Export diversification and resource-based industrialization: the case of natural gas

Olivier MASSOL

Albert BANAL-ESTAÑOL

UNIVERSITAT POMPEU FABRA

CITY UNIVERSITY LONDON

IFP SCHOOL

TAI – Washington DC - Nov. 2011

Context:
The "resource curse"

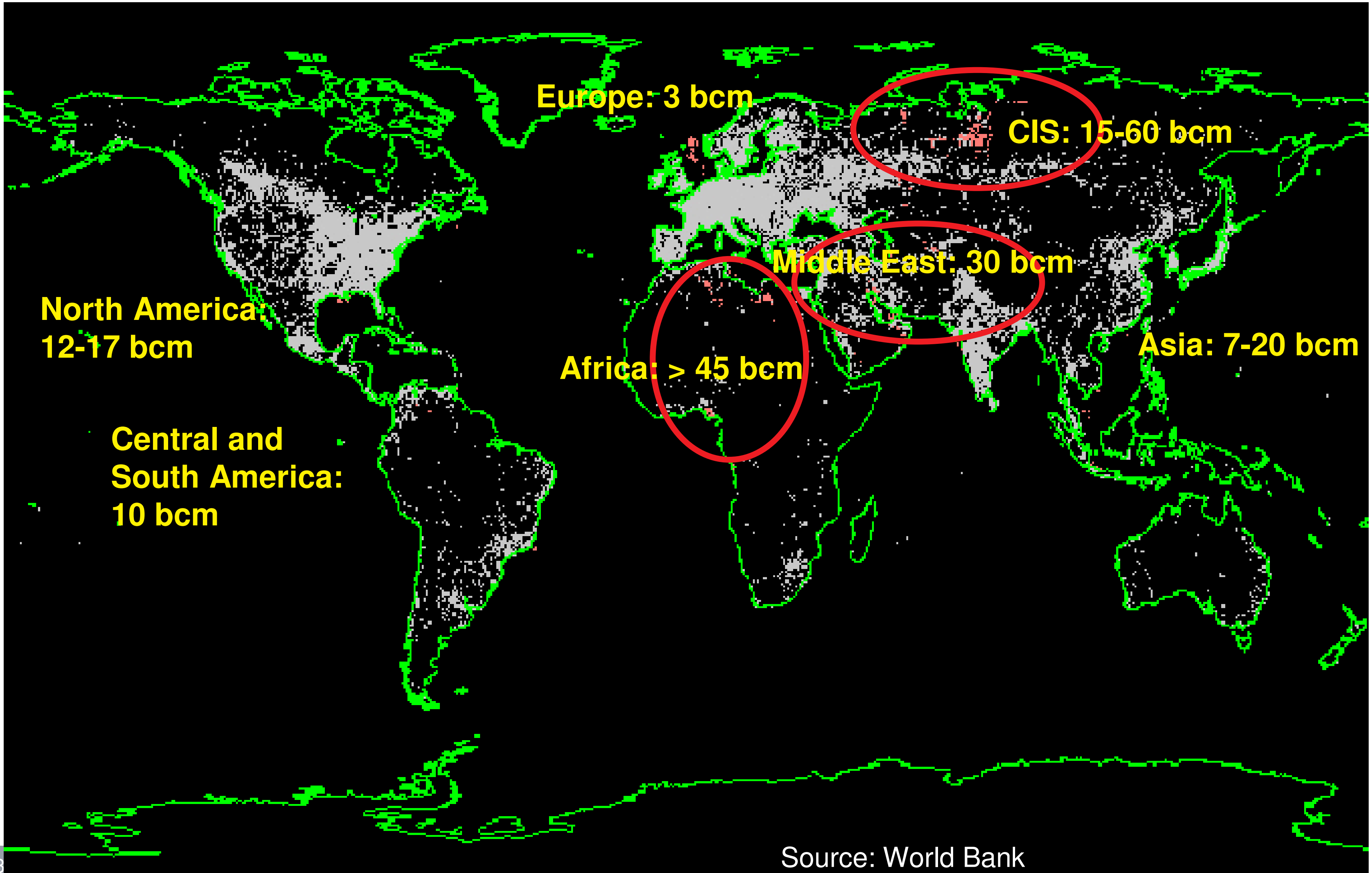
- **A well established fact**
  - Sachs and Warner (1995); Gelb et al., (1988); Auty (2003)

- **What transmission mechanism?**
  - **A – Political mismanagement**
    - cf. Ross (1999); Isham et al. (2005)

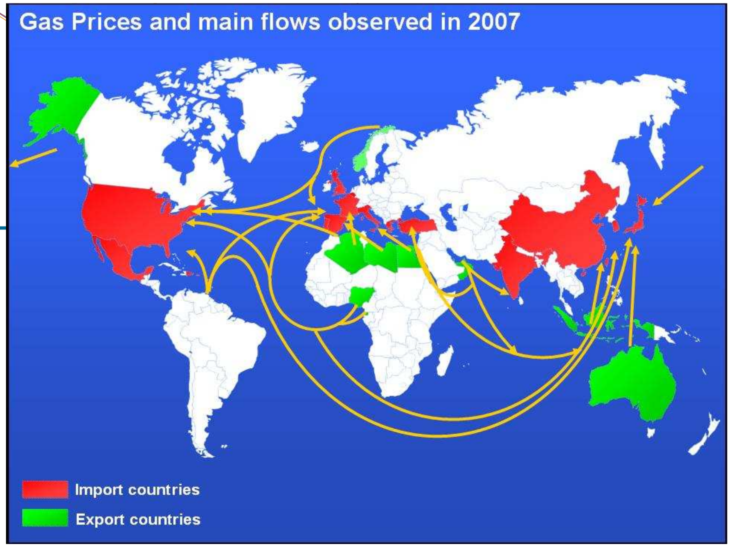
  - **B – Economic explanations**
    - **1950's: a secular decline in the Terms of Trade?**
    - **1960's: the lack of "linkages"** (Hirschman, 1958)
    - **1980's: the Dutch Desease explanation** (Corden & Neary, 1982)
      (1) an appreciation of the state's real exchange
      (2) a tendency of the booming sector to draw resources away from manufactures

    - **1990's: Export revenue volatility harms growth**
      - Easterly et al. (1993); Mendoza (1997); Hausmann and Rigobon (2003)

Natural Gas Flaring



Gas Resources Monetization for a small economy



Gas allows multiple export-oriented strategies:

- **Raw exports (pipelines, LNG vessels)**
- **Processed Primary Products**

Chemical commodities:	Methanol, Olefins
Fertilizers:	Urea
Liquid fuel (GTL technologies):	Diesel Oil
Iron & Steel industry	DRI
Energy Intensive activities	Aluminum

- **Owens and Wood (1997):** resource-rich countries can have a comparative advantage in processed primary goods.

RESEARCH QUESTIONS:

A - Is an export-oriented RBI strategy suitable or not?

B - Which primary products should be given priority over others?

Part I - Methodology

A critical review of existing studies

- **Practitioners:**
  - **basic comparisons based on the E(NPV) criteria (ESMAP)**
- **In the academic literature**
  - **Brainard and Cooper (1968) – an MVP approach**
    - Love (1979), Labys & Lord (1990), Strobl et al. (2009)…

Typical MVP formulation:

$$\max \quad U(q) = \overline{P}^T.q - \frac{\lambda}{2} q^T.\Sigma.q$$

$$\text{s.t.} \quad A^T.q = 1$$

$$q \in \mathbb{R}_+^m$$

Applicability to the gas sector

1 – Can volume instability be neglected? OK

2 – Can costs be neglected? NO!

The technologies at hand: a standard engineering representation

Remarks:

- **Gas processing technologies: the main features**
  - **modular technologies with LR scale economies at the module's level …**
  - **lumpiness + a large range of size for the modules**

Gas use (gauging equipment)	Gas input (Mcf/ton)	Range of implementable processing capacities (ktpa - 10^3 tons per annum)		Investment cost function $C_i(x_i) = \alpha_i . x_i^{\beta_i}$ (US$ with x_i in tpa)	
		Minimum	Maximum	α_i	β_i
Aluminium (line pot)	91.13	50.00	386.00	12 424.33	0.941
Gas-to-Liquid (Fischer-Tropsch reactor)	71.82	110.99	838.61	3 517.74	1.000
Direct Reduced Iron (shaft furnace)	12.17	310.00	1 950.00	2 276.56	0.840
LNG (liquefaction train)	55.35	2 500.00	7 100.00	3 843.43	0.853
Methanol (methanol reactor)	31.76	204.00	3 400.00	3 023.30	0.875
Urea (urea reactor)	21.61	170.00	1 500.00	4 161.45	0.832

- **E&P costs can be excluded**

Assumption

Lemma: on cost minimizing industrial configurations

Assume: -> the concave specification above,

-> $q_i \geq \underline{K}_i$ **and denote** $n_i = \left\lfloor q_i / \overline{K}_i \right\rfloor$

Then, the cost minimizing industrial configuration for *i* is:

Case	Cost-minimizing industrial configuration	Total Cost $C_i(q_i, n_i, \delta_i)$
$n_i \overline{K}_i + \underline{K}_i \leq q_i \leq (n_i + 1).\overline{K}_i$ $\delta_i = 1$	n_i modules with a size $\overline{K}_i$ plus a residual one of size $(q_i - n_i \overline{K}_i)$	$n_i\, c_i(\overline{K}_i) + c_i(q_i - n_i \overline{K}_i)$
$n_i \overline{K}_i \leq q_i \leq n_i \overline{K}_i + \underline{K}_i$ $\delta_i = 0$	$n_i - 1$ modules with a maximum size $\overline{K}_i$ a module of minimum size $\underline{K}_i$ plus the residual one: $q_i - (n_i - 1)\overline{K}_i - \underline{K}_i$	$(n_i - 1) c_i(\overline{K}_i) + c_i(\underline{K}_i)$ $+ c_i\left(q_i - (n_i - 1)\overline{K}_i - \underline{K}_i\right)$

A modified MVP Model

$$\max \quad U(q,n,\delta,\varsigma) = \overline{P}^T.q - C(q,n,\delta,\varsigma) - \frac{\lambda}{2} q^T.\Sigma.q$$

$$\text{s.t.} \quad \underline{1}^T.q = PROD$$

$$diag(\overline{K}).n \leq q \leq diag(\overline{K}).(n+\underline{1})$$

$$diag(\overline{K}).n + diag(\underline{K}).\delta \leq q$$

$$diag(\underline{1}-\delta).q \leq diag(\overline{K}).n + diag(\underline{K})$$

contraints imposed by

the modular cost function

$$q \leq PROD.\varsigma$$

$$diag(\underline{K}).\varsigma \leq q$$

A disjunctive choice:

"*export at least a certain amount, or not at all*".

$$q \in \mathbb{R}_+^m,\ n \in \mathbb{N}^m,\ \delta \in \{0,1\}^m,\ \varsigma \in \{0,1\}^m$$

This is a "well behaved" MINLP

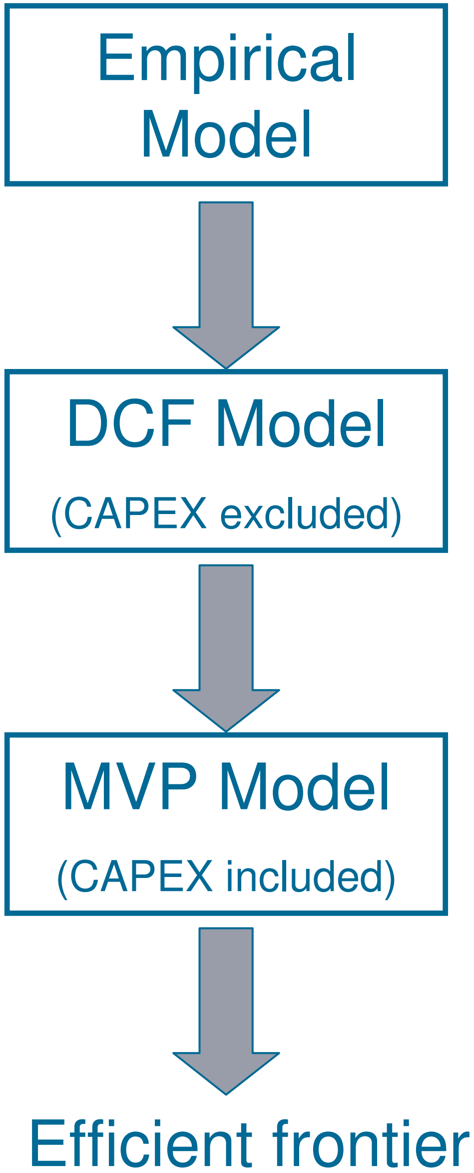
- **feasible**
- **Computationally friendly**

a D-C program with integer variables...

Part II - Application

a) Assessing revenues: an empirical price model

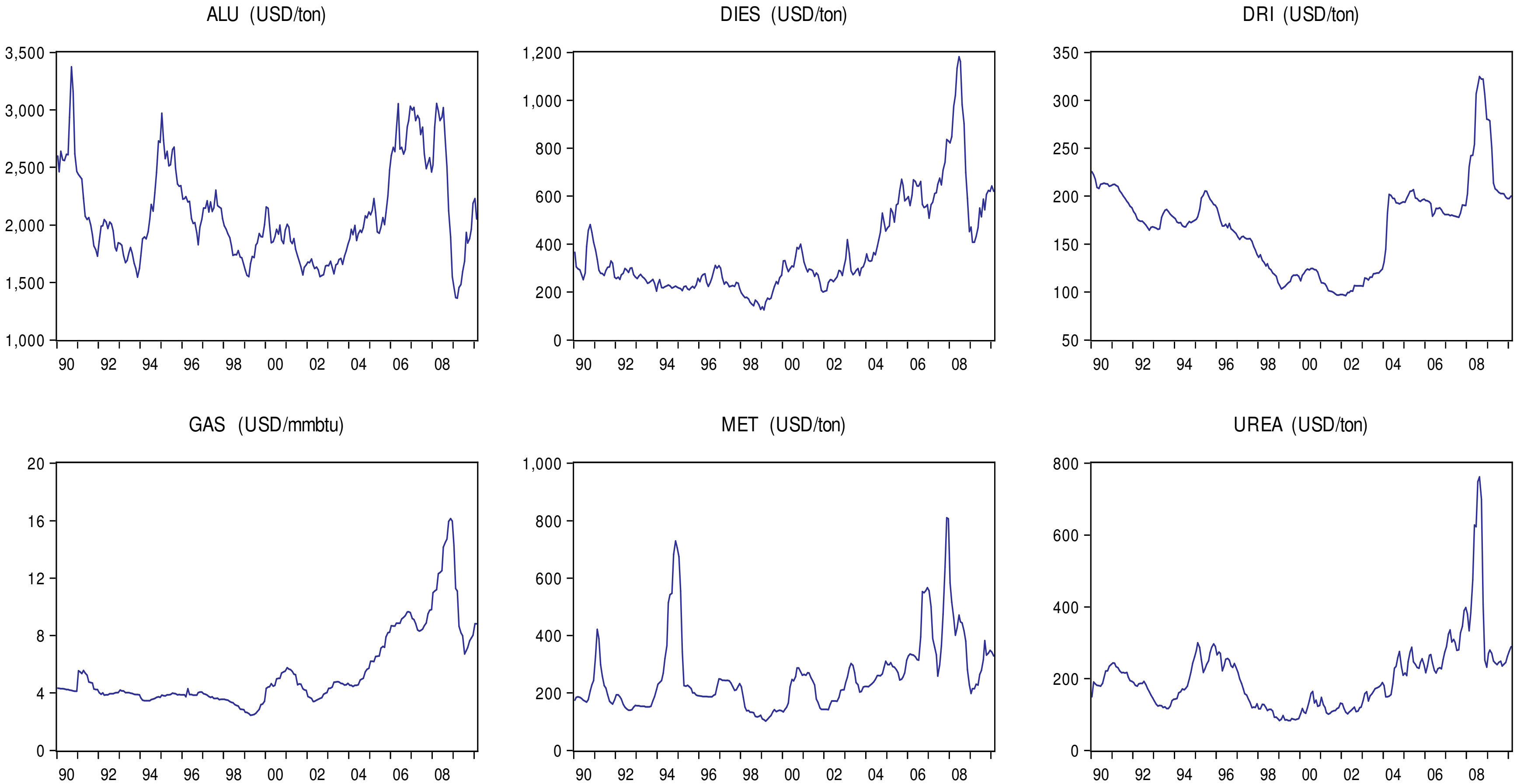
The route to an application



- **Estimation of a time series model**
  - **Simulation: 100,000 price paths are generated**
- **The unit discounted revenues net of linear variable costs are then computed…**
  - **Hypotheses are based on publicly available data:**
    - **construction delays, lifetimes, rate of return, unit O&M costs , freight…**

Data:

242 monthly prices from Jan90 to Feb10 (in 2010 USD)



Sources: World Bank, Platts, USGS.

Preliminary tests:

- **stationarity?** All series are I(1) => use of first differences
- **Cointegration?** Yes => a VECM

Methodology

A data-driven model of the DGP

- **A - Conditional mean equations: a VECM**

$$\Delta P_{\mathbf{t}} = \mathbf{A}_0 + \mathbf{\Pi} P_{t-1} + \mathbf{\Gamma}_{\mathbf{1}} \Delta P_{\mathbf{t-1}} + \ldots + \mathbf{\Gamma}_{k-1} \Delta P_{t-p+1} + \boldsymbol{\varepsilon}_t$$

- **B - The conditional variance equation: a MV-GARCH model**

$$\varepsilon_t = H_t^{1/2} \eta_t$$

  - **the family of correlation multivariate GARCH models:** $H_t = D_t R_t D_t$
  - **where** $D_t = \mathrm{diag}\left\{ \sqrt{h_{i,t}} \right\}$ **and** $h_{i,t} = \omega_i + \sum_{p=1}^{P_i} \alpha_{i,p} \varepsilon_{i,t-p}^2 + \sum_{q=1}^{Q_i} \beta_{i,q} h_{i,t-q}$
  - **Bollerslev (1990) Constant Conditional Correlation (CCC) model:**

$$R_t = \overline{R}$$

Estimation:
A - The conditional mean equation

Step 1: Selecting the lag order of the VECM

- Akaike's FPE: **a 9 lags** specification

Step 2: Determining the cointegrating rank $\Pi = \alpha\beta'$

- Test assumption: an intercept in both the CE & the VAR (Cf. the SBIC)
- Both, the Trace and the λ_{max} test suggest ***r = 2*** at the 5% level

Step 3: Reduction to a parsimonious model

- An iterative "**general-to-specific**" procedure (Brüggemann and Lütkepohl, 2001)
  - SER aimed at minimizing the HQ criterion. => 217 zero restrictions (not rejected by a LR test)
  - The resulting model has been estimated using a feasible GLS procedure.

Equation	Adjusted R^2
ΔALU_t	0.301
$\Delta DIES_t$	0.325
ΔDRI_t	0.529
ΔGAS_t	0.792
ΔMET_t	0.583
$\Delta UREA_t$	0.653

Table 9. Diagnostic checks of the conditional mean equations

Multivariate tests		Statistic	*p*-value
Normality:	JB, $\chi^2(12)$	2222.58	*(0.000)*
Autocorrelation:	LM(10), $\chi^2(360)$	377.26	*(0.255)*
	LM(12), $\chi^2(432)$	462.70	*(0.148)*
	LB(14), $\chi^2(382)$	378.15	*(0.546)*
	LB(24), $\chi^2(742)$	742.46	*(0.488)*
Presence of ARCH:	ARCH(3), $\chi^2(1323)$	1911.86	*(0.000)*

Note: JB is Jarque-Bera multivariate statistic based on Doornik and Hansen (1994). All the other tests are those described in Lütkepohl (2006): LM(x) is the multivariate Breusch-Godfrey LM-test for the x^{th} order autocorrelation, LB(y) is the multivariate portmanteau test for residual autocorrelation up to the order y, and ARCH(3) is the multivariate LM-test for ARCH effect with 3 lags.

Estimation:
B - The conditional variance equation

Step 4:

Table 11. CCC-GARCH model estimates and diagnostic test results

	ΔALU $i=1$	ΔDIES $i=2$	ΔDRI $i=3$	ΔGAS $i=4$	ΔMET $i=5$	ΔUREA $i=6$
Panel A – GARCH estimates						
ω_i	1 624.3913***	13.3677	3.2444	0.0041*	41.5661**	30.9672**
	[2,7007]	*[0,7684]*	*[1,0310]*	*[1,6522]*	*[2,1023]*	*[2,0530]*
α_i	0.1690**	0.0604*	0.3756	0.1140**	0.2759**	0.2134***
	[2,2745]	*[1,8992]*	*[1,3137]*	*[2,0476]*	*[2,0321]*	*[2,7428]*
β_i	0.6133***	0.9256***	0.5560*	0.7213***	0.6826***	0.6835***
	[5,8337]	*[18,7470]*	*[1,8542]*	*[5,9487]*	*[7,5427]*	*[6,8509]*
Panel B – Correlation matrix estimates and related diagnostics						
$\overline{\rho}_{2i}$	0.2388***					
	[4.2246]					
$\overline{\rho}_{3i}$	0.0563	0.0027				
	[0.8492]	*[0.0431]*				
$\overline{\rho}_{4i}$	0.0635	0.1084	-0.1550**			
	[0.9905]	*[1.4575]*	*[-2.3848]*			
$\overline{\rho}_{5i}$	0.1461**	0.0239	-0.0272	-0.0483		
	[2.4365]	*[0.3443]*	*[-0.4792]*	*[-0.7288]*		
$\overline{\rho}_{6i}$	0.015	0.2627***	-0.0667	0.0886	0.0429	
	[0.2432]	*[4.4219]*	*[-0.9751]*	*[1.2901]*	*[0.5592]*	
Associated test:	$\chi^2(15)$ = 48.3461 *(0.000)*					
Panel C – Diagnostics tests conducted on the standardized residuals						
AD normality	0.2465	0.7803	3.1324**	1.1023	1.1170	0.3223
$LB^2(12)$	10.538	5.3951	2.9349	3.7013	5.1015	8.9767
ARCH-LM(4)	2.5267	1.0091	0.6790	0.5832	2.3657	2.1364

The sum < 1
=> a mean reverting variance process.

The correlation matrix is significantly different from the Identity.

Standardized residuals:
Normality? YES
Absence of ARCH? YES
i.i.d. ? YES

Furthermore :
Engle and Sheppard (2001)' test failed to reject the null hypothesis of

$$R_t = \overline{R}$$

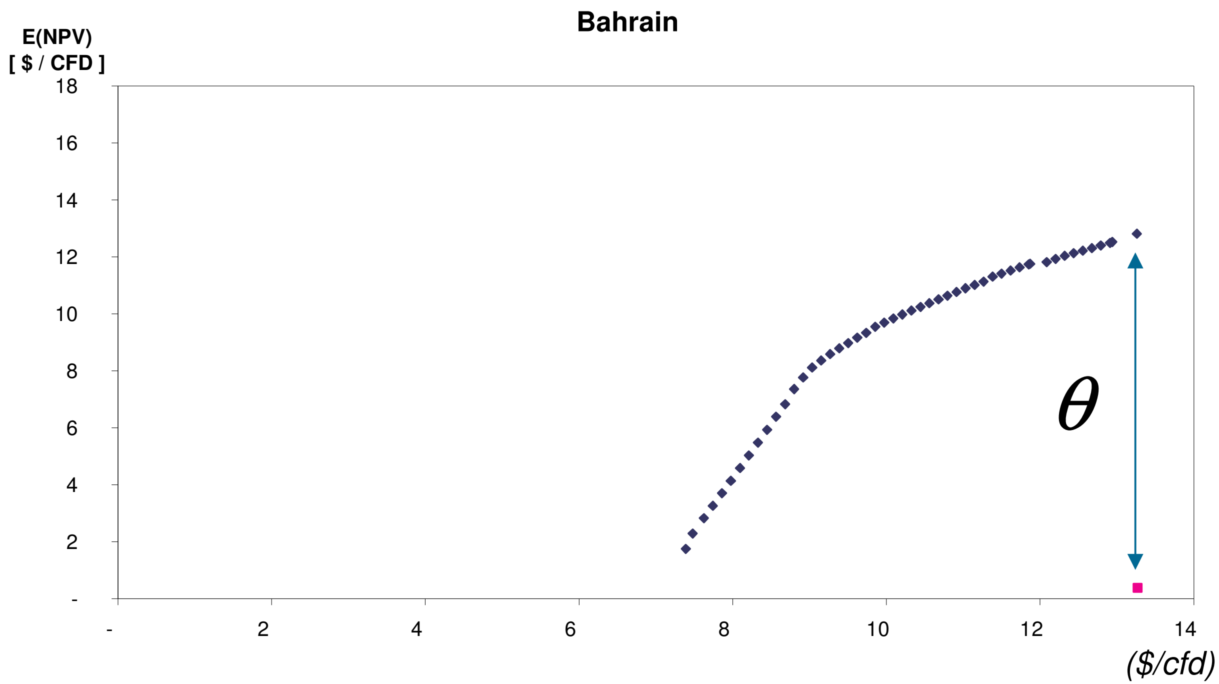
Part II - Application

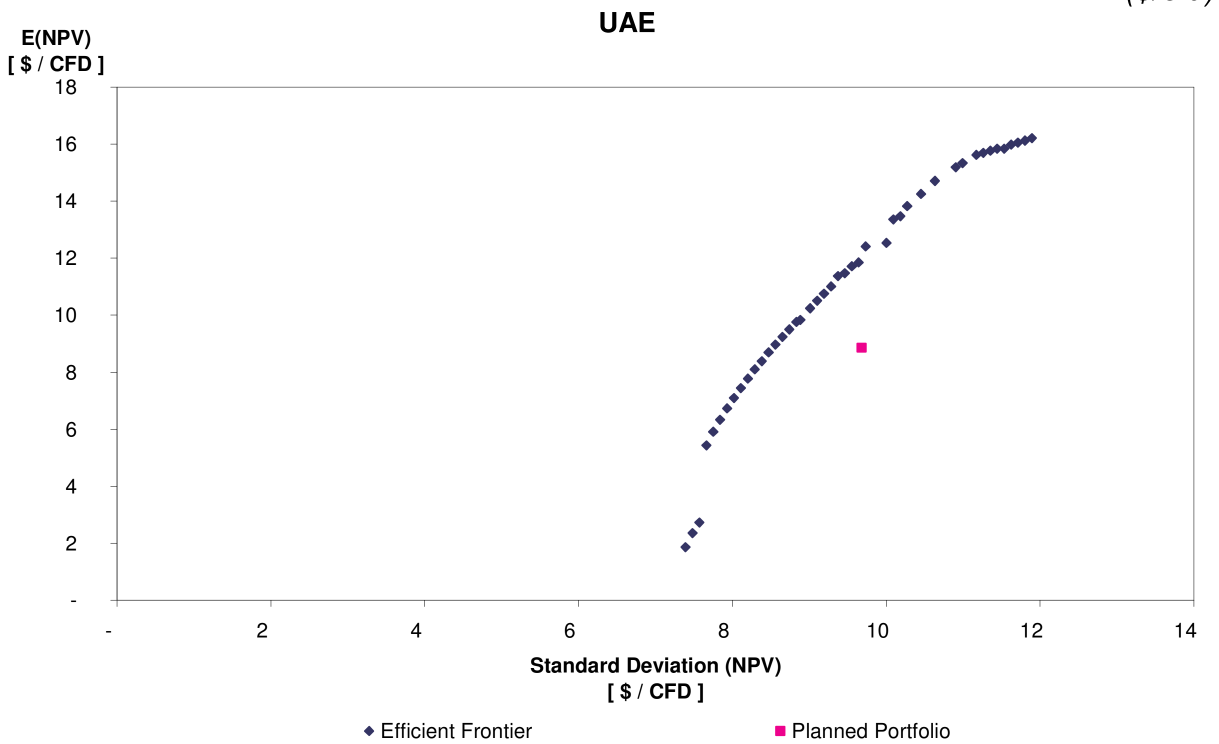
b) Results

Portfolio performance appraisal: -

Morey and Morey (1999), Briec et al. (2004)

	θ
Angola	5.1%
Bahrain	3275.2%
Brunei	1.0%
Equatorial Guinea	0.0%
Nigeria	9.5%
Oman	6.2%
Qatar	13.5%
Trinidad & Tobago	1.6%
U.A.E.	37.9%





Gauging the diversification policies of gas-based economies

Initial portfolios:

	Gas flow (MMCFD)	Allocated Shares (%) Aluminum smelters	GTL plants	DRI plants	LNG trains	Methanol plants	Urea plants	HHI
Angola	938.4	16.0%	-	-	84.0%	-	-	73.2%
Bahrain	342.5	63.5%	-	14.6%	-	11.1%	10.7%	44.9%
Brunei	1 165.8	-	-	-	93.7%	6.3%	-	88.1%
Equatorial Guinea	656.8	-	-	-	85.4%	14.6%	-	75.1%
Nigeria	3 582.6	1.3%	8.9%	-	88.9%	-	0.8%	79.8%
Oman	2 016.2	4.5%	-	2.5%	83.5%	2.4%	7.1%	70.5%
Qatar	12 722.6	1.1%	13.3%	0.6%	82.8%	0.6%	1.5%	70.4%
Trinidad & Tobago	3 069.6	-	0.7%	4.7%	74.6%	18.7%	1.4%	59.4%
U.A.E.	1 454.0	29.0%	-	7.9%	53.7%	-	9.4%	38.8%

Source: own evaluations based on USGS and Global Insight.

Optimal portfolios:

	θ	Allocated Shares (%) Aluminum smelters	GTL plants	DRI plants	LNG trains	Methanol plants	Urea plants	HHI
Angola	5.1%	-	-	13.1%	58.6%	28.3%	-	44.1%
Bahrain	3275.2%	-	-	-	-	100.0%	-	100.0%
Brunei	1.0%	-	-	-	92.3%	7.7%	-	85.9%
Equatorial Guinea	0.0%	-	-	-	85.4%	14.6%	-	75.1%
Nigeria	9.5%	0.3%	-	-	99.7%	-	-	99.3%
Oman	6.2%	-	-	3.7%	84.5%	11.7%	-	73.0%
Qatar	13.5%	-	-	-	92.3%	7.7%	0.1%	85.7%
Trinidad & Tobago	1.6%	-	-	-	64.6%	35.4%	-	54.2%
U.A.E.	37.9%	4.3%	-	20.9%	56.0%	18.8%	-	39.5%

Conclusions & future extensions

- **Numerous LDCs are assessing a gas monetization policy**

  Possible new gas exporting countries: PNG, Mauritania...

- **A general framework:**
  - **could be applied to analyze other RBI/commodities**

    oil: refining and petrochemical activities

    coal: steel and chemicals

    iron ore: steel industry and further manufacturing...

Thank you for your attention!

Olivier MASSOL

Albert BANAL-ESTAÑOL

UNIVERSITAT POMPEU FABRA

CITY UNIVERSITY LONDON

ifp SCHOOL