The Mexican Petroleum 'Play' in Two 'Acts': Taking Hold of Oil Production Data

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1. Introduction

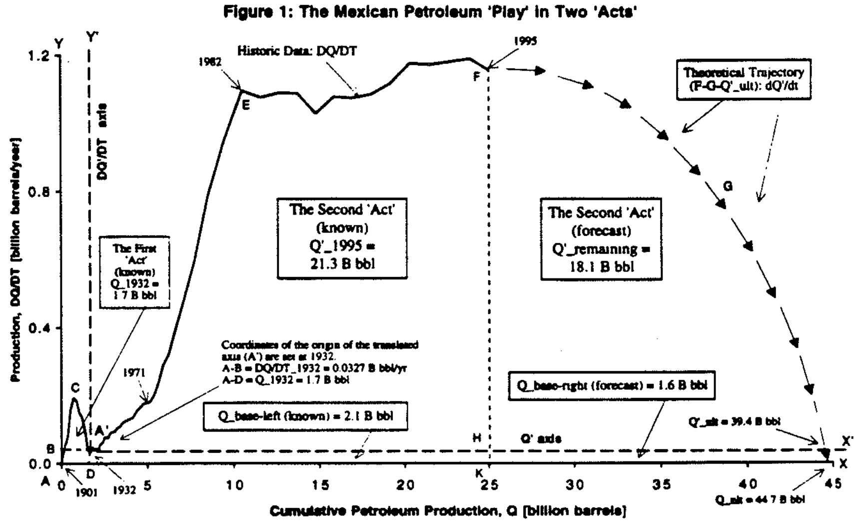
Imagine, for a moment, that you're viewing act #n of a stage play. Thus, you *know* the outcome of the first (n-1) acts, and the very latest status of act #n, now in progress. From this information, you'd like to predict the outcome of the present act and, if possible, the outcome of the whole play. Metaphorically speaking, that is what this paper is all about.

2. The Daisy-Chain Polynomial: Modeler's 'mRNA'?

The daisy-chain polynomial approach, as I call it, treats petroleum production as a continuous 'play,' divided into n 'acts.' Each act, after the first, is measured on the x-axis, *not* by time, but by cumulative petroleum production, e.g., barrels of oil, abbreviated 'Q'.' [NB the prime (').] Each act is referenced to its own translated axis, and in turn, each translated axis is referenced to the origin of the main axis, i.e., to the start of the petroleum production play at $Q = 0$, $dQ/dt = 0$.

Figure 1 illustrates the Mexican petroleum production play in two acts. The first act is minuscule. It began in 1901 and ended in 1932 when oil production fell to a local, but definite, minimum. The outcome of the first act is known from historic data to be 1.7 billion barrels (i.e., Q_{1932} = 1.7 B bbl, the area under curve A-C-A').

Figure 1: The Mexican Petroleum 'Play' in Two 'Acts'



The second act began in 1932 as oil production started a long slow climb. Thus, I take Q_{1932} = 1.7 billion barrels as the x-coordinate for the origin of the translated axis, Y'-A'-X' , Figure 1. Similarly, I set the y-coordinate of the origin of the translated axis, Y'-A'-X' again, at the rate of oil production in 1932, i.e., DQ/DT_{1932} = 0.0327 billion barrels per year.

Then something(s) dramatic happened about 1971 when oil production started to soar (see Figure 1). From historic data, we know that the cumulative petroleum production through 1995 for the *known part* of the second act is 21.3 billion barrels, i.e., Q'_{1995} = 21.3 B bbl, area A'-E-F-H.

In Figure 1, we must also include the 'thin belt' of production labeled, "$Q_{\text{base-left}}$" equal to 2.1 billion barrels (explained later). Totaling Mexican oil production through 1995, we get Q_{1995} = 25.1 billion barrels (i.e., $Q_{1995} = Q_{1932} + Q'_{1995} + Q_{\text{base-left}} = 1.7 + 21.3 + 2.1 = 25.1$).

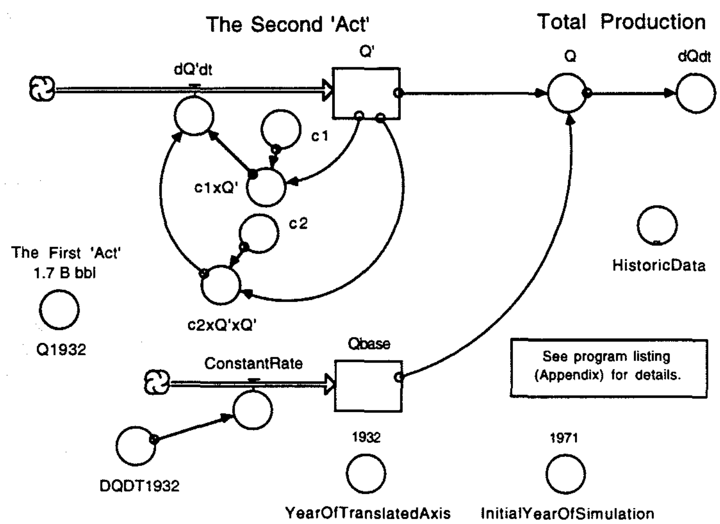
3. Mexican Petroleum Production: A Two-Act 'Play'

Figure 2 shows the connection diagram for the Mexican petroleum production 'play.' *The second act dominates.* The model describes the second act by a 2nd order polynomial, constrained by boundary conditions. (See axis Y'-A'-X' and curve A'-E-F-G-Q'_∞, Figure 1). The equation is,

$$dQ'/dt = c_0 + c_1 * (Q') + c_2 * (Q')^2 \tag{1}$$

in billion barrels per year. Boundary conditions fix $c_0 = 0$, and $c_2 = c_1/Q'_\infty$. (Where 'Q'_∞' means the ultimate magnitude of the cumulative oil production, e.g., $Q'_\infty = 39.4$ billion barrels, Figure 1).

Figure 2. Mexican Petroleum Production in Two 'Acts': Daisy-Chain Polynomial/Translated Axis Method



The values of c_1 and Q'_∞ are determined by the regression of historic oil production data [i.e., regress [(dQ'/dt)/Q'] on Q']. In the model, the *first act* is combined with the *second act* to simulate the two main output variables over time, (1) Mexican total cumulative petroleum production, Q(t), and (2) the rate of Mexican total petroleum production, dQ(t)/dt (discussed later). Regression details are given in Hubbert (1982). Program details are given in the Appendix.

4. 'Daisy-Chain Polynomials' and 'Translated Axes': Breaking the Hubbert Code

M. King Hubbert (1902-1988) was a geophysicist and petroleum geologist *nonpareil*. However, since his remarkable successes in the 1950s-1970s, most average folks have had sub-spectacular success with the his method, perhaps because it was developed specifically as a peak-predictor for US oil production. The Hubbert model (or 'H-model,' for short) applies a single 2nd order polynomial on a single axis [e.g., Equation (1) referenced to axis Y-A-X, Figure 1]. Happily, the daisy-chain polynomial/translated axis approach (or 'D-model,' for short), resolves several problems that beleaguered others while trying the H-model. Four are summarized in Table 1.

Table 1. Comparison of the H-Model and the D-Model Model

H-Model Problem	D-Model Solution
1. The correlation coefficient waffles negative and positive (i.e., $-1 < r < +1$).*	1. The correlation coefficient is consistently negative (i.e., $-1 < r < 0$).*
2. The slope of the regression line waffles negative and positive (related to #1 above).*	2. The slope of the regression line is consistently negative (related to #1 above).*
3. The regression Start Year is ambiguous.*	3. The regression Start Year well defined.*
4. The output is inevitably symmetric.	4. The output is asymmetric for polynomials > 2n.
5. The time-domain model is non-feedback; difficult to include other variables.	5. The model is feedback; easy to include, oil 'price', 'marginal cost', 'technology advance', 'oil reserves', etc.

*See box on next page. *See box on next page.

THE 'REGRESSION START YEAR': FORTY-YEAR MYSTERY SOLVED

The Problem: Different from most mortals, King Hubbert often 'leaped tall buildings in a single bound.' Among his remarkable achievements was the repeated, and successful, use the H-model for energy forecasts. However, as far as I can tell, he never explained how he choose the proper Regression Start Year ('RSY'). And the RSY makes all the difference in the world, because, for example, when I applied the H-model to Mexican petroleum production (see Duncan, 1996a), **if** I choose RSY = 1981, **then** the H-model gave Q_∞ = 36.4 billion barrels. However, **if** I choose RSY = 1971, **then** it gave (sic) Q_∞ = 689.2 billion barrels. A whooping difference of 652.8 billion barrels, or 1,793%! Furthermore, for RSYs between 1971 and 1981, the H-model gave intermediate results. *So what is the correct RSY to use?*

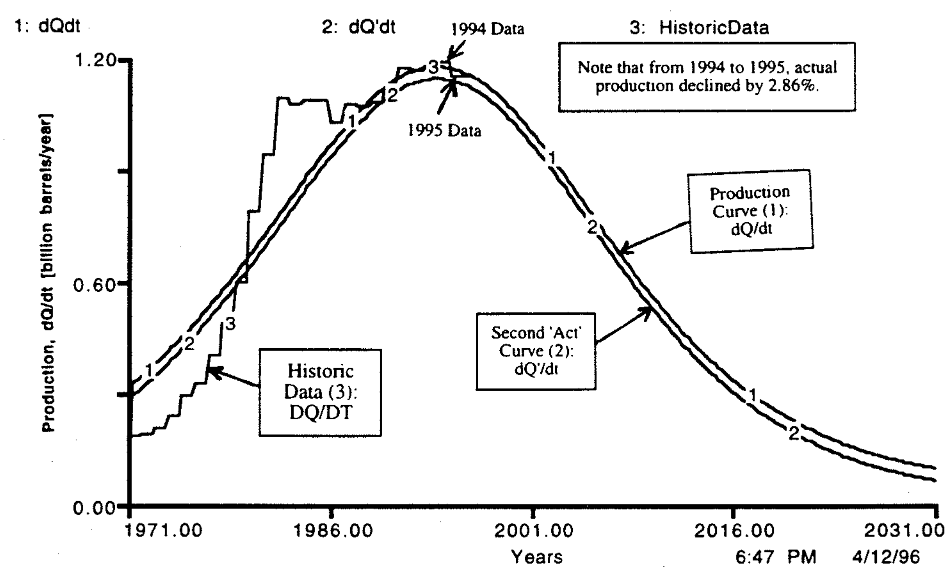
The Solution: It's simple. Just use the translated axis approach, and *presto*, the RSY ambiguity disappears. For example, in this study I used a translated axis with origin at year 1932 (i.e., axis Y'-A'-X', Figure 1), and the exasperating idiosyncrasies mentioned in Table 1 (i.e., items 1, 2, and 3) all vanished — poof! Moreover (for $r^2 > 0.90$), the choice of RSYs narrowed to six (i.e., 1984-1989). Most important, the resulting values of Q_∞ obediently fell into a tight range of 7.7 billion barrels (i.e., 37.6-45.3 billion barrels). *Gratifying indeed.*

5. Mexican Petroleum Production Predicted: Nearing the Brink?

Figure 3 shows the results of a D-model simulation run from 1971 to 2031. Total Mexican oil production, dQ/dt, appears as Curve 1, and only slightly below it, the *dominant* 'second act' petroleum production, dQ'/dt, appears as Curve 2. For comparison, the historic data, 'DQ/DT,' is graphed and (just coincidentally) it appears much like the profiles of the many magnificent Mayan pyramids (steep-steps, flat-tops, historic, fire-topped) on the Yucatan Peninsula within eyesight of the gargantuan oil rigs (flat-tops, ultramodern, fire-topped) that rise above Campeche Bay.

Note that from 1994 to 1995, Mexican petroleum production declined by 2.86% (O&GJ, 1996; PE, 1996), just as I predicted in January, 1995 (Duncan, 1995b). Although production is likely to fluctuate over the next few years, the more powerful D-model (Figure 3) also predicts that Mexican petroleum production is near its all-time peak, and decline is imminent. Time will tell.

Figure 3: Mexican Petroleum Production: 1971-2031



6. Summary and Conclusions

Summary: This paper presents a new method for taking hold of energy production data, no matter how erratic or irregular its overall pattern. The new method is called, the 'D-model'. As an example, it is applied to Mexican petroleum production data from 1901 through 1995.

Figure 1, Section 2, illustrates how Mexican petroleum production is split up into two distinctive 'acts': the first (minuscule and long-finished) is from 1901 through 1931; the second (dominant and still in progress) is from 1932 through 1995. The focus is on the dominant second act which is modeled on a 'translated' axis with its origin at 1932. Figure 2 gives the D-model connection diagram. The program listing appears in the Appendix. Four major D-model parameters (i.e., c_0, c_1, c_2, and Q_∞ are 'extracted' from the historic data, as described in Section 3.

Section 4 compares five advantages of the D-model compared to a well-know predecessor model. D-model advantages are: (1) correlation coefficient [r] consistency, (2) regression-line slope [m] consistency, (3) well defined 'Regression Start Year', (4) broken symmetry, and (5) ease of expansion to include driving variables such as oil 'price', 'technology advance', 'oil reserves', etc.

Figure 3, Section 5, shows the simulation results of the D-model for the years 1971 to 2031. The results indicate that Mexico's petroleum production is now near its all-time peak.

Conclusions: The D-model is a more flexible and more powerful method than previous methods. It can provide a scientific foundation for predicting any energy-production life-cycle.

Appendix: Program Listing [STELLA II™]

```
□ Q'(t) = Q'(t - dt) + (dQ'dt) * dt
  INIT Q' = 2.6
  INFLOWS:
     dQ'dt = c1xQ'+c2xQ'xQ'
□ Qbase(t) = Qbase(t - dt) + (ConstantRate) * dt
  INIT Qbase = Q1932+DQDT1932*(InitialYearOfSimulation-YearOfTranslatedAxis)
  INFLOWS:
     ConstantRate = DQDT1932
○ c1 = 0.11655
○ c1xQ' = c1*Q'
○ c2 = -0.0029557
○ c2xQ'xQ' = c2*Q'^2
○ dQdt = DERIVN(Q,1)
○ DQDT1932 = 0.032715
○ InitialYearOfSimulation = 1971
○ Q = Q'+Qbase
○ Q1932 = 1.7
○ YearOfTranslatedAxis = 1932
⊘ HistoricData = GRAPH(TIME)
  (1971, 0.177), (1972, 0.184), (1973, 0.201), (1974, 0.234), (1975, 0.288), (1976, 0.32), (1977, 0.396),
  0.787), (1981, 0.944), (1982, 1.10), (1983, 1.08), (1984, 1.09), (1985, 1.09), (1986, 1.03), (1987, 1.08),
  (1991, 1.18), (1992, 1.17), (1993, 1.18), (1994, 1.19), (1995, 1.16)
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References

Bermúdez, A. J. (1963). *The Mexican National Petroleum Industry.* Stanford University Press, Palo Alto. [Data]

BP (1981-1995). *BP Statistical Review of World Energy.* British Petroleum Company, London. [Data]

Duncan, R. C. (1996b). Mexico's petroleum exports: Safe collateral for a $50 billion loan? *Institute on Energy and Man.* January 1, 1996.

Duncan, R. C. (1995b). Caution: Falling Mexican oil exports will force default on debts. *Letter* from R. C. Duncan to W. J. Clinton, 31 Jan 1995.

Excel™ (1995). *Microsoft Excel 5.0.* Microsoft Corporation, Redmond, WA. [Model parameters & Figure 1]

Hubbert, M. K. (1982). Techniques of prediction as applied to the production of oil and gas. *Oil and Gas Supply Modeling* (ed. Gass, S. I.), 16-141. NBS Special Publication 631, Washington, D. C.

O&GJ (1996). Worldwide crude oil and gas production. *Oil & Gas Journal,* February 12, **94**:7, p. 62. [Data]

PE (1996). World oil production. Petroleum Economist, February, **63**:2, p. 9. [Data]

STELLA™ (1992). *STELLA II.* High Performance Systems, Inc., Hanover, NH. (Model listing & Figures 2-3]