Simulating Mine Revenues with Historical Gold Price Data from the Bank of England

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Abstract

This paper demonstrates a simulation method using historical prices for gold over a 40-year period. The simulation method can be used to assess variability in a mine plan. In this example, I use monthly gold data from the Bank of England. The total sample size is approximately 450 monthly data points, from which I consider 11 different continuous subsamples with length 100. Some of these blocks of data are overlap, but they are all different. For each block of data, I preform various calculations for a hypothetical mine plan that produces one ounce of gold per month. I report undiscounted total revenue over the 100-month period with real prices corresponding to different historical episodes and note how gold prices have changed over this 40-year period. I also use monthly price differences from each path to simulate gold price paths all starting with the same initial value, which allows for more apples-apples comparison. I show the Revenue Paths in such cases, report the present value for each path, and include a simple cost model in the mine plan to estimate net present value for each path with standardized initial prices.

Keywords: Engineering Economics, Mining, Royalties, Finance

JEL Codes: C00 General; G00 General; L72 Mining, Extraction, and Refining

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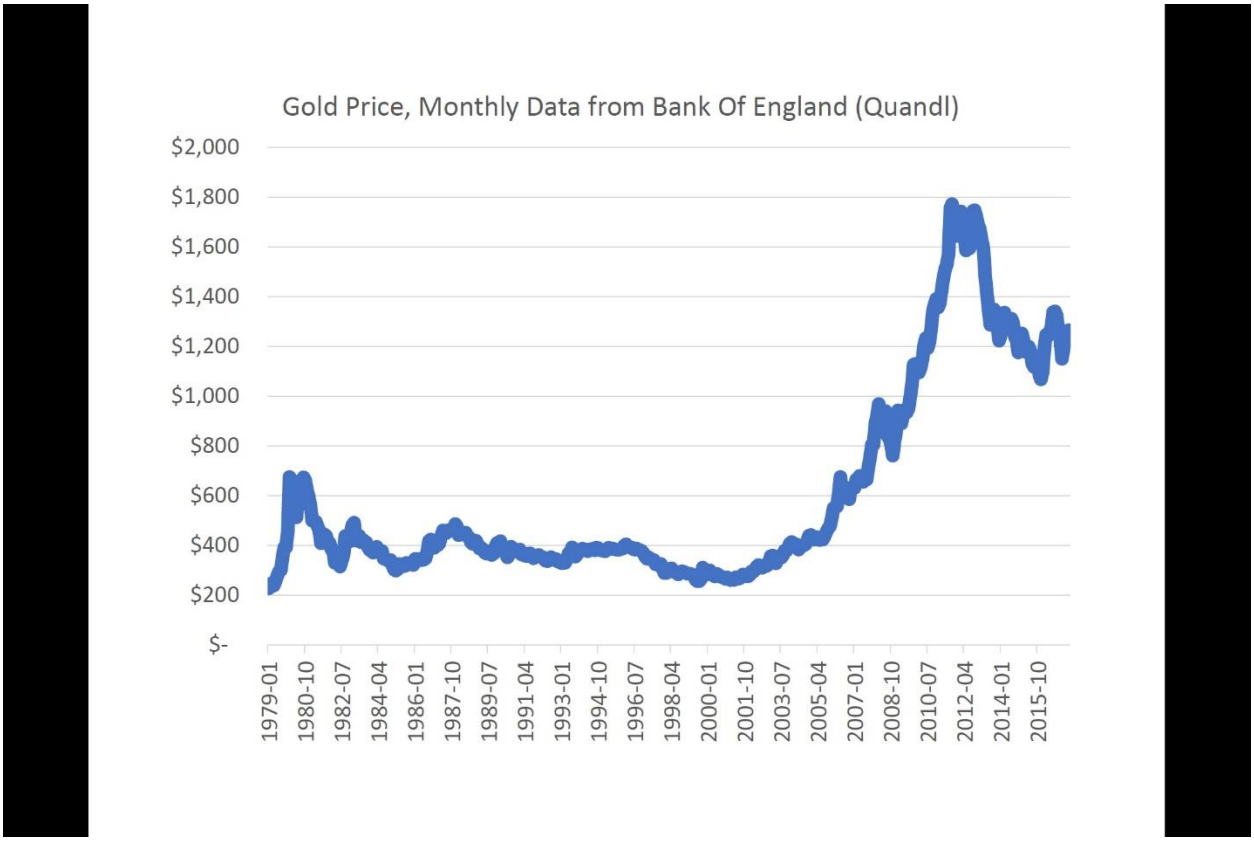
This paper continues in a series on simulations for mine planning, as in Bell (2018). The current paper uses empirical data for gold price from Quandl (2018). I use nearly 40 years of monthly gold price data to conduct simulations against a hypothetical mine production profile. The production profile is simply one ounce of gold per month for 100 months, which is meant to imitate a 10-year life of mine plan.

Within the full data set of 40 years, I consider 11 different blocks of data that are each 100 months long. The blocks are offset by 35 months. Each block represents one life of mine plan and I analyze the variability of the economics of that plan in context of contemporaneous changes in gold prices. The first 100-month block starts January 1979 and ends March 1988. The last block starts February 2009 and end April 2017. As the blocks are overlapping, the data is not independent, however, it is useful for simulation.

Gold Price Data

Monthly gold prices are available for free use from Quandl (2018). The monthly data is relevant to detailed mine planning activities.



The gold price chart shows several interesting features. In particular, note how the more recent data is points larger than earlier data. This rising price could be seen as an example of inflation, as these nominal prices have not been adjusted in any way. One way to account for this increase in gold price is to use the differences in gold price, rather than the gold prices levels themselves: normalize initial gold price to constant value in mine plan, then simulate future price paths based on historical differences.

To see how the rising gold price affects simulations, consider the undiscounted value of the total revenue produced over various historical episodes. The graph below shows the gross vale for each of the 11 episodes considered in this paper, with the most recent episodes showing the largest value for total undiscounted gross revenue.

Dates for each episode are provided in Table 1 below.

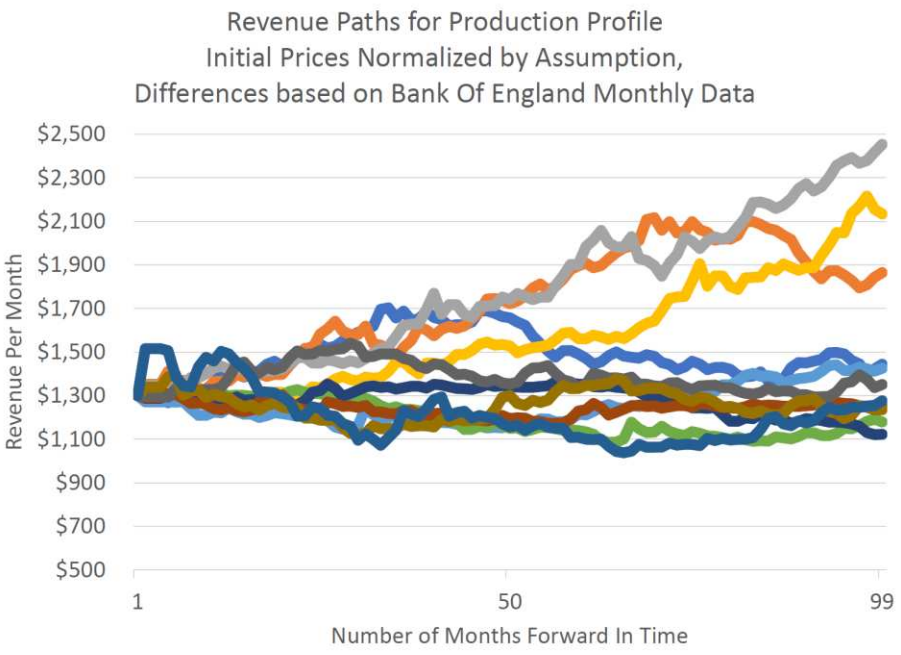
Table 1: Start & End Dates for Historical Episodes.

Start Date	2009-01-31	2006-02-28	2003-03-31	2000-04-30	1997-05-31	1985-09-30	1991-07-31	1988-08-31	1985-09-30	1982-10-31	1979-11-30
End Date	2017-04-30	2014-06-30	2011-07-31	2008-08-31	2005-09-30	2002-10-31	1999-11-30	1996-12-31	1994-01-31	1991-02-28	1988-03-31
Historical Episode	1	2	3	4	5	6	7	8	9	10	11

Notice how the recent episode, 1, has total gross revenue over $80,000. This is the total revenue associated with producing 1 ounce of gold per month for 100 months and selling at prevailing prices from 2009-2017. Other episodes, like 5 from 1997-2005, had much lower levels for total revenue – less than $25,000! All episodes have the same production profile, so the drastic differences in gross revenue reflect long-term statistical properties of the gold price.

Mine Revenue Paths with Normalized Initial Value

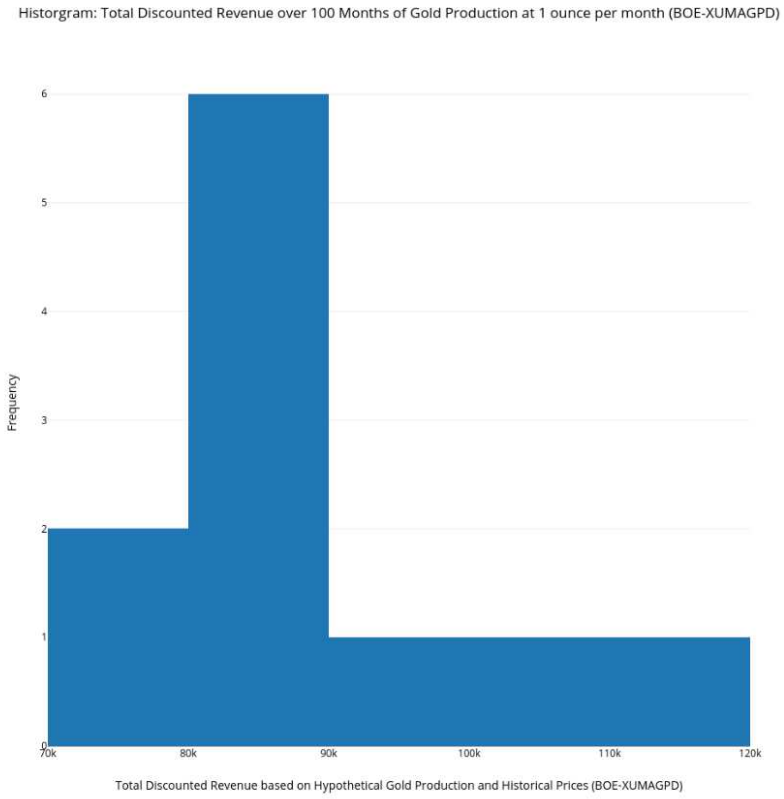
For each 100-month episode, I calculate the differences in the monthly gold price data and use the differences to simulate Price Paths. These paths are normalized to start at the same value, $1,300 to allow for more direct comparisons between paths. As before, I assume there is one ounce of production per month and combine that production with the Price Path to generate a Revenue Path for each episode.



This chart shows the Revenue Paths for all 11 historical episodes I consider. There are a trio of paths that have strong positive trend throughout, which reflect the late 2000s bull market. Most paths cluster around the initial price, which reflects the relatively flat gold price in the 1980s and 1990s.

For each Revenue Path, it is possible to calculate various statistics. However, it is important to note that these simulated data points never actually happened. By using the price differences from various historical episodes and a constant initial price, I have generated data that is realistic but never actually happened.

I calculate the present value for the gross revenue across each of these paths and show the results as a histogram and other chart below. The histogram shows positive skew in the discounted value of gross revenue using normalized prices and the other chart shows these higher values are associated with episodes ending around 2012.



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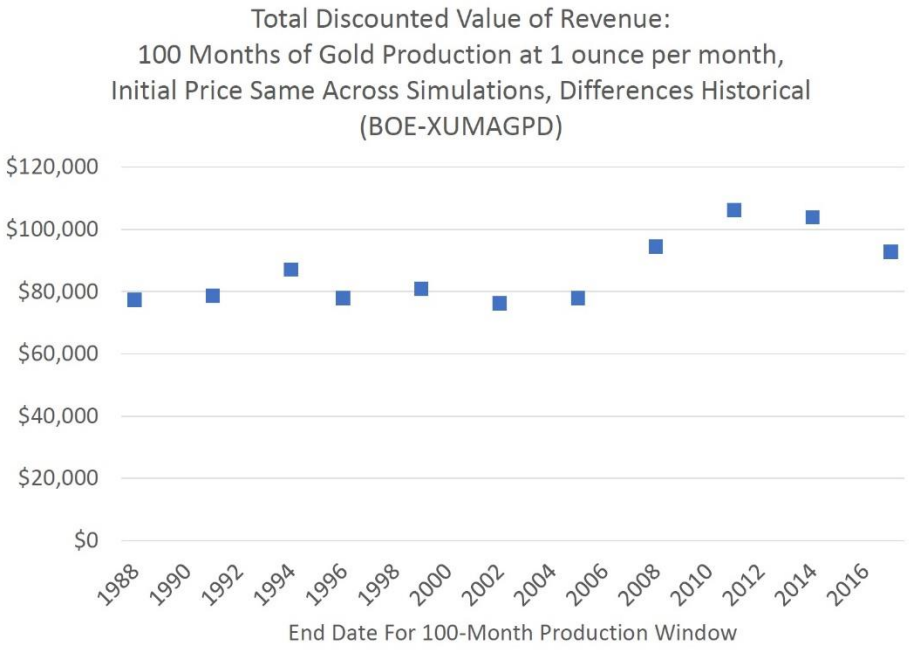

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Forcing the initial price to be $1,300 per ounce of and using the monthly price changes from each historical episode has large effects on the results. For one, it removes the general rise in the gold prices that occurred between the 1980s and 2010s. Still, there is an apparent bullishness to episodes ending around the 2012 episode that reflects the many large positive monthly changes in gold price at that time.

Net Of Mining Costs

Suppose the mine faces production costs equal to 50% of the initial price. Assuming this cost is constant cost over the 100-month life of production, the present value of the total cost of production is just over $40,000 per ounce. Removing this from the total discounted revenue, I calculate net revenue for various historic episodes using normalized initial prices.

Table 2: Present Value of Net Revenue Using Standardized Initial Gold Prices and Historical Episodes for Price Variations.

End Date	2017-04-30	2014-06-30	2011-07-31	2008-08-31	2005-09-30	2002-10-31	1999-11-30	1996-12-31	1994-01-31	1991-02-28	1988-03-31
NET REVENUE	$52,194	$62,943	$65,471	$53,669	$37,003	$35,207	$39,930	$37,019	$46,249	$37,776	$36,382

Discount at 1% per month.
Costs at 50% of initial price.

Although this is a cartoon cost model with constant costs equal to half the initial price, a 50% margin in mining is not unrealistic.

Note that no results have negative NPV, suggesting that this is a model of a healthy mine. As before, historical episodes around the year 2012 have particularly large values. For example, the net present value for one ounce of production per month assuming initial price of $1,300 and chained historical differences following the 2003-2011 episode is $50,000 per ounce after costs.

Discussion

It is possible to improve on this paper in several ways. For one, increase the number of historical episodes considered in the analysis beyond the 11 episodes here. For another, consider a more sophisticated cost model. It may be possible, also, to connect this analysis to stress-testing mine plans using scenario analysis related to the simulations described here.

Note, data file online at
http://cdn.ceo.ca/1drochd-2018-10-08-NewtonResearch-GoldMiningSimulation-1.xlsx

References

Bell, P. (2018). *"Simulation Framework for Economic Modeling of Mineral Resources,"* MPRA Paper 85075, University Library of Munich, Germany. Retrieved from https://ideas.repec.org/p/pra/mprapa/85075.html

Quandl (October 8, 2018). *Monthly Average Gold Price Against US: Bank of England Official Statistics.*. Retrieved from link https://www.quandl.com/data/BOE/XUMAGPD