cool summers
	Dwd	*N/A*	-	-	-	Subarctic, dry winters, very cold winters
E: Polar	E	*1*	71.5	*75.2*	*10501*	Polar
H: Highland	H	*46*	68.6	*70.5*	*10644*	Highland, cold due to elevation

Obs	***871***	**PL**	**Real Y (I$)**	***Open (%)***	***Latitude (absolute)***
Means		**73.2**	**11,422**	**58.1**	**33.4**

Table 5 and 6 look at what difference regional price levels make for estimates of regional incomes. We take estimates of real income based on equation (6), and compare them with nominal incomes. First, for countries without regional data, we take the real estimates of per capita GDP at PPPs from PWT 6.1 as the measure of income. For countries with regional data we also introduce the constraint as follows. From equation 6 we take the estimated value using the country inputs as a ratio to the PWT 6.1 value of the price level. This factor is used to adjust the estimated real income value for each region of a country to the level that is consistent with nominal income for the country. There are other ways this can be done, but the method chosen is fairly simple and makes the levels of the nominal and real estimates comparable.

Table 5 Nominal vs. Real Income	I$ 1996	Mean	Range	CV %
WORLD	Nominal Y	11,468	51,567	79
	Real Y	*11,422*	*46,802*	*78*
Pakistan	Nominal Y	2,081	166	4
	Real Y	*2,090*	*439*	*10*
Brazil	Nominal Y	5,185	5,367	34
	Real Y	*5,095*	*4,931*	*29*
Great Britain	Nominal Y	18,980	14,132	15
	Real Y	*19,923*	*10,999*	*12*
Italy	Nominal Y	19,777	14,008	24

Table 5 Nominal vs. Real Income	I$ 1996	Mean	Range	CV %
	Real Y	*20,098*	*18,464*	*30*
U.S.A.	Nominal Y	27,993	20,193	16
	Real Y	*27,937*	*17,435*	*15*

Table 5 compares the range and variability of nominal and real incomes for a selected group of countries. Brazil and Italy are included in Table 5 because they are both noted for having large North-South differences in income, and the United Kingdom is included because within the European Union it is noted for relative smaller regional variation. Pakistan and Italy illustrate that the income effect on price levels does not dominate in all countries. The range between lowest and highest real incomes increases for these two countries and does so for 6 out of the 36 countries with regional breakdowns (Nigeria, Pakistan, South Africa, Argentina, Spain and Italy). In contrast, the range decreases by over 10% for Great Britain, the United States and Brazil, and by 9% for the world (from 51,567 to 46,802). Taking account of the price variability in this indirect way is suggestive of interesting relationships, but it does not lead us to radically different views of the world.

Table 5 is interesting with respect to within-country relationships, such as the conventional story that the spread of incomes in Italy is much higher than in England. At least for 1996 this is true in real terms but not true in nominal terms. In terms of the coefficient of variation Italy and Brazil have the largest variability and the United States has more variability in real terms than Great Britain.

Finally there are shifts among cities, with Milano being highest in nominal terms but Trieste highest in real terms in Italy. Catanzaro in Calabria is lowest in nominal and real terms, 11,896 and 12,380 respectively. Low honors in Great Britain go to Liverpool at just under 15,000 in nominal and 15,800 in real terms. In the United States, Connecticut is higher in real terms and the District of Columbia in nominal terms; Mississippi takes low place in nominal terms and West Virginia in real terms. Since a great deal of political interest attaches to such figures, it is worth stressing that if our method of correction has merit, there is good reason to use real measures.

In Table 6, our predicted price level estimates are compared to the Accra (previously *American Chamber of Commerce Researchers Association)*[11] estimates for 1996. Their index is based on expenditure weights for upper-level white-collar workers, and collates price reports only for metropolitan areas. Nonetheless ACCRA estimates give us some idea of the variation within the United States, and may expose some of our weaker estimates, for example, Nebraska seems high with a price level of 100 (equal to the US average). Our estimate for Hawaii appears to be too low (93), although there is no comparable Accra estimate for that year.

[11] ACCRA's methodology and cost of living indexes are available on the web at http://www.coli.org.

Table 6		United States	
Accra	**Predicted Equation (6)**	**State**	**City**
93	97	Alabama	Montgomery
126	102	Alaska	Juneau
106	101	Arizona	Phoenix
87	98	Arkansas	Little Rock
103	107	California	Sacramento
104	102	Colorado	Denver
125	104	Connecticut	Hartford
104	103	Delaware	Dover
127	107	D.C.	Washington D.C.
108	100	Florida	Tallahassee
94	100	Georgia	Atlanta
-	93	Hawaii	Honolulu
97	101	Idaho	Boise
101	103	Illinois	Springfield
97	100	Indiana	Indianapolis
99	100	Iowa	Des Moines
96	101	Kansas	Topeka
90	98	Kentucky	Frankfort
100	97	Louisiana	Baton Rouge
-	98	Maine	Augusta
105	103	Maryland	Annapolis
144	101	Massachusetts	Boston
106	102	Michigan	Lansing
100	103	Minnesota	Saint Paul
92	95	Mississippi	Jackson
94	101	Missouri	Jefferson City
102	97	Montana	Helena
90	100	Nebraska	Lincoln
103	102	Nevada	Carson City
104	102	New Hampshire	Concord
-	102	New Jersey	Trenton
113	99	New Mexico	Santa Fe
113	101	New York	Albany
100	99	North Carolina	Raleigh
97	99	North Dakota	Bismark
104	100	Ohio	Columbus
92	98	Oklahoma	Oklahoma City
105	100	Oregon	Salem
101	101	Pennsylvania	Harrisburg
107	98	Rhode Island	Providence
96	97	South Carolina	Columbia
102	99	South Dakota	Pierre
94	100	Tennessee	Nashville
101	99	Texas	Austin
104	97	Utah	Salt Lake City

Table 6		United States	
Accra	**Predicted Equation (6)**	**State**	**City**
107	100	Vermont	Montpelier
103	101	Virginia	Richmond
107	102	Washington	Olympia
99	99	West Virginia	Charleston
112	101	Wisconsin	Madison
95	99	Wyoming	Cheyenne

Two comments about Table 6 relate to the underlying Accra data and to our estimates. Accra data gives a reasonable weight to housing, 20%, but 90% of that is applied to homeowners rent as built up from prices of houses and their costs. Because house price variability is high and comparability is very hard to hold constant across space, the Accra index probably overstates the variability of prices across United States states. However, the variability of our estimates across states is probably low, given the studies of Kokoski, Cardiff and Moulton (1994).

E. Conclusions

This paper argues for the importance of knowing regional differences in prices within countries. While the type of price comparisons needed is analogous to those used in international comparisons, such price data are available for very few countries. Some illustrations make clear that these differences can be quite significant. Further we argue that there are ways to use price data collected for time-to-time price indexes in a way that can allow such estimates.

In terms of regional incomes, we presented models of price level determination that permit price levels to differ between and within countries. The preferred estimating equation takes account of spatial interaction among all possible pairs of the 871 geographical units in our world, using a k-nearest neighbor matrix of weights as a measure of interaction, in addition to climate and regional characteristics. We find that latitude is not a significant variable because it fails to take into account the spatial autocorrelation and spatial spillover effects of the relationship among prices, incomes and openness of the economy. When the resulting real income differences between regions are compared with nominal differences, there is some plausible compression of the distribution overall, but a dispersion of incomes for six relatively large countries. The relative ordering within countries may also change. Examples include Mississippi in the United States, which is the poorest in nominal terms, but richer than West Virginia in real terms.

We believe this paper reinforces the value of having direct regional price information and the need in the future to consider other variables that might better proxy price variations within countries. Another test of our results will be the relative performance of the nominal and real incomes as explanatory variables of other relationships not involved in the construction of our real income measures. Some of this testing will be undertaken by the authors in the future, but we hope also by other researchers[12].

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[13] Available at http://pwt.econ.upenn.edu
[14] Available at http://oecd.org/std/ppp/MTG2001

APPENDIX

Sources of Regional Income Data

- Austria, Belgium, Germany, Spain, France, Italy, Luxembourg, Portugal, Finland, United Kingdom: *Eurostat*
- India: *The Madhya Pradesh Human Development Report (1995), Pauls Press, New Delhi.Statistical Pocket Book: India (1993), National Council of Applied Economic Research, (1993)*
- Japan: *Statistics Bureau Management and Coordination Agency, Government of Japan (1996)*
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