UNITED NATIONS UNIVERSITY

UNU-MERIT

Working Paper Series

#2009-064

A structural nonparametric reappraisal of the CO_2 emissions-income relationship

Théophile T. Azomahou, Micheline Goedhuys and Phu Nguyen-Van

United Nations University - Maastricht Economic and social Research and training centre on Innovation and Technology
Keizer Karelplein 19, 6211 TC Maastricht, The Netherlands
Tel: (31) (43) 388 4400, Fax: (31) (43) 388 4499, e-mail: info@merit.unu.edu, URL: http://www.merit.unu.edu

A structural nonparametric reappraisal of the CO_2 emissions-income relationship

Théophile T. Azomahou[a*], Micheline Goedhuys[a], Phu Nguyen-Van[b]

[a] UNU-MERIT, Maastricht University
Keizer Karelplein 19, 6211 TC Maastricht, the Netherlands

[b] BETA-CNRS, Université de Strasbourg
61 avenue de la Forêt Noire, F-67085 Strasbourg Cedex, France

December, 2009

Abstract

Relying on a structural nonparametric estimation, we show that CO_2 emissions clearly increase with income at low income levels. For higher income levels, we observe a decreasing relationship, though not significant. We also find that CO_2 emissions monotonically increases with energy use at a decreasing rate.

Keywords: Nonparametric triangular systems, EKC; Energy use; CO_2 emissions

JEL Classification: C14; O13

UNU-MERIT Working Papers
ISSN 1871-9872

Maastricht Economic and social Research and training centre on Innovation and Technology, UNU-MERIT

UNU-MERIT Working Papers intend to disseminate preliminary results of research carried out at the Centre to stimulate discussion on the issues raised.

*Correspondence: Azomahou T., Tel. +31 433884440, Fax +31 433884499, e-mail: azomahou@merit.unu.edu; M. Goedhuys (micheline.goedhuys@skynet.be), P. Nguyen-Van (nguyen-van@unistra.fr)

1 Introduction

The concept of the Environmental Kuznets Curve (EKC), introduced by Grossman and Krueger (1995), is a hypothesized relationship among various indicators of environmental degradation and income per capita. In its basic specification, it assumes that during the early stages of economic development, environmental damage and pollution increase. Beyond some level of income per capita, also termed turning point, the trend reverses and economic development leads to environmental quality improvement.

While the inverted U-shape of the EKC has been confirmed for several environmental quality indicators (see Azomahou et al., 2006, for a literature review), for CO_2 emissions a lot of controversy remains. Indeed, the majority of studies mainly based on reduced-form single-equation models find emissions to monotonically increase with income. These models however do not account for possible feedback effects of the environment to economic growth, or for the fact that the economy and the environment are jointly determined, as explained by Perrings (1987). Omission to account for feedback effects may lead to simultaneity bias and inconsistent estimates (Stern et al. 1996). As far as we know, Liu (2005) provided the first study of the relationship between CO_2 emissions and income based on a parametric two-equations system. The author underlined the crucial role of energy use in the system and concludes on a negative relationship between CO_2 emissions and income. However, given the sample used by Liu (2005) – 24 OECD countries over the period 1975-1990 – this result may not be representative to conclude on the existence of a CO_2 emissions-EKC.

In this study, we propose a structural nonparametric estimation of the emissions-EKC, relying on the nonparametric triangular system of Newey et al. (1999). By using a structural model, we improve the specification to account for simultaneity between income and emissions. In addition, by relying on a nonparametric framework we allow for non-linearities of unknown form in the income-environment relationship. It is worth noticing that the nonparametric methodology has been applied to reduced form EKC models (Millimet et al., 2003; Bertinelli and Strobl, 2005; Azomahou et al., 2006; Nguyen Van, 2009) showing indeed important non-linearities. However, to the best of our knowledge, our study is the first to analyse the CO_2 emissions-EKC in a structural nonparametric specification.

We apply this methodology to panel data of 107 countries, both low and high income countries, over a 44 year period (1961-2004), thus having an excellent coverage in time and income dispersion. Although our results are not supportive for the existence of an EKC for CO_2 emissions, we find that CO_2 emissions firstly increase with income at low income levels and then become delinked with income at high income levels. We also find that CO_2 emissions monotonically increases with energy use at a decreasing rate.

2 Structural nonparametric specification

We consider the triangular nonparametric simultaneous specification of Newey et al. (1999):

$$y = m(x, z_0) + \varepsilon \quad (1)$$

$$x = \pi(\mathbf{z}) + u, \qquad \mathbb{E}(\varepsilon|u, \mathbf{z}) = \mathbb{E}(\varepsilon|u) \neq 0, \quad \mathbb{E}(u|\mathbf{z}) = 0 \quad (2)$$

where y, x and z_0 denote respectively CO_2 emissions per capita, GDP per capita and energy use per capita; $\mathbf{z}$ is a set of instruments that includes z_0. The system (1)-(2) is a generalization of the limited information simultaneous equations model to allow for structural nonparametric relation $m(x, z_0)$ between variables y, x and z_0, and a nonparametric reduced form $\pi(\mathbf{z})$. The conditional expectation of equation (1) yields the integral equation:

$$\mathbb{E}(y|\mathbf{z}) \equiv \pi(\mathbf{z}) = \mathbb{E}[m(x, z_0)|\mathbf{z}] = \int m(x, z_0) F(dx|\mathbf{z}) \tag{3}$$

where F denotes the conditional cumulative distribution function of x given $\mathbf{z}$. Thus, functions π and F are the nonparametric generalization of the reduced forms for y and x. Newey et al. (1999) discussed the identification of the system (1)-(2).[1] Starting from a preliminary estimation of the reduced forms $\hat{\pi}$ and $\hat{F}$:

$$\hat{\pi}(\mathbf{z}) = \int m(x, z_0) \hat{F}(dx|\mathbf{z}), \tag{4}$$

the authors developed an estimator for $\hat{m}$ that overcomes the well known ill-posed problem.[2] In order to apply this methodology to analyze the EKC, we specify a generalized additive model (hereafter GAM) for fixed effects panel data.[3] For equation (1), the GAM is

$$y_{it} = \sum_{j=1}^{p} m_j(w_{it}^j) + \mu_i + \varepsilon_{it}, \qquad i = 1, \cdots, N, \quad t = 1, \cdots, T \tag{5}$$

where w_{it}^j is the jth component $(j = 1, \cdots, p)$ of $\mathbf{w}_{it} \equiv (x_{it}, z_{0it})$. For equation (2) we use a semiparametric GAM specification the structure of which is given by

$$x_{it} = \sum_{k=1}^{q} \pi_j \left(z_{1it}^k \right) + \mathbf{z}_{2it}' \gamma + \lambda_i + u_{it}, \qquad i = 1, \cdots, N, \quad t = 1, \cdots, T \tag{6}$$

where z_{1it}^ks is the kth component $(k = 1, \cdots, q)$ of the set of continuous instruments $\mathbf{z}_1$ and $\mathbf{z}_{2it}$ corresponds to other instruments which do enter linearly in the specification. The unobserved fixed effects μ_i and λ_i can be eliminated by first differences:

$$y_{it} - y_{i,t-1} = \sum_{j=1}^{p} \left[m_j(w_{it}^j) - m_j(w_{i,t-1}^j) \right] + \varepsilon_{it} - \varepsilon_{i,t-1} \tag{7}$$

$$x_{it} - x_{i,t-1} = \sum_{k=1}^{q} \left[\pi_j \left(z_{1it}^k \right) - \pi_j \left(z_{1i,t-1}^k \right) \right] + (\mathbf{z}_{2it} - \mathbf{z}_{2i,t-1})' \gamma + u_{it} - u_{i,t-1} \tag{8}$$

Observe that the method of Newey et al. (1999) consists of estimating equation (7) by including an additional control variable which is the first difference residuals $\hat{u}_{it} - \hat{u}_{i,t-1}$ computed from equation (8). Therefore, estimation of equation (7) involves in total five univariate unknown functions associated to x_{it}, $x_{i,t-1}$, z_{0it}, $z_{0i,t-1}$, and $\hat{u}_{it} - \hat{u}_{i,t-1}$. We perform estimation in two steps: (i) we construct semiparametric first differences residuals $\hat{u}_{it} - \hat{u}_{i,t-1}$ of equation (8) where the parametric estimates $\hat{\gamma}$ are obtained using the Robinson's (1988) procedure. (ii) We estimate

[1] Identification is needed as π and F are functionals of the distribution of observables $(y, x, \mathbf{z})$.

[2] The ill-posed inverse problem follows from non-continuity of $\hat{m}$. Indeed, lack of continuity of $\hat{\pi}$ and $\hat{F}$ can translate into large inaccuracies in $\hat{m}$.

[3] See, e.g., Hastie and Tibshirani (1990) for further details on GAM.

the nonparametric model in equation (7) using the residuals $\hat{u}_{it} - \hat{u}_{i,t-1}$ from (i) as additional regressor. In practice, we base our nonparametric estimation on the 'backfitting algorithm' (Hastie and Tibshirani, 1990). Furthermore, as m_j is estimated twice, denoted as $\hat{m}_j^{(1)}$ and $\hat{m}_j^{(2)}$ for w_{it}^j and $w_{i,t-1}^j$ respectively, a simple and more precise estimator of m_j can be obtained by a weighted average: $\hat{m}_j = (\hat{m}_j^{(1)} + \hat{m}_j^{(2)})/2$.

3 Data and estimation results

3.1 Data

The data used for the analysis consist of an unbalanced panel of 107 countries, both developed and developing countries and spanning the period 1961-2004. The data are obtained from the *World Development Indicators* database 2007. For equation (6), GDP per capita, measured in constant 2000 US dollars, is used as dependent variable. The variables included in $\mathbf{z}_1$ are primary energy use per capita (in kilotons of oil equivalent), foreign direct investment (net inflows), population density, trade openness (imports plus exports divided by GDP). Variables included in $\mathbf{z}_2$ are regional dummies (East Asia & Pacific, Europe & Central Asia used as reference, Latin America & Caribbean, Middle East & North Africa, North America, South Asia, Sub-Saharan Africa) and year dummies, to control for autonomous technological change and macroeconomic effects. For equation (5), we use CO_2 emissions per capita (in metric tons) as dependent variable. Similar to Liu (2005), the regressors included in equation (5) are GDP per capita and primary energy use per capita. Statistics in Table 1 (for 1961, 1982, 2004 and for the whole sample) show that on average, GDP and CO_2 emissions increase over time while energy use remains stable.

Insert Table 1 here

3.2 Estimation results

Estimation results are presented in Figure 1 and Table 2. The curves displayed in Figure 1 correspond to the structural nonparametric functions discussed in the previous section.[4] We use the 'gain' statistic (see Hastie and Tibshirani, 1990, for further details) to test the significance of non-linearity in the econometric specification.[5] Table 2 summarizes the 'gain' statistics. As can be checked from the p-values, all the parametric functions are strongly rejected in favor of the nonparametric counterparts, meaning that our nonparametric specification provides a better approximation of the data.

Insert Table 2 here

From Figure 1(a) we observe a positive and significant effect of income on CO_2 emissions for low income levels. The turning point is located near 16500 USD per capita GDP, beyond

[4]We do not report the results of the reduced-form estimation, since the control variables in equation (8) are only used for the sake of instruments. The results are available from the authors upon request. Moreover, in estimations all the nonparametric functions are normalized to have zero means.

[5]The 'gain' is the difference in normalized deviance between the GAM and the parametric linear models. Its distribution is approximated by a χ^2 $(df = df_g - df_l)$, where df_g denotes the degree of freedom of the GAM and df_l is the degree of freedom of the analogue parametric linear model.

this point the relationship turns negative.[6] Nevertheless, this decreasing part is not significant. The proportion of observations located beyond the turning point is about 10%.[7] Compared to Liu (2005) who found a downward slope in a panel of 24 OECD countries over the period 1975-1990, we equally observe such a trend for high income levels implying that the negative effect of income on CO_2 emissions is at least neutralized.

Insert Figure 1 here

In Figure 1(b), we plot the estimated curve for CO_2 emissions and energy use. As outlined by Liu (2005), the latter can be viewed as a proxy to account for differences in industrial structure across nations which may explain their ability to reduce emissions. This relationship is monotonically increasing with a concave pattern, meaning that CO_2 emissions increase with energy use but at a decreasing rate. We can interpret this finding as the presence of a learning effect, a technological improvement, and/or changes in energy composition (shifts from fossil energies, which are sources of CO_2 emissions, to non-fossil energies) that allow for limiting CO_2 emissions when using energy. It seems that more energy intensive economies are more likely to implement cleaner technologies and stringent environmental policies which in turn might neutralize the positive effect of income on CO_2 emissions.

4 Conclusion

We show that CO_2 emissions clearly increase with income at low income levels. For higher income levels, we observe a non significant decreasing slope. This finding reconciles previous results based on different specifications and partial data. Moreover, CO_2 emissions rise with energy use but at a decreasing rate. These results show that for a given industrial structure of the economy, higher income countries are likely to achieve the delinking of CO_2 emissions from income.

References

Azomahou, T., Laisney, F. and P. Nguyen Van, P., 2006. Economic development and CO_2 emissions: A nonparametric panel approach, Journal of Public Economics 90, 1347-1363.

Bertinelli, L. and E. Strobl, 2005. The environmental Kuznets curve semi-parametrically revisited, Economics Letters 88, 350-357.

Grossman, G.M. and A.B. Krueger, 1995. Economic growth and the environment, The Quarterly Journal of Economics 60, 353-377.

Hastie, T.J. and R.J. Tibshirani, 1990. Generalized Additive Models, Chapman and Hall, London, New York.

Liu, X. 2005. Explaining the relationship between CO_2 emissions and national income-The role of energy consumption, Economics Letters 87, 325-328.

[6] The exact value of the turning point is computed at 16457.47 USD per capita GDP.

[7] The corresponding countries are Australia, Austria, Belgium, Canada, Denmark, Finland, Iceland, Israel, Kuwait, the Netherlands, Norway, Sweden, Switzerland.

Millimet, D.L., J.A. List and T. Stengos, 2003. The environmental Kuznets curve: Real progress or misspecified models? Review of Economics and Statistics 85, 1038-1047.

Newey, W.K., J.P., Powell and F. Vella, 1999. Nonparametric estimation of triangular simultaneous equations models, Econometrica 67, 565-603.

Nguyen-Van P., 2009. Energy consumption and income: A semiparametric panel data analysis, Energy Economics, forthcoming.

Perrings, C., 1987. Economy and environment: A theoretical Essay on the interdependence of economic and environmental systems. Cambridge: Cambridge University Press.

Robinson, P.M., 1988. Root-N-consistent semiparametric regression. Econometrica 56, 931-954.

Stern, D.I., M.S., Common and E.B. Barbier, 1996. Economic growth and environmental degradation: The environmental Kuznets curve and sustainable Development, World Development 24, 1151-1160.

Table 1: Descriptive statistics

	GDP per capita				CO_2 emissions per capita				Energy use per capita			
	mean	std.	min.	max.	mean	std.	min.	max.	mean	std.	min.	max.
1961	2996.034	4020.431	77.662	19959.91	2.404	4.726	0.008	36.319	0.00243	0.0021	0.0003	0.01
1982	5163.583	7156.795	124.515	39368.63	4.701	9.238	0.027	90.425	0.00239	0.0034	0.0001	0.023
2004	6678.001	9977.794	86.45	49996.1	5.424	8.05	0.013	69.159	0.00237	0.003	0.0002	0.02
pooled	5258.663	7722.851	56.468	59182.83	4.927	11.02	0.0005	183.836	0.00238	0.003	0.0001	0.036

Table 2: Gain statistics test

Form[a]	Gain value	Degree of freedom	p-value
$\hat{m}_1(x_{it})$	2.518	4.486	0.007
$\hat{m}_1(x_{i,t-1})$	4.311	6.972	0.000
$\hat{m}_2(z_{0it})$	50.863	7.979	0.000
$\hat{m}_2(z_{0i,t-1})$	49.628	4.665	0.000
$\hat{m}_3(\hat{u}_{it} - \hat{u}_{i,t-1})$	2.617	4.996	0.005

[a]: x is GDP, z_0 is energy use, and u is the residuals of equation (4).

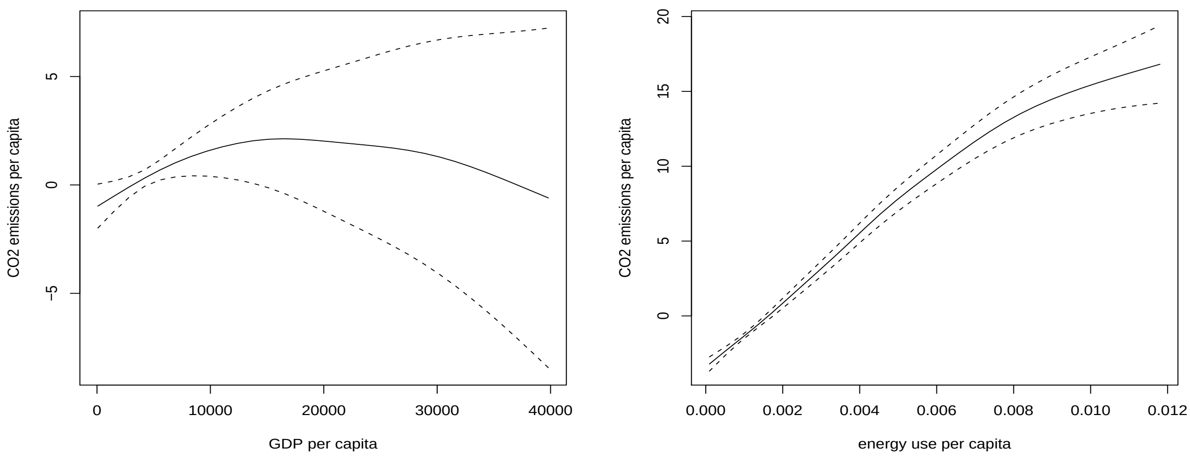

Figure 1: Structural nonparametric estimations. [left (a)]: CO_2 emissions – income relationship. [right (b)]: CO_2 emissions – energy use relationship. The solid line represents the nonparametric fit. The dashed lines correspond to the 95% pointwise confidence interval.

The UNU-MERIT WORKING Paper Series

2009-01 *Effectiveness of R&D Tax Incentives in Small and Large Enterprises in Québec* by Rufin Baghana and Pierre Mohnen
2009-02 *Bridges in social capital: A review of the definitions and the social capital of social capital researchers* by Semih Akçomak
2009-03 *The Role of Firms in Energy Transformation* by Radhika Perrot
2009-04 *Standards as a platform for innovation and learning in the global economy: a case study of Chilean salmon farming industry*
2009-05 *Consumer behaviour: evolution of preferences and the search for novelty* by M. Abraham Garcia-Torres
2009-06 *The role of consumption and the financing of health investment under epidemic shocks* by Théophile T. Azomahou, Bity Diene and Luc Soete
2009-07 *Remittances, lagged dependent variables and migration stocks as determinants of migration from developing countries* by Thomas H.W. Ziesemer
2009-08 *Thinking locally: Exploring the importance of a subsidiary-centered model of FDI-related spillovers in Brazil* by Anabel Marin and Ionara Costa
2009-09 *Are International Market Demands Compatible with Serving Domestic Social Needs? Challenges in Strengthening Innovation Capacity in Kenya's Horticulture Industry* by Mirjam Steglich, Ekin Keskin, Andy Hall and Jeroen Dijkman
2009-10 *Industrialisation as an engine of growth in developing countries* by Adam Szirmai
2009-11 *The motivations, organisation and outcomes of university-industry interaction in the Netherlands* by Isabel Maria Bodas Freitas and Bart Verspagen
2009-12 *Habit Formation, Demand and Growth through product innovation* by M. Abraham Garcia-Torres
2009-13 *The Diffusion of Informal Knowledge and Innovation Performance: A sectoral approach* by M. Abraham Garcia-Torres and Hugo Hollanders
2009-14 *What does it take for an R&D tax incentive policy to be effective?* by Pierre Mohnen and Boris Lokshin
2009-15 *Knowledge Base Determinants of Technology Sourcing in the Clean Development Mechanism Projects* by Asel Doranova, Ionara Costa and Geert Duysters
2009-16 *Stochastic environmental effects, demographic variation, and economic growth* by Théophile T. Azomahou and Tapas Mishra
2009-17 *Measuring eco-innovation* by Anthony Arundel and René Kemp
2009-18 *Learning How to Consume and Returns to Product Promotion* by Zakaria Babutsidze
2009-19 *Strengthening Agricultural Innovation Capacity: Are Innovation Brokers the Answer?* by Laurens Klerkx, Andy Hall and Cees Leeuwis
2009-20 *Collinearity in growth regressions: The example of worker remittances* by Thomas H.W. Ziesemer
2009-21 *Foreign Direct Investment in Times of Global Economic Crisis* by Sergey Filippov and Kálmán Kalotay
2009-22 *Network-independent partner selection and the evolution of innovation networks* by Joel Baum, Robin Cowan and Nicolas Jonard
2009-23 *Multinational enterprises, development and globalisation: Some clarifications and a research agenda* by Rajneesh Narula and John H. Dunning
2009-24 *Why Rural Rich Remain Energy Poor* by Bilal Mirza and René Kemp
2009-25 *Compliance with the private standards and capacity building of national institutions under globalization: new agendas for developing countries?* by Michiko Iizuka and Yari Borbon-Galvez
2009-26 *The Impact of the Credit Crisis on Poor Developing Countries: Growth, worker remittances, accumulation and migration* by Thomas H.W. Ziesemer

2009-27 *Designing plans for organizational development, lessons from three large-scale SME-initiatives* by Tinne Lommelen, Friso den Hertog, Lien Beck and Raf Sluismans
2009-28 *Growth with imported resources: On the sustainability of U.S. growth and foreign debt* by Thomas H.W. Ziesemer
2009-29 *Innovative Sales, R&D and Total Innovation Expenditures: Panel Evidence on their Dynamics* by Wladimir Raymond, Pierre Mohnen, Franz Palm and Sybrand Schim van der Loeff
2009-30 *Malthus' Revenge* by Luc Soete
2009-31 *Preparing for the Next, Very Long Crisis: Towards a 'Cool' Science and Technology Policy Agenda For a Globally Warming Economy* by Paul A. David
2009-32 *Innovation and Economic Development* by Jan Fagerberg, Martin Srholec and Bart Verspagen
2009-33 *Attracting and embedding R&D by multinational firms: policy recommendations for EU new member states* by Rajneesh Narula
2009-34 *Student Network Centrality and Academic Performance: Evidence from United Nations University* by Ying Zhang, Iman Rajabzadeh and Rodolfo Lauterbach
2009-35 *Reverse knowledge transfer and its implications for European policy* by Rajneesh Narula and Julie Michel
2009-36 *Innovation for the base of the pyramid: Critical perspectives from development studies on heterogeneity and participation* by Saurabh Arora and Henny Romijn
2009-37 *Caste as Community? Networks of social affinity in a South Indian village* by Saurabh Arora and Bulat Sanditov
2009-38 *How productive are academic researchers in agriculture-related sciences? The Mexican case* by René Rivera, José Luis Sampedro, Gabriela Dutrénit, Javier Mario Ekboir and Alexandre O. Vera-Cruz
2009-39 *Alliance-based Network View on Chinese Firms' Catching-up: Case Study of Huawei Technologies Co.Ltd.* by Ying Zhang
2009-40 *Innovation dynamics in Tuberculosis control in India: The shift to new partnerships* by Nora Engel
2009-41 *Internationalization of Chinese firms in Europe* by Ying Zhang and Sergey Filippov
2009-42 *Fits and Misfits: Technological Matching and R&D Networks* by Robin Cowan, Nicolas Jonard and Bulat Sanditov
2009-43 *Explaining the lack of dynamics in the diffusion of small stationary fuel cells* by Bert Droste-Franke, Jörg Krüger, Stephan Lingner and Thomas H.W. Ziesemer
2009-44 *FDI, R&D and Innovation Output in the Chinese Automobile Industry* by Chen Fang and Pierre Mohnen
2009-45 *Inertia, Interaction and Clustering in Demand* by Zakaria Babutsidze and Robin Cowan
2009-46 *What Do Complex Adaptive Systems Look Like and What Are the Implications for Innovation Policy?* by Andy Hall and Norman Clark
2009-47 *Environmental innovation: Using qualitative models to identify indicators for policy* by Minna Kanerva, Anthony Arundel and René Kemp
2009-48 *Firm Ownership, FOEs, and POEs by Alice H. Amsden*
2009-49 *Types of Entrepreneurship and Economic Growth* by Erik Stam and André van Stel
2009-50 *Innovation Policy, Entrepreneurship, and Development: A Finnish View* by Otto Toivanen
2009-51 *The Growth of Knowledge-intensive Entrepreneurship in India, 1991-2007* by Sunil Mani
2009-52 *Technological Innovation, Entrepreneurship and Development* by David B. Audretsch and Mark Sanders
2009-53 *Innovation and Microenterprises Growth in Ethiopia* by Mulu Gebreeyesus

2009-54 *Incubators as Tools for Entrepreneurship Promotion in Developing Countries* by I. Semih Akçomak
2009-55 *Is that Innovation? Assessing Examples of Revitalized Economic Dynamics among Clusters of Small Producers in Northern Vietnam* by Jaap Voeten, Job de Haan and Gerard de Groot
2009-56 *R&D Behaviour and the Emergence of Fat-tailed Firm Size Distributions* by Zakaria Babutsidze
2009-57 *From Quantity to Quality: Challenges for Investment Promotion Agencies* by Sergey Filippov and José Guimón
2009-58 *Tacit Knowledge and Innovation Capacity: Evidence from the Indian Livestock Sector* by Rasheed Sulaiman V., Laxmi Thummuru, Andy Hall and Jeroen Dijkman
2009-59 *Technology frontier, labor productivity and economic growth: Evidence from OECD countries* by Théophile T. Azomahou, Bity Diene and Mbaye Diene
2009-60 *A Different Look at Inward FDI into Mainland China* by Ying Zhang
2009-61 *Inactions and Spikes of Investment in Ethiopian Manufacturing Firms: Empirical Evidence on Irreversibility and Non-convexities* by Mulu Gebreeyesus
2009-62 *Systems of Innovation* by Luc Soete, Bart Verspagen and Bas ter Weel
2009-63 *Assessing risk discourses: Nano S&T in the Global South* by Minna Kanerva
2009-64 *A structural nonparametric reappraisal of the CO_2 emissions-income relationship* by Théophile T. Azomahou, Micheline Goedhuys and Phu Nguyen-Van