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Short Communication

A bumpy road to the top: Statistically defining a peak in oil production

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HIGHLIGHTS

- Oil production is volatile which makes it difficult to determine peak production.
- A measure of volatility based on oil production figures is described (PPP_{max}).
- A frequency distribution of PPP_{max} gives insight into national production profiles.
- PPP_{max} elucidates global production.

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ABSTRACT

Twenty-four countries where oil production is in decline were identified. A simple metric of the volatility of oil production on the upslope of their production curves, called decline as a proportion of pre-peak production (or PPP_{max}), was created. PPP_{max} was determined for the post-peak countries and plotted as a frequency distribution. PPP_{max} varied from 0–56%, but was skewed toward the lower part of the range (median 6.2%). As global production is determined by the total contribution of production from all countries, the variation in PPP_{max} will represent the lower and upper bound of the "bumpiness" of global oil production. It also enables a retrospective approximation of the when global oil production is most likely past its peak.

1. Introduction

Much intellectual effort has gone into determining when global oil production will peak (Aleklett et al., 2010; Hirsch, 2005; Jakobsson et al., 2009; Maggio and Cacciola, 2009; Nashawi et al., 2010; Owen et al., 2010; Sorrell et al., 2010). This has been a controversial endeavour. By contrast, the important concept of determining the likelihood of being past peak production (PP) based on oil production figures has attracted little interest. This study will attempt to statistically define PP, in other words determine the probability that oil production will not exceed previous peak production once a downturn has occurred. This is an important determination as, if it can be accurately defined, it will give policymakers a tool to understand oil production and perhaps give some insight globally.

In a hypothetical scenario of a region which follows a classic bell-shaped production curve, the ability to determine precisely when PP occurs is straightforward: it occurs at the first measurable downturn in production (Fig. 1A). Unfortunately, a real-world situation virtually never follows a perfect bell-curve. As a result, a decline in production due to reservoir depletion is difficult to distinguish from other factors causing volatility (or "bumpiness") whether they are investment, geopolitical, technical, market-related or geological (Fig. 1B). Only one attempt has been made to study the behaviour of national production around the peak (Hirsch, 2008). In that study, a plateau of production with a 3–4% variation in production was implied as a criterion to distinguish the start of the decline phase. This was based primarily on production experience in the North America and Europe. This 3–4% band has, for example, been used in analysing decline curves (HÖÖk et al., 2009).

This study will explore the behaviour of 24 national production profiles where it is clear that they are past their peak in production. A simple measure of bumpiness is described called proportion of production pre-peak, or PPP_{max} (Fig. 1B), which is defined as the largest proportion that production turns down prior to PP (i.e. on the upward slope of the production curve). This can be thought of as the amount that a country's oil production must decrease before it breaks through volatility and enters permanent decline. An example of oil production for Norway showing PPP_{max} for that country is shown (Fig. 1C).

A frequency distribution of PPP_{max} illustrates the best and worst case scenarios of volatility in national production profiles. As this distribution can be thought of as a measure of the frequency

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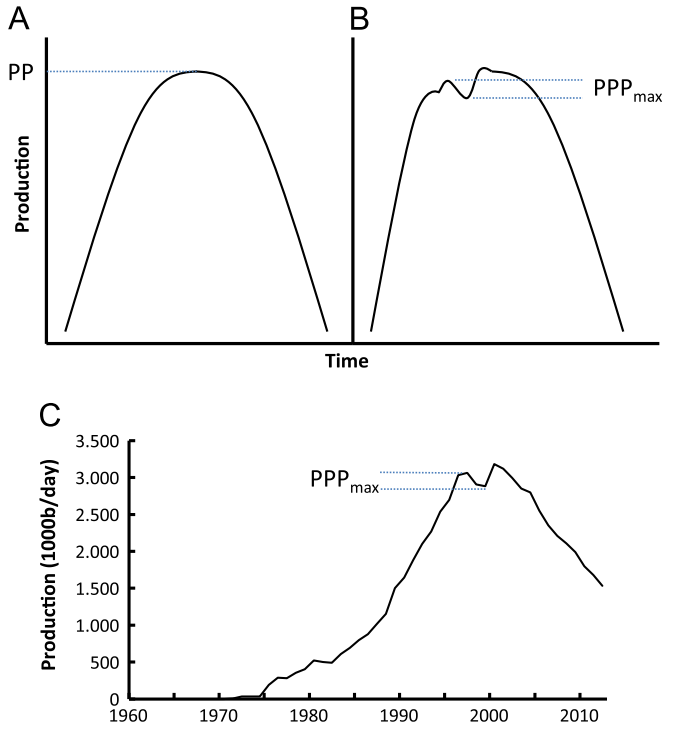

Fig. 1. PPP$_{max}$ is a measure of oil production volatility. (A) An ideal bell-shaped production curve showing peak production (PP). (B) A representation of a realistic production curve showing volatility on the upslope of the curve. The region showing PPP$_{max}$ is indicated. (C) A real example of an oil production curve for Norway showing its PPP$_{max}$.

of the level of "bumpiness" on the upslope of the curve, it therefore gives an estimate of the probability of PP once a certain downturn in production has occurred. From the results presented in this work, a small downturn in production (6.2%) may indicate that PP has occurred for that country on the balance of probability ($p < 0.5$). Certainty of PP ($p < 0.05$) will come only after production has declined by more than 35%. It also assists in determining when peak global production has occurred. The rationale underlying this is that as global oil production is the sum of national production, its behaviour is determined by the collective behaviour of those countries.

2. Methods

Publicly available data for annual oil production since 1960 from Organization of Oil Exporting Countries (OPEC, 2014) or, where data on a country was otherwise unavailable, from British Petroleum (BP, 2014) were used. Post-peak countries were identified as those countries where production had declined for 10 or more years (2004 or earlier). A value for the maximum downturn in the proportion of production pre-peak (PPP$_{max}$) was determined for each country. This was calculated by determining the largest difference (prior to peak production) between a maximum on a production curve and a later minimum, given as a percentage of the maximum value (Fig. 1B). The only exception to this was when production was is its early stage and PPP$_{max}$ was disproportionate; for example, Brunei. In this case, a significant later value was used instead. A frequency distribution was plotted by sorting countries into groups on the basis of a 5% incremental range for PPP$_{max}$. The lowest range incremental group (0–5%) also included those countries where there was no measurable downturn in production prior to PP. The largest group included the single country where was greater than 35%.

3. Results

The production from all oil producing countries identified as being past PP was plotted (see Fig. S1). From this plot, PPP$_{max}$ was calculated. A frequency distribution of the PPP$_{max}$ (Fig. 2) varied from 0–56%. The distribution was heavily skewed to a low proportion drop after which production did not return to the peak value (average for PPP$_{max}$, 12.1%; median, 6.2%). In other words, 50% of countries had peaked after a relatively small downturn in production (6.2% or less), which is defined as the criterion for probable determination ($p < 0.5$). However, one country ($\sim$5% of the total) required a drop of more than 35% in the proportion of production before peak production was clearly established. A downturn of 35% or more was therefore set as the criterion for certainty ($p < 0.05$).

4. Discussion

Previous studies have suggested a 3–4% fluctuating band, or "bumpy plateau" to determine the PP threshold (Hirsch, 2008). This value was determined using the production profiles of North America and Europe, and does not enable a probabilistic determination of PP. Notably, the 3–4% band is less than the median value of 6.2% for probable PP, and considerably less than the $>35\%$ value for certainty in this study. As data from the North America and Europe were used to determine the 3–4% band, the smaller value may reflect the more stable political environment, and access to technology and resources available in these countries, resulting in a smoother production curve. By contrast, the larger

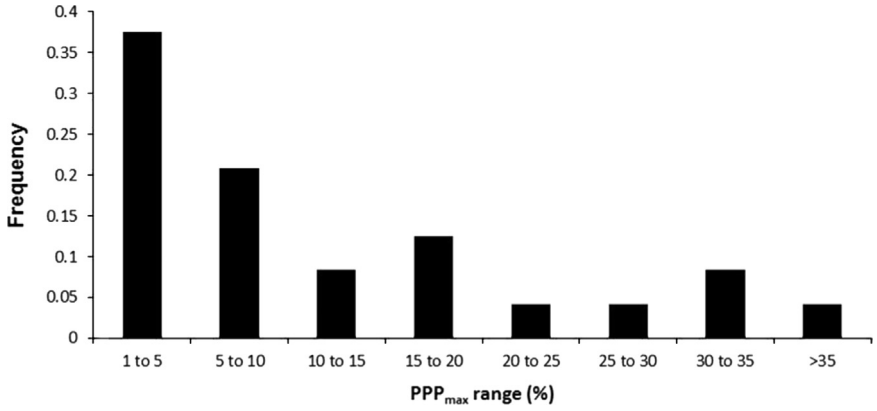

Fig. 2. Frequency distribution for PPP$_{max}$. The distribution is divided into increments of 5%. The last is PPP$_{max}$ greater than 35%.