Effects of technological progress and external costs on upstream petroleum supply

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Abstract

As the increase in world energy consumption over the coming decades will occur predominantly in Asia, the region will be influential in determining the role and combination of oil and gas in the world's energy mix. To assess physical and economic availability of these resources, supply curves are estimated in this study by distributing volumetric quantities across production cost categories. The supply figures show how Asian oil and gas resources, both conventional and unconventional, vary with costs over time. The role of exogenous technological advancement until the year 2035 is included, as are the external (environmental) costs of production. On an axis showing quantities, the curves include resources estimated with a size-distribution method. The findings suggest that oil and gas in Asia is abundant and economically feasible to produce, with costs potentially decreasing in the future as technology progresses. Given appropriate public policies, gas in particular may experience rising market share in the energy mix and aid in the transition towards a low carbon economy.

Keywords: Technological progress; Oil and gas; Supply curves; External costs

1. Introduction

Asia is expected to account for virtually all of the world's energy demand growth in the first half of the current century (EIA, 2020; IEA, 2020; OPEC, 2020). The use of oil and gas to satisfy energy requirements in the region will depend on numerous economic, technical and policy factors, including efforts to accelerate a transition to alternatives such as renewable energy. If oil and gas development is to continue, technological progress will be necessary to establish reserves, reduce costs of production and minimize environmental impacts.

At times there have been concerns about inadequate supply of petroleum – defined by United States Geological Survey (USGS) as oil, natural gas and natural gas liquids (NGL) – in the region due to surging demand in emerging economies like China and India. Others question the role of petroleum in the transition towards a low carbon future. Thus, this paper assesses the issues by estimating conventional and unconventional petroleum supply curves for the region[1], including costs to address environmental impacts. Oil and NGL are grouped together for the purpose of the volumetric and supply curve estimation, while natural gas is considered separately. The end results are two-dimensional representations of availability over the long term versus average production costs; i.e. supply curves.

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[1] Asia includes: Afghanistan, American Samoa, Australia, Bangladesh, Bhutan, Brunei, Cambodia, China, Fiji, French Polynesia, Gilbert-Kiribati, India, Indonesia, Japan, Korea (DPR), Laos, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, New Zealand, Papua New Guinea, Pakistan, Philippines, Republic of Korea, Singapore, Solomon Islands, Sri Lanka, Taiwan, Thailand, Tonga, Vanuatu, Vietnam, Western Samoa.

In Asia, economic growth over the past 50 years has been predominantly powered by oil and coal. As the region develops, natural gas may become central in providing energy services and acting as a transition fuel to non-fossil sources (Aguilera, 2014a). Some experts claim that increased use of abundant and widely-distributed gas will help alleviate the current dependence on coal and oil, which would lead to enhanced energy security and reduced atmospheric pollution (Hefner III, 2009; Smil, 2015).

The availability of petroleum will depend partly on the physical quantities in the subsurface and the costs of recovery. Factors above the ground, such as political and regulatory/fiscal regimes, must be favourable for successful development (Imran Kahn, 2017). In Asia, petroleum markets remain less developed relative to those in North America and Europe – in terms of numbers of buyers and sellers, liquidity and market hubs. To augment the future role of petroleum in the energy mix (particularly coal-to-gas switching), supportive policies would be needed to incentivize exploration, build upstream and midstream infrastructure, create well-functioning markets and pricing mechanisms, and reduce carbon dioxide emissions.

There is considerable literature on the technical, economic and policy aspects of petroleum development in Asia, and the literature is quoted and drawn upon in the pages which follow. However, a comprehensive and integrated outlook has not been treated adequately in earlier works. This provides the rational for a novel contribution to further the knowledge on the prospects for petroleum in the future Asian energy mix. More specifically, the paper expands the existing literature by estimating the total remaining volumes of oil and gas in the region (including in previously unassessed geological provinces), combined with estimates of production costs. As the resulting supply curve figures are static, the effects of future technological progress and environmental costs (via carbon prices) are then included in the assessment to gain insights into how the availability of petroleum in Asia may evolve over time. While the work is speculative, it is intended to serve as a useful entry point for further discussion and interdisciplinary research on the subject in the coming years.

Following this introduction, the paper proceeds as follows. Section 2 describes the methodologies used for the construction of supply curves and delves into the modelling of petroleum quantities in previously unassessed areas. Section 3 presents the petroleum production costs, rates of future technological progress and external costs. The section goes on to combine all the earlier results for the estimation of supply curves. Section 4 gives a discussion of the results, while section 5 closes with concluding remarks and ideas for future research, mostly in the context of policy efforts to address climate change.

2. Methodologies

The construction of supply curves is explained conceptually by Tilton and Guzman (2016). The actual methodology, which is similar to that utilized in the Global Energy Assessment (2012) and Rogner (1998), starts by distributing oil and gas volumes across categories that account for the quality of the resources. Low and high limits of production costs are then given to each category. With the resources now matched to production costs, graphical supply curves can be generated, based on the present state of technological conditions. Additional supply curves are constructed assuming technological progress until 2035, with cost reduction rates between 0.5% and 1.5% per year used to project the 2035 production costs. Historically, average technical advancement rates have been estimated at about 1% per year over recent decades (Aguilera and Radetzki, 2016).

Remaining conventional oil (and NGL) and gas volumes in Asia, used in the supply curves, are calculated with the Variable Shape Distribution (VSD) model (first developed in Aguilera, 2006). The natural gas volumes estimated with the VSD are taken from Aguilera and Ripple (2011), which had used USGS (2000) data as an input to the model.[2] The oil and NGL quantities are estimated with the VSD in the present paper. The unconventional oil and gas quantities are taken from EIA/ARI (2015).[3] Production costs of the conventional and unconventional petroleum quantities are based on several publically available sources (see section 5).

Despite the substantial efforts by governments to internalize the external costs associated with energy production, such as environmental pollution and global warming, there is still considerable disagreement over just how large the remaining external costs are. External costs are nevertheless included in the production cost estimates, based on carbon pricing averages derived from Rana (2018), Timilsina and Toman (2018), and Kameyama et al (2016), among others.

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[2] USGS (2000) is a comprehensive and transparent world petroleum assessment still used as a benchmark resource study today.

[3] EIA/ARI (2015) presents estimated oil and gas quantities from shale formations, though the term “unconventional” is used interchangeably with “shale” throughout this paper.

2.1 VSD Model

Previously unassessed petroleum endowment quantities in Asia are evaluated with the VSD, a statistical size-distribution model. Endowments, as defined by USGS, refer to the sum of cumulative (past) production, remaining reserves, and undiscovered volumes. Traditionally, statistical models have been utilized in combination with geological appraisal methods (Divi, 2004). Although geological methods are the most dependable means of estimating undiscovered resources, size distribution models have proven useful as well. The advantage of the latter is that they are faster and easier to employ as they require less time and resources. As the VSD is not the focus of the present paper, an abridged description follows – full details can be found in Aguilera and Ripple (2011), and Aguilera (2006).

Historically, methods to estimate petroleum volumes statistically relied on an “assumed form of the size-frequency distribution of the natural population of oil and gas accumulations” (Barton, 1995), with lognormal and Pareto distributions being the most used (Kaufman, 2005; Drew, 1997). These types of statistical distributions are believed to be representative of many natural and social occurrences (e.g. resource distribution in nature; income distribution across population). Aguilera (2006) found that lognormal methods tended to underestimate petroleum volumes, while the Pareto overestimated them.

What makes the VSD different is that it begins by observing, on log-log coordinates, the relationship between the number and size of petroleum provinces from USGS (2000). The VSD model permits the data itself to determine the distribution of the provinces, yet provides a very close match. Given that validation, the model can be extrapolated to the provinces that were not assessed by the USGS.

A typical prerequisite for the successful application of a size distribution model is that the largest data points should be known (Tangen and Molnvik, 2009). The implication is that the largest petroleum provinces are assumed to be found, while the ones not assessed will be smaller in terms of petroleum volumes. Having the largest data points in hand permit the estimation of key slope and intercept parameters (of the theoretical Pareto straight line).

The VSD is a non-linear least squares model, as shown in Equation 1:

$$\min_{\{V_x, a_p, V_s, \psi, S\}} \sum_{i=1}^{n} (V_i - \hat{V}_i)^2 \tag{1}$$

Subject to:

$$\hat{V}_i = \frac{\left\{ \left[\left(\frac{1}{N_t} - \left(\frac{V_m}{V_x} \right)^{\left(\frac{\log N_x - \log N_m}{\log V_x - \log V_m} \right)} \right)^{\frac{1}{a_p}} + \frac{V_m}{V_x} \right] \cdot V_x \right\} \times (\psi)}{(\psi) + [1 - (\psi)] \cdot \left[1 - \exp\left(- \left\{ \left[\left(\frac{1}{N_t} - \left(\frac{V_m}{V_x} \right)^{\left(\frac{\log N_x - \log N_m}{\log V_x - \log V_m} \right)} \right)^{\frac{1}{a_p}} + \frac{V_m}{V_x} \right] \cdot V_x \right\} \div V_s \right) \right]^S} \tag{2}$$

where:

a_p - slope of “Pareto” straight line based on available USGS data

N_m - lowest number of USGS provinces (= 1)

N_t - total number of provinces

N_x - highest number of provinces

S - severity exponent to change slope of estimated VSD curve where it deviates from “Pareto” line (on right-hand tail of the graph)

V_m - smallest USGS province volume

V_s - approximate volume where USGS data starts deviation from “Pareto” line (on right-hand tail of the graph)

$\hat{V}_i$ - estimated volume of a province

V_x - highest volume (barrels of oil equivalent, BOE) given by “Pareto” line (at $N_m = 1$)

ψ - separating ratio controlling separation between Pareto line and the calculated VSD curve (on right-hand tail of the graph)

Equation 1 shows the five parameters of the VSD to be estimated with non-linear regression: V_x, a_p, V_s, ψ, and S. Their estimated values (see Table 1) determine the closest possible fit of the available USGS (2000) data. Those exact parameters remain constant as the VSD is extended out of the sample to estimate volumes in the previously unassessed provinces.

Validation of the VSD model is achieved by a comparison of the conventional oil and NGL (referred to as oil hereafter) endowment volumes in Asia, given by USGS (2000), with the values estimated by the VSD. Moreover, the goodness of fit is based on visual inspection of the curves and inspection of the coefficient of determination (R^2).

The graph in Figure 1 shows the size vs. number of provinces in Asia estimated by the VSD and USGS. The bottom curve in the figure represents the oil endowment in 58 provinces previously estimated by USGS (2000) at 168 billion barrels of oil equivalent (BBOE) – note these volumes are not inclusive of unconventional oil or provinces located offshore in water deeper than 4000 meters. The VSD model is then run and also gives an estimate of 168 BBOE for the 58 provinces, with a coefficient of determination of 0.98. Table A.1 (in Appendix A) provides a list of those provinces and the corresponding endowment quantities. Next, the VSD is used to calculated the oil endowment in all 290 provinces recognized to exist in Asia by the USGS – of which 232 were not assessed. This is represented by a dashed-line curve in Figure 1 and provides an estimate of 244 BBOE.

Turning now to natural gas, Aguilera and Ripple (2011) used the VSD to estimate the endowment of conventional volumes in unassessed Asian provinces. The bottom curve of Figure 2 represents the 77 provinces in the region assessed by the USGS (2000) study, totalling 1100 trillion cubic feet of gas (TCFG). Meanwhile, the VSD generated an estimate of 1101 TCFG for the same provinces. Appendix Table A.2 lists those provinces and the corresponding endowment quantities. Aguilera and Ripple (2011) then used the VSD to estimate the endowment of gas in all 290 Asian provinces – 213 of those not assessed by the USGS – giving a total of 1437 TCFG (see dashed curve of Figure 2). Appendix Table A.3 provides a list of all 290 provinces recognized to exist in Asia by the USGS.

Considering that unconventional oil and gas resources have potential to be sources of supply in Asia, they are included in the supply curves of this paper. The quantities of unconventional oil – represented here by shale oil – are taken from EIA/ARI (2015). Other sources like heavy oil and oil shale (kerogen) are not considered here (refer to Global Energy Assessment, 2012, for estimates of those resources). The total, approximately 56 BBOE of technically recoverable shale oil, is equal to nearly a quarter of the total conventional oil endowment (244 BBOE) estimated by the VSD model.[4] Unconventional gas quantities in Asia – represented here by shale gas – are also taken from EIA/ARI (2015). At approximately 1373 TCFG of technically recoverable shale gas, the estimate is nearly as large as the conventional gas endowment (1437 TCFG) estimated by the VSD model.

2.2 Resource Categories

Despite the inconsistencies around the many classification schemes for petroleum quantities, valuable attempts to create recognized systems have been carried out by SPE et al (2018) and UNFC (2009). As in Global Energy Assessment (2012) and Rogner (1998), this study distinguishes conventional petroleum volumes in five categories. The first, CI, represents attractive exploitation conditions, like those associated with shallow formations. For instance, proved reserves (normally defined as P90 or 1P) fall under CI. The next category, CII, represents undiscovered volumes with a realistic chance of being discovered. Probable reserves, known as P50 or 2P, fall under category CII. Petroleum volumes assigned to the third category, CIII, are more uncertain when it comes to geological data and commercial viability – akin to possible

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[4] Endowments, as defined by the USGS, are technically recoverable. Thus, it is deemed reasonable to compare that resource category to the “technically recoverable” resource definition in EIA/ARI (2015).

reserves: P10 or 3P. Over time, the higher categories may eventually move into the lower ones as technological and economic conditions evolve. Categories four and five, CIV and CV, represent increasingly uncertain quantities, in terms of economic, technical, geological and environmental considerations. Enhanced oil and gas recovery techniques, for example, could fall under CIV. The fifth category, CV, accounts for volumes that are not accessible with the state of the art technology; e.g. those located in very deep offshore formations. In this paper, unconventional oil and gas resources are treated as a separate, higher-cost entity; i.e. outside of the CI to CV system.

3. Production Costs and Supply Curves

Petroleum costs of production are based on several factors, such as depth of formations, organic content, and availability of service industries, to name a few. Cost levels for conventional petroleum in Asia are fairly wide ranging (Aguilera, 2014b; Wood Mackenzie, 2018; and Rystad Energy, 2018, 2019). Recent costs of production for conventional oil range between 40 – 65 USD per BOE (Table 2). For conventional gas, the costs range from 4 – 9 USD per thousand cubic feet (MCF) (Table 3). The cost numbers include capital and operating expenditures, but not taxes or royalties, which can vary substantially even within countries.

The production costs of the unconventional sources are based on Aguilera (2014b), IHS Markit (2014), Aguilera and Radetzki (2016) and Le (2018). Current unconventional oil costs are estimated to fall in a range of 65 to 125 USD per BOE (Table 2), while the unconventional gas costs range between 9 and 15 USD per MCF (Table 3).

Supply curves can be constructed by attaching production costs to remaining petroleum quantities. Costs are in turn influenced by technological change and carbon prices. The technological progress (or cost reduction) rates shown in Tables 2 and 3 can be considered as approximate averages over time, as cost levels can fluctuate significantly. As stated by Adelman decades ago (1993, p. 81), “the most important variable in the long run is the least predictable: technical progress both in supply and in utilization.”

Table 2 lists costs of production of oil, per BOE, in 2018 USD; the rates of technological advancement for each category; and the resulting costs estimated for the year 2035. As described earlier, five cost categories are developed for conventional oil and gas, plus an extra category for unconventional, with low and high bounds given to every category. The higher quality categories are assumed to experience faster progress compared with the lower quality ones. In Category CI, for instance, advancement of 1.5% per year reduces the upper bound from 45.00 USD/BOE in 2018 to 34.80 USD in 2035. Category CV, meanwhile, is assigned a rate of 0.5%, meaning progress of 0.5% per annum from 2018 until 2035 lowers the high bound from 65.00 to 59.69 USD/BOE.

When the ranges of costs are matched with the remaining conventional oil quantities in Asia, supply curves emerge for oil in the region. According to Aguilera (2014b), oil resources are allocated to the cost categories as follows: 5% for CI, 25% for CII, 45% for CIII, 15% for CIV, and 10% for CV. The lower portion of Table 2 shows the estimated production cost category of unconventional oil, with the cost range based on IHS Markit (2014), Aguilera (2014b) and

Aguilera and Radetzki (2016). The rate of technological progress is estimated to be 0.5% per year (same rate used for category CV).

Table 3 shows the natural gas costs of production per MCF in 2018 USD; the rates of technological advancement for each category; and the resulting costs estimated for the year 2035. The rates of progress range from 0.75 – 1.25% per annum. In category CV, for instance, advancement of 0.75% each year until 2035 lowers the high limit from 9.00 to 7.68 USD/MCF. Based on Aguilera (2014b), conventional gas quantities can be allocated to cost categories as follows: 30% for CI, 35% for CII, 20% for CIII, 10% for CIV, and 5% for CV. The lower portion of Table 3 shows the single production cost category for unconventional gas, with the cost estimates based on the ranges presented in Aguilera (2014b) and Le (2018). Unconventional gas is assumed to benefit from a progress rate of 0.75% per year (the same rate used for CV).

Going back to the case of oil, Figure 3 show supply curves for remaining oil volumes and their production costs based on technological conditions in 2018 and then 2035, and another curve (for 2035) that includes external costs in the form of a carbon tax. Introduction of such a tax would likely be applied progressively over the years, and is assumed to reach a level of 30 USD/ton of CO2 in the year 2035 (based on Rana, 2018; Timilsina and Toman, 2018; Kameyama et al, 2016; among others). The tax is applied uniformly to the supply curve in 2035, and it equates to an additional cost of 12.57 USD/BOE (Hafstead and Picciano, 2017).

The quantities used in the 2035 curves subtract a constant level of annual production until then from the quantity of the 2018 curve (constant production based on current level taken from

British Petroleum, 2019). Moreover, as “endowments” (used in the earlier VSD analysis) include the oil already produced in the past, that historical quantity has to be subtracted from the endowment to estimate the remaining volumes needed for the curves in Figure 3. Thus, the remaining oil volume in 2018 is calculated at 286 BBOE. This result is attained by subtracting Asian historical production of oil until 2018 (118 BBOE; British Petroleum, 2019) from the conventional oil endowment estimated by the VSD (348 BBOE), plus the EIA/ARI-estimated unconventional endowment (56 BBOE). In 2035, the volume has fallen to 239 BBOE due to a constant oil output level of 2.8 BBOE each year from 2018 to 2035 (British Petroleum, 2019).

As with the oil curves, Figure 4 shows three supply cost curves representing natural gas: one assumes 2018 technology, another 2035 technology, and another includes the effects of carbon pricing. In this case, the assumed carbon tax of 30 USD/ton of CO2 in 2035 is equivalent to an additional 1.59 USD/MCF for the gas supply curve in that year.

The remaining natural gas quantity in 2018 is calculated to be 3191 TCFG. This is the result of subtracting Asian historical gas output until 2018 (422 TCFG; British Petroleum, 2019) from the conventional gas endowment estimated by the VSD (2240 TCFG) plus the EIA/ARI-estimated unconventional gas endowment (1373 TCFG). By 2035, the volume has been reduced to 2897 TCFG on account of a constant gas output level of 22.3 TCFG each year from 2018 – 2035 (British Petroleum, 2019).

4. Results and Discussion

Petroleum resources in Asia are found to be vast and could have a major role in satisfying energy demand requirements in the region. Not only are there large existing conventional reserves, but also significant quantities in unassessed areas and unconventional formations. Natural gas in particular may act as a bridge towards widespread renewable energy development in Asia – as gas can act as a backup for intermittent renewables like solar and wind.

Figures 1 and 2 show curves that represent the conventional oil (and NGL) and gas endowments in Asia, as estimated by the VSD. The upper curves give total volumes of 244 BBOE for conventional oil plus NGL, and 1437 TCFG for conventional gas – for the sake of comparison, past production in the region until 2018 was around 118 BBOE and 422 TCFG, respectively. EIA/ARI (2015) estimates unconventional (shale) oil at a total of 26 BBOE and unconventional (shale) gas at about 1373 TCFG.

Petroleum in Asia is generally found to be economically viable, despite the depressed market prices of recent years. This can be inferred from the supply curves seen in Figures 3 and 4, which are estimated by combining the costs of production presented in Tables 2 and 3 to the petroleum quantities presented in section 3. The role of technological change over time is found to further diminish production costs to the year 2035. Future annual rates of technical advance in the exploitation of oil and gas are said to range from 0.5 – 1.5% per year. While uncertain, they are similar to the cost developments in the industry over recent decades. Costs of production of oil in 2018 range from 40 – 65 USD/BOE for conventional and 65 – 125 USD/BOE for the unconventional. By 2035, the forecasted costs lay between 30.94 – 59.69 USD/BOE for conventional and 59.69 – 114.79 USD/BOE for the unconventional. Estimated production costs of natural gas in 2018 range from 4 – 9 USD/MCF for conventional and 9 – 15 USD/MCF for the unconventional. In 2035, the forecasted costs range between 3.23 – 7.68 USD/MCF for conventional and 7.68 – 12.80 USD/MCF for the unconventional.

The supply curves of Figures 3 and 4 are based on technological conditions in 2018 and 2035. Despite the costs having been lowered over time on account of improved productivity, the remaining volumes at the end of the time horizon are lower due to continuous production each year until 2035 (assuming the level of production recorded in 2018). With the addition of uniform carbon taxes of 30 USD/ton of CO2 in 2035, the figures show that the full costs of production are higher than would otherwise be reported by the industry.

Despite the inherent variability associated with the presented supply curves, the greatest source of uncertainty arguably relates to the estimation of available quantities of petroleum, in terms of the resources underground (McGlade, 2014) and their future production (Wachtmeister et al, 2018). As for unconventional resources, in general they are poorly known outside of North America. Jialiang et al (2015) provide a comprehensive review for the case of China.

5. Conclusions

Notwithstanding this paper’s findings, it is not enough for any given region to have abundant and commercially viable petroleum resources. Importantly, the mitigation of environmental impacts and the gaining of social licences are essential for successful development. On the other hand, overly demanding regulatory regimes could impose excessively high costs for the industry that would deter investment. Thus, policies will have to provide incentives for investment in technological development as well as environmental mitigation. The latter is important as the industry has been under increasingly intensified pressure in recent years – from investors, policy makers, and the public – to significantly reduce and eventually eliminate greenhouse gas emissions. In line with these issues, potential future research could examine the effects on petroleum availability in Asia of policy requirements to proceed with a clean energy transition. Already several countries throughout the region have pledged to become carbon neutral around the middle of the century – though actions will determine outcomes. Ambitious efforts to stabilize climate change could significantly reduce the consumption and production of oil and gas and potentially lead to stranded assets. Such risk requires further study, as it may have profound implications for petroleum development in Asia.

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Table 1
Parameters used for estimating oil and natural gas in previously unassessed provinces (parameters defined under Equations 1 and 2)

Parameter	Oil
V_x - Highest volume given by Pareto line	95 BBOE
a_p - Pareto slope exponent	0.855
V_s - Volume of separation	10 BBOE
ψ - Separation ratio	0.35
S - Severity exponent	8
Parameter	**Natural Gas**
V_x - Highest volume given by Pareto line	1,540 TCFG
a_p - Pareto slope exponent	0.697
V_s - Volume of separation	3,707 TCFG
ψ - Separation ratio	0.025
S - Severity exponent	1.146

Table 2

Oil costs of production, 2018 and 2035, USD/BOE.

Cost Category	Production costs (2018) [a]		Technology [b] change %/year	Production costs (2035) [c]	
	Low USD/BOE	**High USD/BOE**		**Low USD/BOE**	**High USD/BOE**
		Oil and NGL			
CI	40.00	45.00	1.50%	30.94	34.80
CII	45.00	50.00	1.50%	34.80	38.67
CIII	50.00	55.00	1.00%	42.15	46.36
CIV	55.00	60.00	0.50%	50.51	55.10
CV	60.00	65.00	0.50%	55.10	59.69
Unconventional Oil [d]	65.00	125.00	0.50%	59.69	114.79

a. 2018 conventional oil costs based on Aguilera (2014b), Rystad (2018), Wood Mackenzie (2018).
b. Rates of technological progress based on Aguilera and Radetzki (2016).
c. 2035 conventional oil costs estimated in this study.
d. Unconventional oil costs based on Aguilera (2014b), IHS Markit (2014) and Aguilera and Radetzki (2016) .

Table 3

Natural gas costs of production, 2018 and 2035, USD/MCF.

	Production costs (2018) [a]		**Technology** [b]	**Production costs (2035)** [c]	
Cost	**Low**	**High**	**change**	**Low**	**High**
Category	**USD/MCF**	**USD/MCF**	**%/year**	**USD/MCF**	**USD/MCF**
		Natural Gas			
CI	4.00	5.00	1.25%	3.23	4.04
CII	5.00	6.00	1.25%	4.04	4.84
CIII	6.00	7.00	1.25%	4.84	5.65
CIV	7.00	8.00	0.75%	5.98	6.83
CV	8.00	9.00	0.75%	6.83	7.68
Unconventional gas [d]	9.00	15.00	0.75%	7.68	12.80

a. 2018 conventional natural gas costs based on Aguilera (2014b) and Rystad (2019).
b. Rates of technological progress based on Aguilera and Radetzki (2016).
c. 2035 conventional gas costs estimated in this study.
d. Unconventional gas costs based on Aguilera (2014b) and Le (2018).

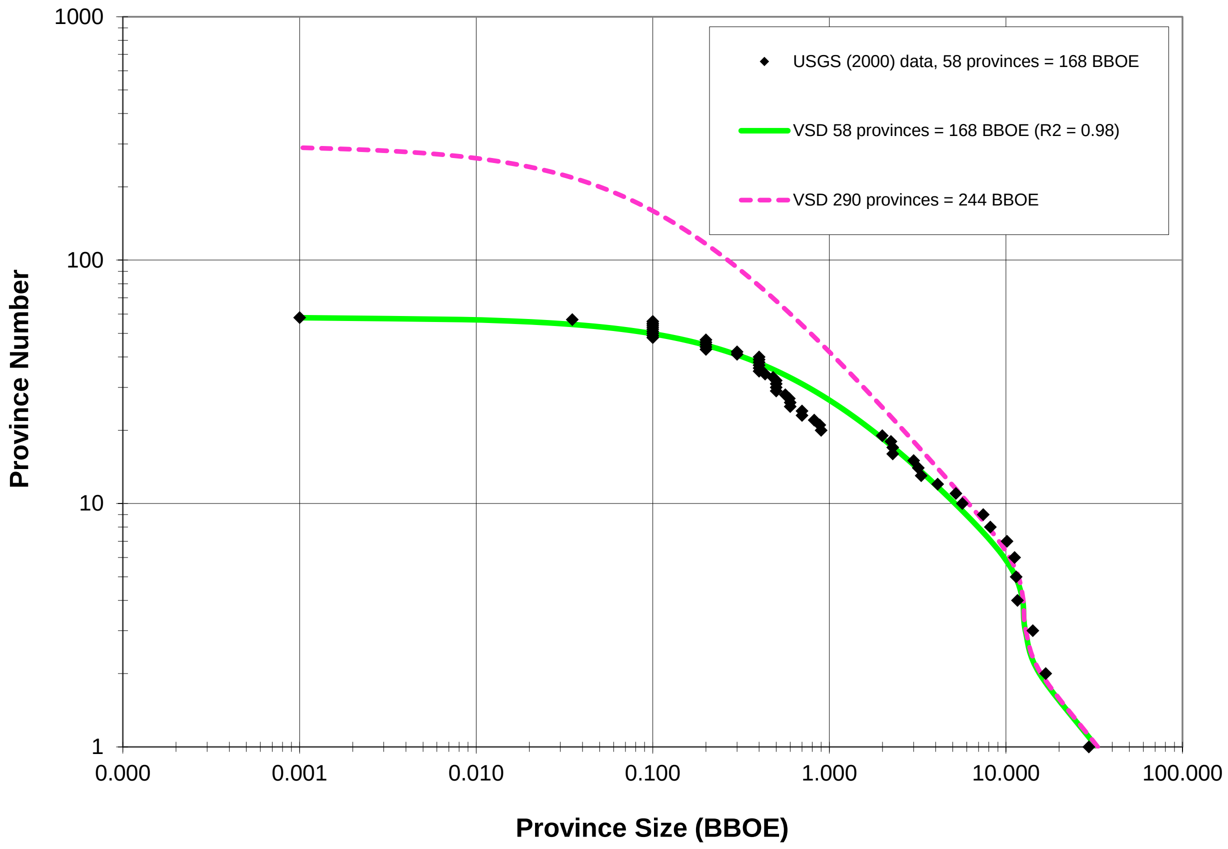

Fig. 1. VSD oil and NGL estimate for Asia provinces, including provinces not previously assessed (estimated in this study).

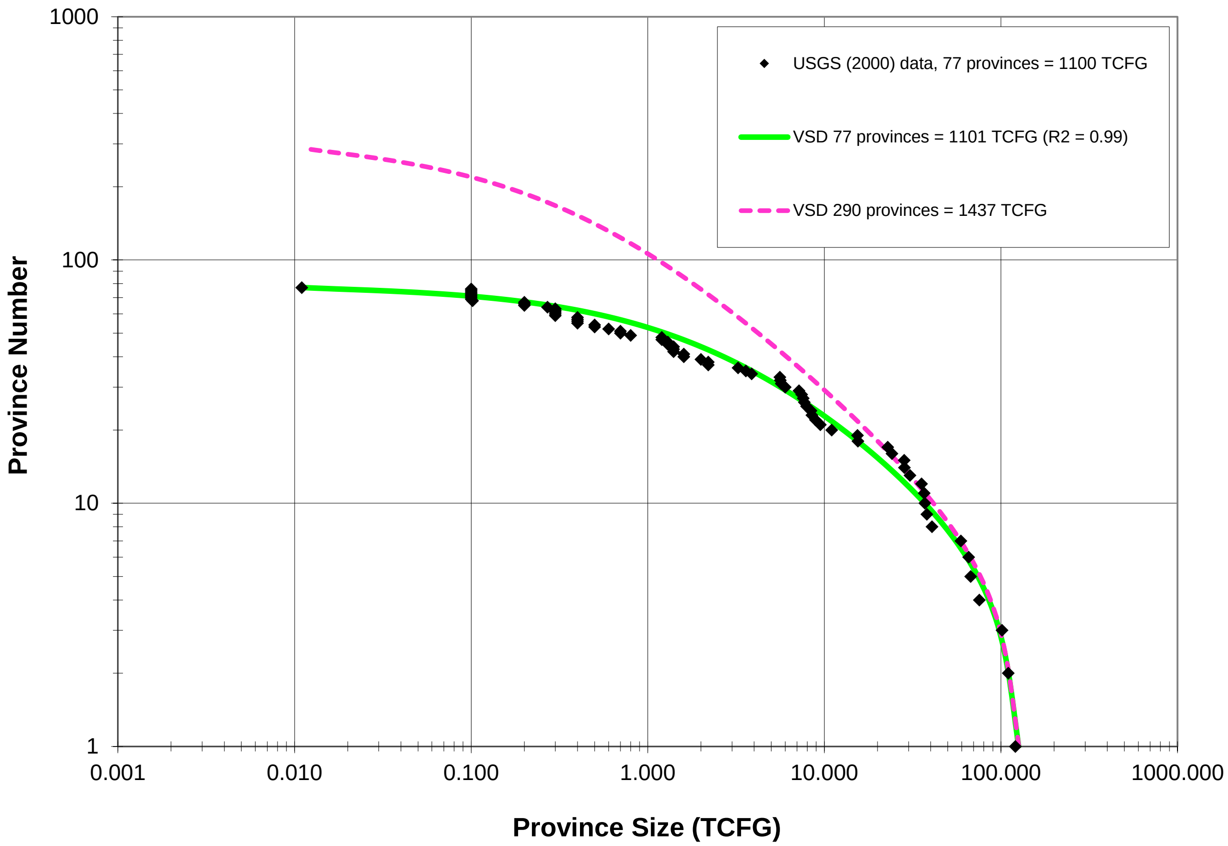

Fig. 2. VSD natural gas estimate for Asia provinces, including provinces not previously assessed (Aguilera and Ripple, 2011).

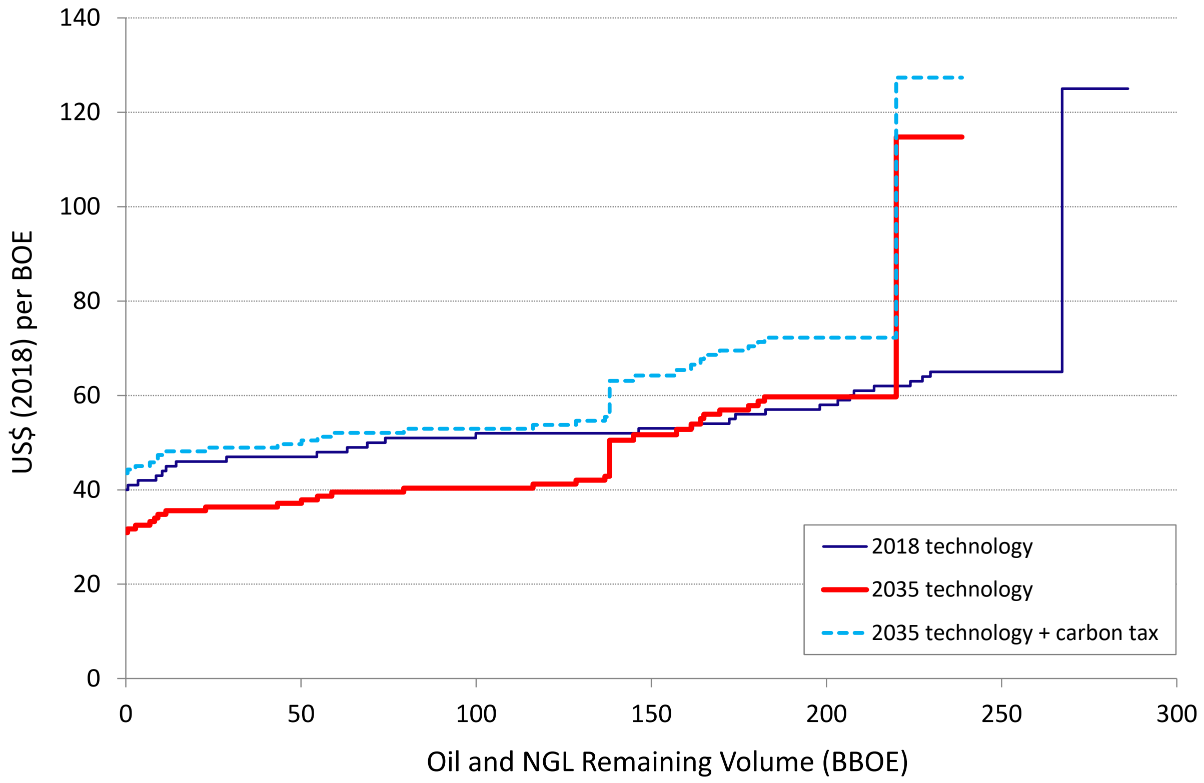

Fig. 3. Supply curves for oil, Asia. Curves show how remaining oil quantities vary with production costs. Cost categories (from Table 2) rise sequentially along vertical axis.

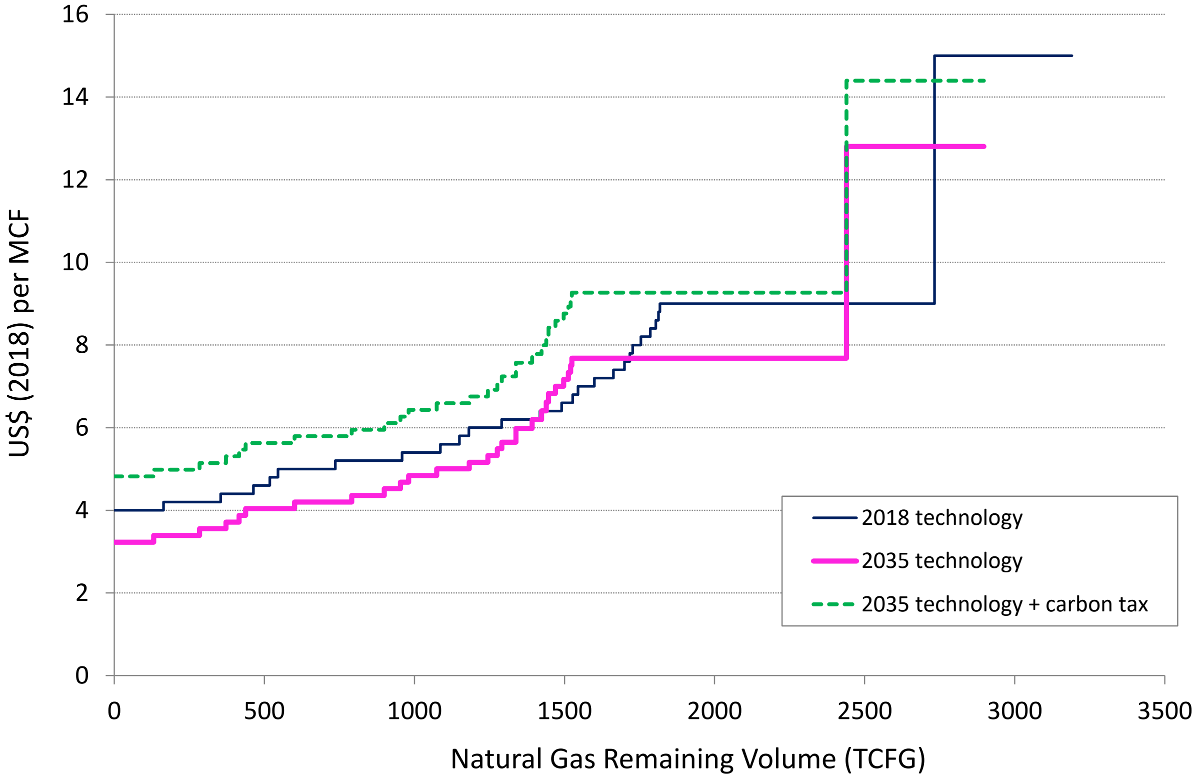

Fig. 4. Supply curves for natural gas, Asia. Curves show how remaining gas quantities vary with production costs. Cost categories (from Table 3) rise sequentially along vertical axis.

APPENDIX A

Table A.1

Oil endowment volumes for 58 Asia provinces assessed by USGS

R^2 coefficient of determination = **0.9831570**

a_p =	0.855	N_x =	58
r_m =	1.0526E-05	N_m =	1
		V_x =	95
V_s =	10	V_m =	0.001
Ψ =	0.35	a_m =	0.354
severity =	8	$(r_m)^{am}$ =	0.017

Province Code	Province Name	Cumulative # of Provinces N_t	USGS Oil + NGL Endowment (BBOE)	r_v	r_t	a_t	function	$\hat{V}_i$ (BBOE)
	TOTAL		**168.061**					**167.780**
3127	Bohaiwan Basin	1	29.470	0.97986	0.97987	0.00000	9.99275E-01	32.596
3144	Songliao Basin	2	16.813	0.42667	0.42668	0.81382	8.69258E-01	15.505
3808	Central Sumatra Basin	3	14.211	0.26001	0.26002	0.81560	4.93175E-01	12.893
3701	Baram Delta/Brunei-Sabah Basin	4	11.641	0.18178	0.18179	0.81312	2.08802E-01	12.444
3817	Kutei Basin	5	11.420	0.13699	0.13700	0.80968	7.87970E-02	11.354
8043	Bombay	6	11.216	0.10825	0.10826	0.80592	2.90163E-02	9.759
3154	Tarim Basin	7	10.153	0.08836	0.08837	0.80203	1.08458E-02	8.229
3948	Northwest Shelf	8	8.173	0.07385	0.07386	0.79808	4.18040E-03	6.963
3115	Junggar Basin	9	7.437	0.06285	0.06286	0.79411	1.66999E-03	5.953
3703	Malay Basin	10	5.672	0.05424	0.05425	0.79012	6.91617E-04	5.147
3930	Gippsland Basin	11	5.210	0.04733	0.04735	0.78612	2.96400E-04	4.495
3824	Northwest Java Basin	12	4.107	0.04169	0.04170	0.78211	1.31094E-04	3.961
3910	Bonaparte Gulf Basin	13	3.318	0.03700	0.03701	0.77809	5.96624E-05	3.516
3828	South Sumatra Basin	14	3.194	0.03305	0.03306	0.77405	2.78594E-05	3.141
8034	Assam	15	3.007	0.02968	0.02969	0.77000	1.33105E-05	2.820
3702	Greater Sarawak Basin	16	2.289	0.02677	0.02678	0.76593	6.49010E-06	2.545
8048	Irrawaddy	17	2.287	0.02425	0.02426	0.76183	3.22197E-06	2.305
3913	Browse Basin	18	2.235	0.02203	0.02205	0.75770	1.62503E-06	2.094
3822	North Sumatra Basin	19	1.994	0.02008	0.02009	0.75354	8.31005E-07	1.909
3503	Mekong/Cuulong/Vung Tau Basin	20	0.900	0.01835	0.01836	0.74935	4.30084E-07	1.744
8042	Indus	21	0.884	0.01680	0.01681	0.74511	2.24890E-07	1.597
3128	Ordos Basin	22	0.822	0.01541	0.01542	0.74083	1.18622E-07	1.464
3130	Pearl River Mouth Basin	23	0.700	0.01415	0.01416	0.73651	6.30209E-08	1.345
3126	Nanyang Basin	24	0.700	0.01301	0.01303	0.73212	3.36757E-08	1.237
3825	Penyu/West Natuna Basin	25	0.600	0.01198	0.01199	0.72768	1.80746E-08	1.139
3147	Subei Yellow Sea Basin	26	0.600	0.01104	0.01105	0.72318	9.73124E-09	1.050
3142	Sichuan Basin	27	0.594	0.01018	0.01019	0.71860	5.24877E-09	0.968
8026	Kohat-Potwar	28	0.564	0.00939	0.00940	0.71396	2.83259E-09	0.893
3966	New Guinea Foreland Basin-Fold	29	0.500	0.00866	0.00867	0.70923	1.52754E-09	0.824
3805	Bintuni/Sulawati Province	30	0.500	0.00799	0.00800	0.70441	8.22094E-10	0.760
3507	Thai Basin	31	0.500	0.00737	0.00738	0.69950	4.40960E-10	0.701
3131	Qaidam Basin	32	0.500	0.00679	0.00680	0.69449	2.35413E-10	0.646
8025	Sulaiman-Kirthar	33	0.481	0.00626	0.00627	0.68936	1.24908E-10	0.596
8047	Ganges-Brahmaputra Delta	34	0.433	0.00576	0.00577	0.68412	6.57681E-11	0.548
3924	Eromanga Basin	35	0.400	0.00530	0.00531	0.67874	3.43082E-11	0.504
3809	East Java Basin	36	0.400	0.00487	0.00488	0.67323	1.76997E-11	0.463
3606	Pamusian Tarakan Basin	37	0.400	0.00446	0.00448	0.66756	9.01305E-12	0.425
3605	Palawan Shelf	38	0.400	0.00409	0.00410	0.66172	4.52040E-12	0.389
3505	Saigon Basin	39	0.400	0.00373	0.00375	0.65569	2.22755E-12	0.356
3031	Taranaki Basin	40	0.400	0.00340	0.00341	0.64946	1.07553E-12	0.324
3112	Jianghan Basin	41	0.300	0.00309	0.00310	0.64301	5.07216E-13	0.295
3103	Beibuwan Basin	42	0.300	0.00280	0.00281	0.63630	2.32776E-13	0.267
8045	Krishna-Godavari	43	0.200	0.00253	0.00254	0.62932	1.03509E-13	0.241
3508	Thailand Mesozoic Basin Belt	44	0.200	0.00227	0.00228	0.62201	4.43686E-14	0.217
3156	Turpan Basin	45	0.200	0.00203	0.00204	0.61436	1.82187E-14	0.194
3114	Jiuquan Minle Wuwei Basin	46	0.200	0.00180	0.00181	0.60629	7.11163E-15	0.172
3110	Erlian Basin	47	0.200	0.00158	0.00159	0.59776	2.61375E-15	0.152
8044	Cauvery	48	0.100	0.00138	0.00139	0.58868	8.93454E-16	0.132
3804	Barito Basin	49	0.100	0.00119	0.00120	0.57895	2.79530E-16	0.114
3803	Banda Arc	50	0.100	0.00102	0.00103	0.56843	7.83357E-17	0.097
3308	Niigata Basin	51	0.100	0.00085	0.00086	0.55696	1.90817E-17	0.082
3304	Japan Volcanic Arc/Accreted Terr	52	0.100	0.00069	0.00070	0.54427	3.86763E-18	0.067
3146	South China Fold Belt	53	0.100	0.00055	0.00056	0.52999	6.10018E-19	0.053
3135	Qinling Dabieshan Fold Belt	54	0.100	0.00041	0.00042	0.51352	6.70210E-20	0.040
3124	Luxi Jiaoliao Uplift	55	0.100	0.00029	0.00030	0.49380	4.18487E-21	0.028
3109	East China Sea Basin	56	0.100	0.00018	0.00019	0.46871	9.55493E-23	0.018
3916	Carnarvon Basin	57	0.035	0.00008	0.00009	0.43246	2.18237E-25	0.008
8035	North Burma	58	0.001	0.00000	0.00001	0.35426	9.99600E-33	0.001

Table A.2

Natural gas endowment volumes for 77 Asia provinces assessed by USGS

R^2 coefficient of determination = **0.9900130**

a_p =	0.697	N_x =	77
r_m =	7.1429E-06	N_m =	1
		V_x =	1,540
V_s =	3707	V_m =	0.011
Ψ =	0.02532303	a_m =	0.367
severity =	1.1456242	$(r_m)^{am}$ =	0.013

Province Code	Province Name	Cumulative # of Provinces N_t	USGS Natural Gas Endowment (TCFG)	r_v	r_t	a_t	function	$\hat{V}_i$ (TCFG)
	TOTAL		**1099.632**					**1101.219**
3948	Northwest Shelf	1	120.956	0.98142	0.98143	0.00000	2.85484E-01	126.074
3817	Kutei Basin	2	110.230	0.35621	0.35622	0.67152	1.03030E-01	110.476
3702	Greater Sarawak Basin	3	101.411	0.19530	0.19531	0.67268	5.37363E-02	98.026
3703	Malay Basin	4	75.614	0.12676	0.12676	0.67119	3.32823E-02	85.583
8047	Ganges-Brahmaputra Delta	5	67.380	0.09023	0.09023	0.66911	2.27426E-02	74.099
3154	Tarim Basin	6	65.719	0.06808	0.06809	0.66683	1.65576E-02	64.041
3701	Baram Delta/Brunei-Sabah Basin	7	59.426	0.05347	0.05348	0.66449	1.25995E-02	55.463
3822	North Sumatra Basin	8	40.682	0.04325	0.04326	0.66211	9.90449E-03	48.228
3913	Browse Basin	9	38.053	0.03577	0.03577	0.65972	7.98220E-03	42.144
8043	Bombay	10	37.137	0.03010	0.03011	0.65733	6.56055E-03	37.020
3910	Bonaparte Gulf Basin	11	36.796	0.02569	0.02570	0.65495	5.47830E-03	32.688
8042	Indus	12	35.560	0.02219	0.02219	0.65257	4.63468E-03	29.006
8048	Irrawaddy	13	30.530	0.01935	0.01935	0.65019	3.96399E-03	25.858
3828	South Sumatra Basin	14	28.455	0.01701	0.01701	0.64781	3.42182E-03	23.151
8025	Sulaiman-Kirthar	15	28.376	0.01505	0.01506	0.64544	2.97725E-03	20.809
3127	Bohaiwan Basin	16	24.186	0.01341	0.01341	0.64306	2.60818E-03	18.771
3142	Sichuan Basin	17	22.837	0.01200	0.01201	0.64068	2.29847E-03	16.989
3824	Northwest Java Basin	18	15.508	0.01079	0.01080	0.63830	2.03610E-03	15.423
3930	Gippsland Basin	19	15.433	0.00975	0.00975	0.63591	1.81194E-03	14.039
3966	New Guinea Foreland Basin-Fold	20	11.000	0.00883	0.00884	0.63352	1.61900E-03	12.812
3805	Bintuni/Sulawati Province	21	9.500	0.00803	0.00803	0.63111	1.45181E-03	11.718
3507	Thai Basin	22	8.900	0.00732	0.00732	0.62870	1.30604E-03	10.740
3924	Eromanga Basin	23	8.500	0.00669	0.00669	0.62628	1.17825E-03	9.861
3159	Yingehai Basin	24	8.400	0.00612	0.00613	0.62384	1.06567E-03	9.070
3808	Central Sumatra Basin	25	7.944	0.00562	0.00563	0.62139	9.66024E-04	8.355
8034	Assam	26	7.712	0.00517	0.00517	0.61892	8.77470E-04	7.707
3809	East Java Basin	27	7.600	0.00476	0.00476	0.61644	7.98468E-04	7.118
3144	Songliao Basin	28	7.449	0.00439	0.00439	0.61393	7.27742E-04	6.582
3031	Taranaki Basin	29	7.200	0.00405	0.00406	0.61141	6.64220E-04	6.091
3505	Saigon Basin	30	6.000	0.00374	0.00375	0.60887	6.06998E-04	5.642
3825	Penyu/West Natuna Basin	31	5.700	0.00346	0.00347	0.60630	5.55309E-04	5.231
3128	Ordos Basin	32	5.630	0.00321	0.00321	0.60370	5.08500E-04	4.852
3605	Palawan Shelf	33	5.600	0.00297	0.00298	0.60108	4.66011E-04	4.503
3115	Junggar Basin	34	3.879	0.00275	0.00276	0.59844	4.27358E-04	4.181
3606	Pamusian Tarakan Basin	35	3.600	0.00255	0.00256	0.59576	3.92125E-04	3.884
8026	Kohat-Potwar	36	3.245	0.00237	0.00238	0.59305	3.59949E-04	3.608
3308	Niigata Basin	37	2.200	0.00220	0.00220	0.59030	3.30514E-04	3.353
3969	Papuan Basin-Shelf Platform	38	2.200	0.00204	0.00205	0.58752	3.03544E-04	3.116
3151	Taiwan Thrust and Fold Belt	39	2.000	0.00189	0.00190	0.58471	2.78797E-04	2.896
3304	Japan Volcanic Arc/Accreted Terr	40	1.600	0.00176	0.00176	0.58185	2.56057E-04	2.691
3181	South China Continental Shelf Sl	41	1.600	0.00163	0.00164	0.57895	2.35138E-04	2.500
3109	East China Sea Basin	42	1.400	0.00151	0.00152	0.57600	2.15870E-04	2.322
8045	Krishna-Godavari	43	1.400	0.00140	0.00141	0.57300	1.98106E-04	2.155
3958	Surat Basin	44	1.400	0.00130	0.00131	0.56996	1.81713E-04	2.000
3503	Mekong/Cuulong/Vung Tau Basin	45	1.300	0.00120	0.00121	0.56686	1.66573E-04	1.855
3306	Kanto Basin	46	1.300	0.00112	0.00112	0.56370	1.52580E-04	1.719
3903	Amadeus Basin	47	1.200	0.00103	0.00104	0.56048	1.39638E-04	1.592
3950	Otway Basin	48	1.200	0.00095	0.00096	0.55720	1.27663E-04	1.473
3131	Qaidam Basin	49	0.800	0.00088	0.00089	0.55384	1.16577E-04	1.361
3952	Perth Basin	50	0.700	0.00081	0.00082	0.55041	1.06310E-04	1.256
3502	Khorat Platform	51	0.700	0.00075	0.00075	0.54690	9.68009E-05	1.158
3806	Bone Basin	52	0.600	0.00069	0.00069	0.54331	8.79915E-05	1.066
3833	Sumatra/Java Magmatic Arc	53	0.500	0.00063	0.00064	0.53962	7.98304E-05	0.979
3153	Taixinan Basin	54	0.500	0.00058	0.00058	0.53584	7.22707E-05	0.898
3611	Sulu Sea Basin	55	0.400	0.00053	0.00053	0.53195	6.52696E-05	0.822
3832	Sumatra/Java Fore-Arc Basins	56	0.400	0.00048	0.00049	0.52794	5.87882E-05	0.750
3316	Tsushima Basin	57	0.400	0.00044	0.00044	0.52381	5.27911E-05	0.683
8044	Cauvery	58	0.400	0.00040	0.00040	0.51954	4.72458E-05	0.620
3130	Pearl River Mouth Basin	59	0.300	0.00036	0.00036	0.51512	4.21226E-05	0.561
3147	Subei Yellow Sea Basin	60	0.300	0.00032	0.00033	0.51054	3.73947E-05	0.506
3508	Thailand Mesozoic Basin Belt	61	0.300	0.00029	0.00030	0.50578	3.30371E-05	0.454
3907	Bass Basin	62	0.300	0.00026	0.00026	0.50082	2.90272E-05	0.406
3303	Ishikari Hidaka Basin	63	0.300	0.00023	0.00023	0.49564	2.53444E-05	0.360
8023	Central Afghanistan	64	0.271	0.00020	0.00021	0.49021	2.19698E-05	0.318
3804	Barito Basin	65	0.200	0.00017	0.00018	0.48450	1.88862E-05	0.279
3146	South China Fold Belt	66	0.200	0.00015	0.00016	0.47847	1.60778E-05	0.242
3305	Joban Basin	67	0.200	0.00013	0.00014	0.47207	1.35306E-05	0.208
3916	Carnarvon Basin	68	0.102	0.00011	0.00012	0.46524	1.12317E-05	0.177
3103	Beibuwan Basin	69	0.100	0.00009	0.00010	0.45791	9.16993E-06	0.148
3156	Turpan Basin	70	0.100	0.00007	0.00008	0.44999	7.33525E-06	0.122
3829	Sulawesi Accretionary Prism	71	0.100	0.00006	0.00006	0.44133	5.71923E-06	0.098
3160	Yinshan Da and Xiao Hingganling	72	0.100	0.00004	0.00005	0.43179	4.31507E-06	0.077
3609	Reed Bank Basin	73	0.100	0.00003	0.00004	0.42112	3.11789E-06	0.058
3810	East Natuna Basin	74	0.100	0.00002	0.00003	0.40903	2.12535E-06	0.041
3823	Northern Irian Jaya Waropen Basi	75	0.100	0.00001	0.00002	0.39516	1.33904E-06	0.028
3113	Jiangnan South Jiangsu Fold Belt	76	0.100	0.00000	0.00001	0.37954	7.68603E-07	0.017
8035	North Burma	77	0.011	0.00000	0.00001	0.36658	4.64894E-07	0.011

Table A.3

All provinces in Asia (including previously unassessed)

1	Adelaide and Kanmantoo Fold Belts
2	Afghan
3	Akita Basin
4	Alashan Yinshan Fold Belt
5	Albany-Fraser Province
6	Altunshan Fold Belt
7	Amadeus Basin
8	Arafura Basin-Irian Jaya
9	Arunta Block
10	Assam
11	Australian Arafura Basin
12	Bali Basin
13	Baluchistan
14	Banda Arc
15	Bangemall and Nabberu Basins
16	Baram Delta/Brunei-Sabah Basin
17	Barito Basin
18	Bass Basin
19	Bassian Rise
20	Bau Waters Basin
21	Beibuwan Basin
22	Bellona Plateau
23	Bicol Shelf Basin
24	Bijianan Basin
25	Bintuni/Sulawati Province
26	Birrindudu Basin and Tanami Block
27	Bligh Water Basin
28	Bogdashan Fold Belt
29	Bohaiwan Basin
30	Bombay
31	Bonaparte Gulf Basin
32	Bone Basin
33	Bose Basin
34	Bowen Basin
35	Bremer Basin
36	Browse Basin
37	Cagayan Basin
38	Canning Basin
39	Cape Vogel Basin
40	Capricorn Basin
41	Carnarvon Basin
42	Carpentaria Basin
43	Cauvery
44	Celebes Sea
45	Central Afghanistan
46	Central Sumatra Basin
47	Central Vietnam Basin
48	Challenger Plateau
49	Chatham Rise
50	Chindwara
51	Choybalsan Basin
52	Chuxiong Basin
53	Clarence-Moreton Basin
54	Coen-Yambo Block
55	Cotabato Basin
56	Cuoqing Lupola Basin
57	Daly River Basin
58	Damodar
59	Darling Basin
60	Drummond Fold Belt and Anakie High
61	East China Sea Basin
62	East Java Basin
63	East Natuna Basin
64	East Ontong Java Rise
65	Erlian Basin
66	Eromanga Basin
67	Eucla Basin
68	Fiji Islands
69	Fiji Ridge
70	Flores Basin
71	Galilee Basin
72	Ganges-Brahmaputra Delta
73	Gascoyne Block
74	Gawler Block
75	Gensan Basin
76	Georgina Basin
77	Gippsland Basin
78	Gobi Basin
79	Gorontalo Basin
80	Great Australian Bight Basin
81	Great Lake Basin
82	Great Lake Uplift
83	Great South Basin
84	Greater Sarawak Basin
85	Gyeongsang Basin
86	Halifax Basin
87	Halls Creek Province
88	Halmahera Basin
89	Halmahera Platform
90	Heilongjiang Basin
91	Hikurani Trough
92	Himalayan
93	Himalayan Foreland
94	Hodgkinson/Lachlan Fold Belt
95	Honshu Ridge
96	Huskan Platform
97	Indian Shield
98	Indispensable Reef
99	Indo-Burman
100	Indus
101	Irrawaddy
102	Ishikari Hidaka Basin
103	Japan Volcanic Arc/Accreted Terrane
104	Java/Banda Sea
105	Jianghan Basin
106	Jiangnan South Jiangsu Fold Belt
107	Jiuquan Minle Wuwei Basin
108	Joban Basin
109	Junggar Basin
110	Kanto Basin
111	Karamay Thrust Belt
112	Kermadec Ridge
113	Ketuneau/Sintang Terrane
114	Khorat Platform
115	Kimberley Basin
116	Kohat-Potwar
117	Konkan
118	Korba Bay Basin
119	Korean Continental Shelf
120	Korean Craton
121	Krishna-Godavari
122	Kumukulig Basin
123	Kunlunshan Fold Belt
124	Kutei Basin
125	Lacklan Fold Belt
126	Lakshadweep
127	Lanping Simao Basin
128	Laura Basin
129	Leidong Basin
130	Lhasa Basin
131	Lhasa Terrane
132	Longmenshan Dabashan Fold Belt
133	Lord Howe Rise
134	Loyalty Island Ridge
135	Luxi Jiaoliao Uplift
136	Mahanadi
137	Makran
138	Malakula/Aoba/Banks Basin
139	Malay Basin
140	Malay Peninsula
141	Maldives
142	Marion Terrain
143	Maryborough Basin
144	McArthur Basin
145	Mekong/Cuulong/Vung Tau Basin
146	Melanesia Border Plateau
147	Melawi Basin
148	Mellish Reef
149	Meratus High
150	Merauke Platform
151	Miyazaki Basin
152	Mohe Basin
153	Money Shoal Basin
154	Mongol-Okhotsk Folded Region
155	Mt. Isa Block
156	Murray Basin
157	Musgrave Block
158	Nanpanjiang Depression
159	Nanyang Basin
160	New Caledonia
161	New England Fold Belt
162	New Guinea Foreland Basin-Fold Belt
163	New Guinea Mobile Belt
164	New Hebrides Arc
165	New Ireland Basin
166	New Zealand East Coast Basin
167	New Zealand Orogenic Belt
168	Ngalia Basin
169	Niigata Basin
170	Norfolk Island Ridge
171	North Banda Basin
172	North Burma
173	North Sumatra Basin
174	Northern Irian Jaya Waropen Basin
175	Northland Basin
176	Northwest Java Basin
177	Northwest Shelf
178	Nyalga Basin
179	Officer Basin
180	Okinawa Trough
181	Ordos Basin
182	Otway Basin
183	Palawan Shelf
184	Pamusian Tarakan Basin
185	Panjang/Cardomomes Basin
186	Papuan Basin-Shelf Platform
187	Paterson Province
188	Pearl River Mouth Basin
189	Penyu/West Natuna Basin
190	Perth Basin
191	Philippine Accretionary Prism
192	Philippine Magmatic Arc
193	Pilbara Block
194	Pine Creek Geosyncline
195	Pranhita-Godavari
196	Qabdu Basin
197	Qaidam Basin
198	Qiangtang Tanggula Basin
199	Qiangtang Terrane
200	Qilianshan Fold Belt
201	Qinling Dabieshan Fold Belt
202	Qiongdongnan Basin
203	Queensland Plateau
204	Rajang-Crocker Accretionary Prism
205	Reed Bank Basin
206	Rocky Cape Block/Dundas Trough
207	Russell Basin
208	Ryukyu Volcanic Arc
209	Sagara Basin
210	Saigon Basin
211	Samoa Basin
212	Sanshui Basin
213	Satpura-Brahmani
214	Sea Of Japan Backarc Basin
215	Sepik-Ramu Basin
216	Shanxi Plateau
217	Shiwan Dashan Basin
218	Shorland Basin
219	Sichuan Basin
220	Sinzi Uplift
221	Solander-Waiau Basin
222	Solomon Islands
223	Songliao Basin
224	Songpan Ganzi Fold Belt
225	South Banda Basin
226	South Bismarck Volcanic Arc
227	South China Continental Shelf Slope
228	South China Fold Belt
229	South China Ocean Basin
230	South China Sea Platform
231	South Makassar Basin
232	South Sumatra Basin
233	Southeast Afghanistan
234	Sri Lanka
235	Stuart Shelf
236	Subei Yellow Sea Basin
237	Sulaiman-Kirthar
238	Sulawesi Accretionary Prism
239	Sulawesi Magmatic Arc
240	Sulongshan Fold Belt
241	Sulu Arch
242	Sulu Sea Basin
243	Sumatra/Java Accretionary Prism
244	Sumatra/Java Fore-Arc Basins
245	Sumatra/Java Magmatic Arc
246	Sumba Province
247	Sunda Platform
248	Surat Basin
249	Sydney Basin
250	Tagaung Myitkyina Fold Belt
251	Taihangshan Yanshan Fold Belt
252	Taikang Hefei Basin
253	Taiwan Melange Belt
254	Taiwan Thrust and Fold Belt
255	Taixinan Basin
256	Taranaki Basin
257	Tarim Basin
258	Tasmania Basin
259	Temtsag Hailar Basin
260	Tenasserim-Shan
261	Tennant Creek Block
262	Thai Basin
263	Thailand Mesozoic Basin Belt
264	Three Kings Rise
265	Tokachi Basin
266	Tonga Ridge
267	Tonle Sap-Phnom Penh Basin
268	Tottori Basin
269	Truong Son Fold Belt
270	Tsushima Basin
271	Turpan Basin
272	Ulan Bator Basin
273	Ulan Bator Basin
274	Ushumun Basin
275	Vanikoro Basin
276	Victoria River Basin
277	Visayan
278	Waikato Basin
279	Wanganui Basin
280	Weber Basin
281	Wiso Basin
282	Xichang Yunnan Fold Belt
283	Xisha Trough
284	Yilgarn Block
285	Yingehai Basin
286	Yinshan Da and Xiao Hingganling Uplift
287	Yitong Graben
288	Yunnan Guizhou Hubei Fold Belt
289	Zambalez/Central Luzon Basin
290	Zhangguangcailing Uplift