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ORIGINAL ARTICLE

The tulipmania: Fact or artifact?

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Abstract The famous tulipmania, which saw the reported prices of several breeds of tulip bulbs rise to above the value of a furnished luxury house in 17th century Amsterdam, was an artifact created by an implicit conversion of ordinary futures contracts into option contracts in an imperfectly successful attempt by Dutch futures buyers and public officials to bail themselves out of previously incurred speculative losses in the impressively price-efficient, fundamentally driven, market for Dutch tulip contracts. There was thus nothing maniacal about prices in this period. Despite outward appearances, the tulipmania was not a bubble because bubbles require the existence of mutually-agreed-upon prices that exceed fundamental values. The "tulipmania" was simply a period during which the prices in futures contracts had been legally, albeit temporarily, converted into options exercise prices.

Keywords Public officials · Legislatures · Instability · Herd effects · Tulipmania · Holland · 17th century · Futures contracts · Options contracts · Thirty Years War · Black-Scholes · Breeders markets · Equilibrium price paths

1. Introduction

Whenever economists or economic commentators search for evidence of extreme market instability, bubbles, herd effects, multiple equilibria, or related economic horror stories, they almost invariably light upon and cite 17th century Holland's tulipmania. Despite recent attempts to unseat the tulipmania from its place as history's most extreme example of an economically unexplained price cycle, the fact remains, as we shall see in Section 1 and Appendix I below, that – without any known shocks in either production costs or utilities – the contract price of tulips in early February 1637 reached a level that was about 20 times higher than in both early November 1636 and early May 1637.

The predominant unseating attempts have been due to Peter Garber, who, using the bulb-price history of Krelage, has hypothesized that other bulb markets have displayed price

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patterns very similar to those possessed by 17th century Dutch tulips. In particular, the data shows that there are several 5–15 year time intervals during which initially very expensive 18th and 19th century tulip and hyacinth bulb prices declined by a cumulative magnitude equal to that of bulbs in the tulipmania. Although one might as easily infer from the later data that bulb markets are congenitally susceptible to irrational speculative excesses as infer that the tulip market has been efficient, we shall show, in Section 4 below, that Garber's high annual 18th and 19th century bulb-price declines are indeed fully consistent with a competitive equilibrium in a realistic market for breeding bulbs. However, a more complete data set, which we employ in Sections 1–3 below, would have shown his many readers that the decline in bulb prices at the end of the tulipmania displayed a crash that required much less time than his allegedly "comparable" 18th and 19th century bulb-price declines. Thus, once we complete Garber's reported tulip price data by employing his basic data sources, we find that the peak reached in early February 1637 was over 20 times higher than tulip prices only three months after this peak. The annualized rate of price decline here is not the 18th–19th century maximum average annual rate of 40%, but rather 99.999%!

Moreover, Garber overlooks the crash in tulip prices in October 1636, choosing instead to characterize tulips as increasingly fashionable up to its February 1637 peak. Once this initial – we shall see fundamentally based – October price-decline is recognized, there is a 20-fold price rise and matching decline from early November 1636 to early May, 1637. Since there were no obvious changes in either the costs or utilities for tulips during this twenty-fold, 6-month, apparent roller-coaster ride, it appears to be a premier example of a market bubble. Garber offers no rational explanation for this tulipmania. Although Garber does dismiss the extraordinarily high prices occurring around the peak of the tulipmania, which were about 20% higher than the prices in the surrounding tulipmania dates, suggesting that these prices were the result of the nonchalance of inebriated amateur traders who deal in taverns, he fails to note that: (1) similarly high-priced trades during the same peak episode took place in regular auction markets other than in taverns; (2) taverns were a common site of financial transactions during the cold winters of 17th century Holland (De la Vega); and (3) tavern trading sessions possessed quite detailed and formalized procedures (Chancellor).

Finally, Garber ignores the fact that his own data reveal the existence of some current-cash for-future-delivery transactions that were from 1/12 to 1/20 of the prices in *nearly simultaneous* normal futures transactions in early December, 1636. We will explain this two-price anomaly, as well as the above-described price history and bubble-pattern, in what follows.

2. The raw data

Figure 1 summarizes the available data on tulip prices with a quality-weighted price index over this time interval. Since the relevant tulip bulbs are regularly planted in the Fall and only dug up in the Spring, the relevant prices here are the prices that appear in contracts for future delivery. Appendix I identifies our sources, which are both standard and verified by economic historians from primary sources, and explains the weighting process. Given the acknowledged absence of basic economic shocks over this relatively short span of time, the unmistakable "bubble" pattern appears to speak for itself.

But appearances are sometimes quite deceiving.

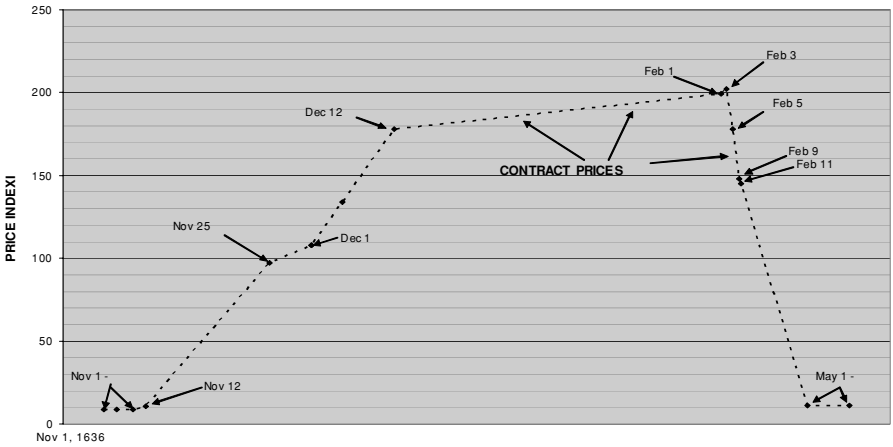


Fig. 1 An index of prices recorded in Dutch tulip contracts

3. Fact and artifact

Both the famous popular discussion of Mackay and the famous academic discussion of Posthumus (1929) point out a highly peculiar part of this episode. In particular, they tell us that, on February 24, 1637, a large organization of Dutch florists and planters, in a decision that was later ratified by Dutch legislatures and courts, announced that all contracts written after November 30,1636 and before the re-opening of the cash market in the Spring possessed provisions that were not in the original contracts. The new provisions relieved their customers of their original unconditional contractual obligations to buy the future tulips at the specified contract price but demanded that they compensate the planters with a fixed percentage of their contract prices The provisions, in effect, converted the futures prices in the original contracts to exercise prices in options contracts. The corresponding option price paid to the planters was only later determined. In particular, after over a year of political negotiation, the legislature of Haarlem, the center of the tulip-contract trade during the "mania," determined the compensation to the sellers to be only $3\frac{1}{2}$% of the contract price for those contracts made between November 30,1636 and the spring of 1637.

The solid-line graph on Figure 2, supported by Appendix II, shows the spot or genuine futures prices paid to planters during the "tulipmania." The figure contrasts these prices with the broken-line tulipmania prices of Figure 1, the divergence, of course, arising after the November 30th contract conversion date. (The immediately preceding, late-November excess of realized over commonly expected prices will be discussed in the next section.) Contemporary journalists and subsequent pamphleteers, the latter whose intent was mainly to dramatize the social costs of speculation by exaggerating the extent of the losses faced by the common speculator, may perhaps be excused for failing to distinguish between speculating in options and futures contracts. However, it is not at all clear why subsequent economist-scholars failed to make the appropriate contract and price adjustments, thereby failing to describe the "tulipmania" price pattern as a contractual artifact.

While it might be argued that expectations were not rational, that the traders were unaware of the conversion of futures to option contracts, Mackay (pp. 104–105) emphasizes the public nature of the extensive negotiations over the details of the contract conversions since almost the beginning of the upturn. Moreover, as detailed in the Appendix II, there is a late December

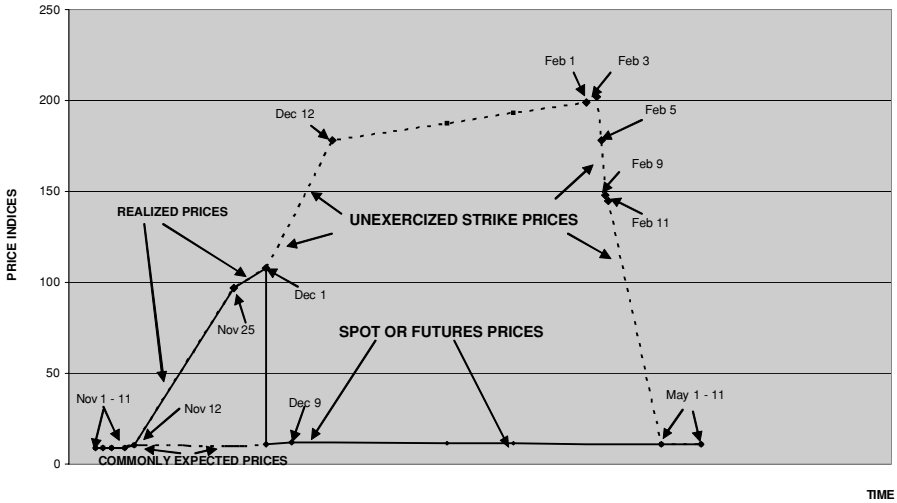


Fig. 2 Commonly expected, realized and unexercized strike prices

contract implying the assertion that if the government converts the contract price to a call-option exercise price, the buyer will have to pay a special fee (a small fraction of the contract price) for the option. These facts rationalize, for most of the tulipmania period, a rational expectations assumption. Indeed, as shown in Section 5, the values that the competing planters expected to receive for their sold contracts were approximately the spot or futures prices on Figure 2 rather than the call-option exercise prices represented by the broken line on the figure.

4. Why the contractual conversion?

As so often happens in economics, answer one question and up pops another. Why did Holland's legislatures and judges approve of the seemingly buyer-favoring conversions of the contracts? This is especially peculiar in that the policies do not appear to have had any significant effect on the spot or expected future spot prices of tulips during most of the tulipmania. We should, of course, look back in time to try to gain some understanding of what the government officials were up to.

4.1. Background

Figure 3 displays a broader perspective on tulip prices going back to 1634, which is widely acknowledged to be the first or second year in which the prices of tulips had begun to rise to levels significantly above those of the previous year. Appendix III in elaborates on the data sources for this figure. We can see that the price of tulips was generally rising up to sometime in October 1636. The standard literature consistently reports a widespread and increasing volume, with heavy public participation in the boom. Even public officials were buying. The sellers were mostly professional tulip planters and tenders, people who had been doing quite well in the rising market. But the spot and futures tulip prices collapsed in October to where, by early November, prices were even lower than the late l634 prices.

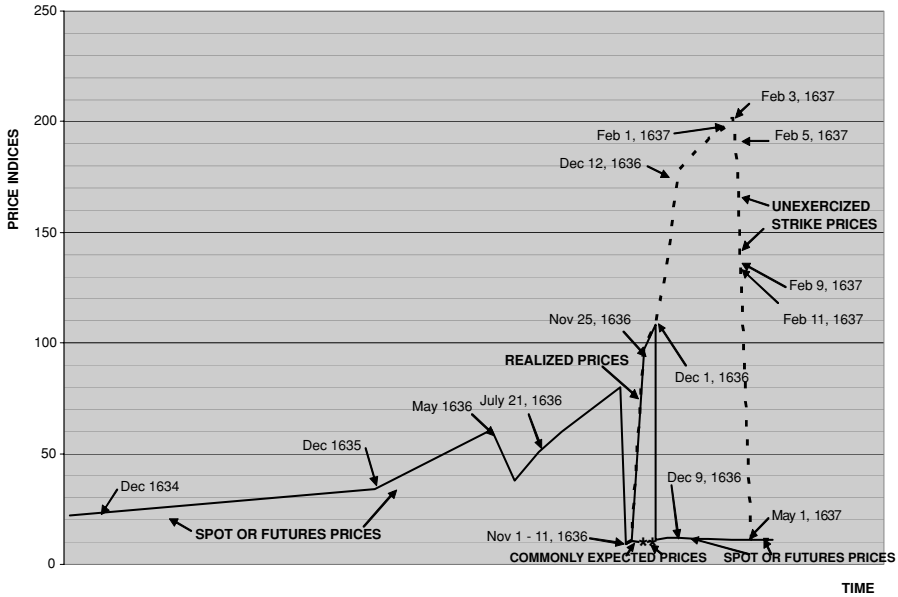


Fig. 3 Tulip prices over the 1634–1637 period

Now, although not at all integrated into the literature on the tulipmania, the October crash and subsequent tulipmania roughly coincided with the end of the first, religious, phase of the deadliest war in European history, the Thirty Years War (1618–1648). The pleasant surprises in the last four years of this first phase probably accounted for the tulip price expansion from 1632 to the Fall of 1636. For the German armies had been steadily pushing back the previously successful, initially religiously inspired, Swedes in the early-mid 1630's, and tulips had, since the end of the previous century, been an established favorite of the Princes of western and northern Germany, which featured a climate that was exceptionally receptive to the new flowers. (On all this, see Appendix IV.) Moreover, although peasant revolts had been seriously threatening the northwestern German countryside - in particular the swarms of tulips grown around the countryside castles - the death in 1632 of Johan Tilly, the leader of the Harz Mountain Rebels, left the Rebels in disarray and thereby greatly expanded the demand for tulips in this important consuming area. Thus, up through the summer of 1636, it looked as if the War was winding down in favor of Germany and the peasant revolts were a thing of the past. Although France, apparently in fear of German dominance, had entered the War on the side of Sweden in mid – 1635, their early defeats in central France made it appear that the War was basically over. It should therefore be no surprise that tulip prices were generally rising at an abnormally high rate during the early 1630's and increasingly so up to the Fall of 1636.

However, quite unexpectedly, the French - supported Swedes resoundingly defeated the Germans at Wittstock in early October of 1636. For reasons discussed in Appendix IV, this turnaround began the second, property-phase, of the Thirty Years War. The new assault continued toward Thuringia (see the map at the end of Appendix IV) and the extensively tulip-decorated Castles of Western Germany (e.g., Wedgewood, p. 366) and was immediately followed by renewed German peasant revolts, which thereafter remained an occasionally realized threat for well over a century. This eliminated the enormous prospective German

demand for tulips in the foreseeable future and also probably increased the market supply of tulips because it now paid the Princes to dig up their tulips, which are usually planted outside the Castle walls and thus very vulnerable to both extended warfare and peasant revolts. In view of these fundamentals, it is no surprise (as is theoretically justified in Section 4 below) that tulip prices plummeted to 1/7 of their October 1636 peak by early November, as can be seen on Figure 3.

Although one might be tempted to label this boom and bust some kind of "mania," the fact that the price observations followed a series of fundamental shocks should completely eliminate this idea from consideration. Besides, the tulipmania described in the literature concentrates on the higher prices observed during the later episode, which begins with the activities of the recent buyers and their similarly positioned political representatives, especially the local Dutch mayors, or burgomasters.

4.2. Contract buyers, public officials, and planters

The early-November investment losses represented a personal financial disaster to many buyers, including several public officials. Some of these heavily margined speculative buyers were having their livelihoods threatened at the expense of professional tulip planters, who had already become rich during the extended upturn. So it should be no surprise that the public officials quickly met with the concerned public after the crash in order to discuss the "problem." The above-described contract conversion was natural to them. After all, the more knowledgeable planters – who probably immediately understood the effect of Wittstock and even hyped the sale of tulip futures in mid-October in order to liquidate their dealer inventories at favorable prices – could afford it. As the information of the public officials' deliberations and plans entered the market in late November, contract prices soared to reflect the expectation that the contract price was now a call-option exercise, or strike, price rather than a price committed to be paid for future bulbs. The contract price would not have to be paid if the future spot price turned out to be less than the contract price. The only cost was that, if the option holders refused delivery, they would have to compensate the sellers in their contracts with a small fraction of the contract price. The public officials were suggesting 0%.

However, the planters were not totally lacking in political power. Although, after lengthy deliberations, the planters subsequently announced that they would, as expected, accede to the conversion of their contracts and accept a price equal to a mere 10% of the contract price, they demanded a later conversion date than the October date that had been publicly supported by most of the government officials. In particular, the planters announced, again on February 24th, that they would convert only those contracts that had originated after November 30th, a date by virtually all traders knew that the ostensible futures prices would be converted into option exercise prices, with a 0–10% price for the option to be subsequently determined by Holland's legislatures and courts.

Settling on a November 30th rather than an October termination date for the original contracts heavily favored, besides the planters, those speculators who sold contracts in late November to individuals who held the common expectation that contracts written in November would be options rather than futures contracts. The negotiating public officials, being much more informed than the public, could therefore more than offset their losses on their earlier purchases by selling contracts in late November, when, based on the previous announcements of the trusted public officials, the buyers had already begun treating the contract prices as option strike prices set at around 10 times the actual prices, as shown in Figure 2. These innocent late November buyers, not the planters, were the real victims of

the contractual conversion, victims because they thought they were buying an option but were forced to pay the falsely assumed exercise price out as a futures price because the contractual conversion was delayed at least a month beyond the public officials' previously announced date. The involved public officials even made a tidy net profit on their sales despite the losses on their original, otherwise disastrous, investments. Indeed, as described in Dash (p. 194), subsequent records show burgomasters and their heirs still collecting on these sales contracts decades after the mania was over.

The above arguments serve to qualitatively rationalize the tulipmania and the critical period that preceded it. We now attempt to quantitatively rationalize these price observations.

5. The fundamental volatility of the price of breeding capital

Suppose a new variety of bulb has been discovered, one expected to create a positive consumers' demand price of $p(x)$, where x is the accumulated stock of the bulbs, and assume that these final bulb demanders are able to breed new bulbs at a rate that will just cover their depreciation through abuse, disease, age, etc., in which case the bulbs represent simple consumer durables. Although we begin with only one bulb, there also exist specialized bulb-breeders who can freely reproduce the bulbs at an expected rate of m bulbs per year. The owner of the first bulb can sell for a substantially positive money price, $p(1)$, to the highest demander in the consuming public or to a breeder. A breeder is willing to pay at least $mp(m)/(1+r)$ for the bulb, where r is the money rate of interest. Since we are not interested in one-bulb markets, we assume that $mp(m)/(1+r) > p(1)$. The breeders compete the price of the bulb in the first period up to the present value of their returns so that

$$p_1^* = mp_2^*/(1+r).$$

where the prime signifies that the corresponding variable is at an equilibrium level. If the breeders outbid the consumers for some of the bulbs in period 2, the price in the second year is similarly

$$p_2^* = mp_3^*/(1+r).$$

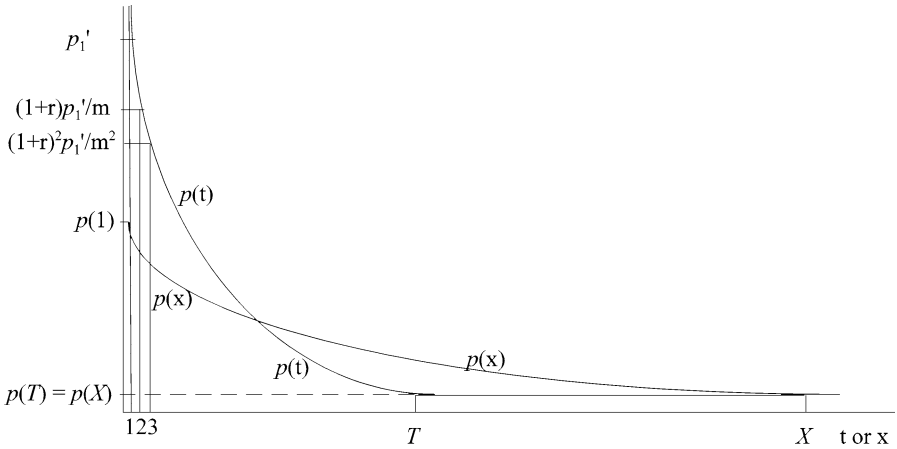
The steady annual rate of price decline, taken from the lower level, during any breeding era, as can be seen in the above two equations, is $[(m/1+r) - 1]\%$. This continues on, with the quantity rising each period by mn_p where n, is the number of bulbs the breeders compete away from the consumers, until n_t reaches zero because the breeders' demand price begins to fall short of $p(X)$, where X is the equilibrium total bulb quantity, which is then the final equilibrium price toward which the earlier prices fall.

Some breeders remain in the market as long as they are willing to pay a higher price than the lowest-positive additional consumer demand-price in the market, i.e., as long as $mp_t^*/(1+r) > p(x_t+1)$, where t is a time index. And prices will continue to fall at the same substantial rate of $[(m/1+r) - 1]\%$ until this inequality fails or the price for an additional bulb would be zero, at which point in time, call it T, all of the breeders are gone from the market and the price is at its minimum level, at which it will stay forever unless there is a change in market conditions.

The above-described equilibrium is illustrated in the following graph.

Suppose now, beginning in this long run equilibrium, that there is a significant exogenous shock that uniformly reduces the final demand prices for tulips bulbs. Although this

will lower the price from its already extremely low level to zero, this is a quantitatively insignificant price effect and the shock will have no effect whatsoever on breeding, which does not exist in a long-run equilibrium.



But these price and quantity effects of a negative exogenous shock are much different if the bulb market is fairly young so that breeders are still active in the market. Such breeding certainly characterized the mid -1630's Dutch tulip market and the subsequent 18th and 19th century bulb markets described by Krelage and Garber. If, during any such extended breeding period, there is a sudden reduction in demand, say one that will eliminate the last round of breeding, prices will *immediately* decline by $[m/(1+r)-1]\%$. This can be graphically seen by shifting the above $p(t)$ curve to the left by one year, thereby hastening the number of years to drive the breeders out of the market by one, and observing that each price decline from the prior level is $[m/(1+r)-1]\%$ of its later level. Or, if the shock eliminates the final two rounds, the price decline will be equal to the product of two such shifts, or to $[m/(1+r)]^2-1$ of its later level. Generalizing, prices fall by a percentage from the lowest level equal to $[(m/1+r)]^k-1$, where k is the number of breeding years eliminated by the negative demand shock.

At this point, we bring in the valuable 18th and 19th century price data employed in the Garber study, such data being presented because of between-bulb similarity to the Dutch distribution of bulb prices in and around the tulipmania. In the absence of large unexpected 18th and 19th century external shocks, which we infer because of the rough regularity of the price declines, breeders of the dozen most expensive popular hyacinth bulbs generated an average annual depreciation rate of about 28%. Also, from the length of the substantial price declines in the study, we find that it took about 8 years to exhaust the high levels of depreciation characteristic of the median bulb's breeding stage. The decline in Dutch tulip breeding following the post-1636 elimination of the German market, which halted professional breeding in substantially below median tulip bulbs and maintained breeding in substantially above-median bulbs, can thus be assumed to have eliminated approximately 8 breeding years of these comparable relative-quality bulbs, thereby collapsing an otherwise steady, 28%, average annual price decline from the peaking-out late 1636 Dutch tulip market into the single month of October, 1636. Using the above price-decline equation, the price of a tulip bulb in October 1636 would thus be $(1/1.28)^8$, or approximately 1/7, of its pre-shock

level, which is about the same as the decline we actually observed in the fundamentals-based crash that immediately preceded the tulipmania.[1]

The consistency of the price fundamentals of the 18th and 19th century bulb markets with the fundamental price effects of the October 1636 price crash, while unrelated to the tulipmania, help reinforce the idea that bulb markets are fundamentally driven. Similarly, if, during a breeding phase of a bulb market, demand steadily rises, as it actually did, through a series of positive shocks, thereby cumulatively adding a few rounds of breeding to the market, prices are likely to substantially rise in anticipation of these extended breeding rounds. This could easily explain the similarly substantial, good-war-news-based price-run-up from 1632 prior to the bad War news and October crash.

6. The magnitude of the "mania"

To more clearly understand the relationship between the nominal, or option-exercise, price on the broken line and real price on Figure 2, consider first what happens to a futures contract when, *cet. par.,* the buyer is suddenly given the option of refusing delivery and keeping his money should the market price of the asset be lower on the planned delivery date than the nominal price on the contract. This price should soar to infinity. No finite exercise price would satisfy a seller who had freely given his customers an opportunity to cancel the contract if the market price were less than the exercise price. Of course, to clear the market at a finite exercise price, the buyer should be expected to pay the seller a separate charge for the option. If, in particular, governmental decree sets this price for the call option as a small percentage of the contract, or exercise, price, the seller must respond by creating a very high contract price in order to lower his expected cost of providing the option to where it equals the small compensation he is given to provide the option. In this way, the strike price on the option will rise until the seller's return on the option equals its cost. In symbols,

$$\propto P_c = C + \int_{P_c}^{\infty} (p - P_c) f(p)\, dp, \tag{1}$$

where $\propto$ is the statutory rate the government sets on the option contract, P_c is the exercise price on the option, C is the cost of engaging in the transaction, and f is a probability density of the tulip price distribution function so that the integral in the equation represents the seller's expected cost of having the buyer actually exercise the option.

[1] While the higher-priced bulbs took well over 8 years to develop relatively slow depreciation rates, the lowest-priced among these still relatively high priced bulbs never did depreciate at the rate of the high-priced bulbs and were therefore presumably not professionally bred. Thus, for example, since the rate of price depreciation of the highest priced hyacinths was 38%, we might infer from the 28% overall average hyacinth depreciation rate that at least 1/3 of the hyacinths were not professionally bred. Similarly, there was much non-professional tulip breeding of many of the lower quality tulip bulbs prior to the October 1636 crash. Theoretically, once the upward demand shocks ceased in 1636 and tulip bulb prices started their predicable slide, the more expensive, professionally bred, bulbs would have depreciated at a higher rate than the lower quality bulbs. Therefore, the October shock should have produced a much larger decline in the high-quality bulb market than the lower quality bulbs. In other words, the decline in the price of high-priced bulbs should theoretically have substantially exceed 1/7 while the decline in the price of low-priced bulbs should have substantially fallen short of 1/7. Indeed, one of the salient features of the post-October-1636 market, in addition to the continuation of professional breeding of only relatively high-quality tulip bulbs, was a sharp rise in the price of low-priced bulbs compared to high-priced bulbs.

In our case, the rationally expected $\propto$ is 0.035. To estimate C, the planters' per-bulb transaction costs, note that, from early in the negotiations, the planters position was that they were willing to forgive the buyers their debts for a payment of 10% of the contract price while the Public officials were insisting that, dating purchases back to the beginning of October, the buyers of tulip futures had the right to free options. Assuming, as is customarily rationalized as a best-estimate given our ignorance of such matters, that the total negotiation costs of both buyers and sellers are equal and that the total negotiation costs is 1/2 of the surplus being fought for, an objective estimate of the seller's part of the special negotiation cost is 1/4 of 10% of the average contract price. Substituting this estimate of C into Equation (1), we have

$$.01P_c = \int_{P_c}^{\infty} (p - P_c) f(p)\, dp. \tag{2}$$

The problem is to solve Equation (2) for P_c. Using a log-normal approximation of $f(p)$ and thus following Black-Scholes, we can use numerical methods to solve the equation once we know the standard deviations of the price distribution. Assuming an annual standard deviation of observed tulip price of 33.4, the observed annual standard deviations of tulip prices for the 10 months of 1636 prior to the beginning of the tulipmania in Novermber, this yields a theoretical value of P_c of approximately 180, which is extremely close to the actual average contract price observed during the tulipmania, as can be seen on Figures 2 and 3.

A second, alternative, approach is to check the consistency of the data observed during the tulipmania with data observed in modern options markets. We begin by re-writing Equation (1) as:

$$P_c = C/.035 + \left[\int_{P_c}^{\infty} (p - P_c) f(p)\, dp\right] \Big/ .035. \tag{3}$$

Since our estimate of C is 1/4 of 10% of the average contract price during the tulipmania, which is approximately 1/2 of the observed price of corresponding tulip futures, we can write

$$C = (1/2)P,$$

where P is the normal futures price of the asset. Hence, our contract, or exercise, price is

$$P_c = 14.3P + \left[\int_{P_c}^{\infty} (p - P_c) f(p)\, dp\right] \Big/ .035. \tag{4}$$

To empirically estimate the bracketed term on the right of Equation (4) above, the expected financial cost to the planter from having the customer exercise the option, we perused the actual CBOE prices for 6-month call options of very high volatility stocks that sold for approximately l/15th of the option's exercise value. We found that such options yielded a price range of.01% to.25% of the contract's exercise price.[2] Using Equation (4) above, for such

[2] The companies we found with suitable price collapses were J.Jill, Dec. 1999, Global Sports, June 2000, Mim Corp, June 2000, Ostotech, June 2000, Connetics, Dec. 2000, S One Corpororation, Dec. 2000, Hollywood Entertainment, Jan. 2001, Merix, Feb. 2001, Anaren Microwave, April-May, 2001 Broadcom, May 2001, Applied Micro Circuits, June 2001, At Road, June 2001, Emulex, June 2001, Molecular Devices, June 2001, and First Horizon Medical, Sept. 2002.

low option prices, and the average gross spot bulb index price during the tulipmania of 12.5, a reasonable estimate of the efficient-markets contract price, or exercise price, range is 179 to 192. A visual inspection of Figure 2 or Figure 3 reveals that this empirically-based estimate is also an accurate estimate of the range of exercise prices observed during the tulipmania.

7. Market efficiency

Although the exercise prices during the tulipmania were thus approximately efficient under an assumption of rational expectations on the part of the roughly constant-cost, competing sellers, there is still a question of rational expectations on the part of the buyers. Excessive optimism on their part would simply expand the number of contracts supplied without having a substantial effect on price. Hence, again under reasonably constant costs, there could have been substantially inefficient overoptimism and corresponding over-speculation in the 1637 tulip options market. This is especially likely given the abnormal additional gamble with respect to the prices the buyers would eventually have to pay for their options. The resulting social waste of transaction costs and negative externalities to the gamblers' families and creditors would then make the markets substantially inefficient despite the efficient market prices. An efficient Dutch government would thus be very likely to close these highly speculated markets in response to the high volumes observed in early February. The same appropriately occurs in modern times when market overseers determine that a market is the subject of excessive speculation.

8. Conclusion

A centuries-old literature has entirely misrepresented the "tulipmania." It is not an illustration of what Mackay termed "Popular Delusions and the Madness of Crowds." On the contrary, tulip contract prices before, during, and after the "tulipmania" appear to provide a remarkable illustration of efficient market prices, where options prices approximated the expected costs to the informed suppliers. What makes this efficient pricing so remarkable is that contract prices quickly and accurately reflected the underlying economics of a market in which the emotions of exuberance and depression based upon contemporaneously experienced capital gains and losses might well have been expected to create substantially inefficient price patterns.

Appendix I

This appendix explains the process which led to the construction of Figure 1 above. The raw price data for this time series begins in early November, 1636 with bulbs prices reported in *the Dialogues of Waermont and Gaergoedt.* (Posthumus, 1929, p. 453). These dialogues were extremely valuable in creating a reasonably accurate picture of the price movements from early November 1636 to early May 1637, the months during which the tulipmania took place. Indeed, they have been the standard source of tulip price data for the period and have been verified by both Posthumus, 1927,1929,1934, and Garber 2000, Appendix Al, through cross-referencing to official notary records.

Given the large implicit differences in relative bulb qualities, an appropriate quality-adjustment was necessary for our general price index to accurately reflect the price movements of the overall tulip market. All standard sources have long recognized P. Cos' Tulip book

(1637) as the most useful source of relative tulip prices around the height of the mania. This famous florist's collection of 54 gouaches is now particularly valuable as the only of its kind to systematically record the weight and price at which each bulb depicted inside the catalog was sold at the beginning of 1637, thus allowing us to almost perfectly capture the relative value of many bulbs. Calculating a price for each type of bulb in terms of guilders per aas (about l/564th of an ounce), and interpreting these newly found relative prices as relative quality measures, allowed us to eliminate the enormous quality distortions in what otherwise would have been an un-weighted price index. The result was the price index for a standardized tulip bulb depicted in Figure 1.

The first prices reported in the *Dialogues* were a series of four prices in early November, whose index values were very similar and whose average value we display on the Figures as the realized bulb prices running from November 1 through November 10. Consequently, the first series of prices on Figures 1 and 2 reflect these sales and their average price. More specifically, the *Dialogues* indicate that several bulb sales occurred immediately after the end of the planting season, which would have put these sales in approximately the first 10 days of November. The prices for several bulbs such as two Gel en Rot van Leijen (46 guilders for a 515-aas bulb and 100 guilders for a 1,000 aas bulb, or an average of 0.9 guilders per aas), and two Admiral De Man (a 130-aas bulb for 15 guilders and a 1,000 aas bulb for 90 guilders, or an average of approximately 0.1 guilders per aas) yielded adjusted average index values of, respectively, 10.2 and 7.7, for an overall average index value of 8.9.

Waermont and Gaergoedt then report that on November 12, 1636, according to the broker's record, a 375-aas Ghemarmerde de Goyer was exchanged for the price of 70 guilders, or an index value of 10.5. This and related transactions will be discussed further in Appendix II.

The next value is taken from the November-25 trade of a Gouda weighing 66 aazen which exchanged for 446 guilders (Garber, p. 139), or 6.76 guilders per aas, representing an index value of 97.

Next, the Dialogues report that on or about December 1,1636, the respective exchange prices for a Gheele en Root van Leyden and a Admirael de Man were 1.2 guilders per aas (index value of 122) and 1.35 guilders per aas (index 94), representing an arithmetically averaged index level of 108. While the precise dates of these transactions are unknown, Gaergoedt, a professional tulip broker, refers to the exchanges as taking place "about a month after" the sales reported at the beginning of November (Posthumus, 1926, p. 42).

Then on December 12, a Gouda is reported to have been contracted for 10.83 guilders per aas, which represents an index value of 176 (Posthumus, 1929, p.456).

After this date, the direction of the trend in the price of tulips remains undisputed by all traditional sources. Contract prices rose to new heights until word of a trading suspension reached the traders on February 2nd and 3rd (Posthumus, 1929, p. 444), after which prices sagged until the actual suspension of trading at the market center at Alkmaer on February 5th 1637.

It has been accepted that February 5, 1637 was almost certainly the day the tulip trade was first suspended. Many trades were recorded on that day. Unfortunately, there is no information pertaining to the order in which the sales took place throughout the day. So the only sensible response, we must agree with most of our predecessors (Garber's graphs, probably for dramatic purposes, reported only a highest observed price on that date), is to compute an average and accept it to be the price level for February 5. The *Dialogues* (Posthumus, 1927, pp. 43–44) report 7 Gouda trades on this date. Their prices are, in terms of guilders per aas, 7.47, 8.12, 9.32, 10.08, 56.25, 3.6, 6.14 and 7.11, or, respectively, index values of 122, 132, 152, 164, 916, 58, 100 and 116. The Dialogues and Krelage report 5 trades of Gel en Rot van Leijen bulbs. These bulbs sold for .7, .35, 1.06, .58 and .979, or

respective index values of 71, 36, 108, 59 and 100. Averaging all these index values comes out to be a February 5 price index value of 178.

The enormous variation in prices on February 5 can be understood by recognizing that markets were closed down at different times. By far, the largest market, which was in Alkmaer, was the first to be closed down. Traders in the secondary markets, suddenly aware that their trading opportunities would also end shortly and that they no longer could use the Alkmaer market for arbitrage, were thus put into either highly monopolistic or highly monopsonistic market settings. In such settings, it is perhaps not surprising that prices would jump to an index value of 916, over 3 times the average price of the now-illegal contracts, or fall to an index value of 58, less than 1/3 of the average. Indeed, while the price variation in the 10 February 5th trades occurring in Alkmaer was not exceptionally large, of the above-noted pair of February 5th outliers, the high price occurred in Haarlem and the low one in an unspecified outside hinterland location.

Since price data is strangely sparse in the long period between December 12 and February 5, we could not, from the bulbs in our index, measure the magnitude of the decline in bulb prices just prior to the price decline in early February. To gain some idea of the magnitude of this decline, we noted that there were some prices available for a relatively low quality bulb, called a "Switser," even though these prices did not appear in our index because Cos did not deal in these bulbs. Krelage (p. 51) presents Switser price data for several days in early February, which allowed us to link Switsers to our price index. The resulting index numbers are 199 for February 1,202 for February 3, 178 for February 5, when we had both Switser and non-Switser prices available so as to link the two series together.

In fact, trading continued in the secondary markets in Haarlem and Amsterdam for several days after February 5. Krelage (p. 52) reports a price for one pound of Switsers at 1,100 guilders in a trade on February 9th. The corresponding index value is 148. Posthumus (1934, p. 234–5) reports two February 11 contracts written in Amsterdam in which four different one-pound packages of Switsers were sold, respectively, for 1,060, 1,065, 1,100, and 1,100 guilders. This yields an average index value of 145.

Finally, we gain some new perspective on the post-tulipmania market price for bulbs as Gaergoedt describes a large-volume cash transaction dated of May 1,1637. At that point, the broker details the sale of many bulbs, including, among others, a Gel en Rot van Leijen, sold for 22 guilders when, "if they had been sold at the moment of highest price in the winter, they would have made over 400 guilders; at least they would have been promised for it" (Posthumus, 1929, p. 459). This price reveals that in the spring of 1637, contract prices were worth only slightly more than l/20th of their all-time high value, thus giving us a May-1 index value of 11, this value being representative of the actual magnitude of the "tulipmania" between early February and early May 1637. The above-noted discussion of Gaergoedt of the weeks following the May 1st trade make it clear that the market was basically unchanged during the month of May.

Appendix II

Figure 2 introduces other kinds of bulb prices observed during the period stretching from November 12, 1636 to May 1637. Although many of these prices often fall within a few days of those reported in Appendix I, most of them are an order-of-magnitude lower than the Appendix I prices. Waermont and Gaergoedt discuss, on page 456, a sale that took place on November 12, 1636. According to Waermont's record, a 375-aas Ghemarmerde de Goyer was exchanged for the price of 70 guilders, an index value of 10.5. A careful reading of

the trader's records should clarify the atypical nature of this low-price transaction. While the price and weight of the bulb are succinctly recorded, there is no mention of any further obligation on the part of the buyer, no alternative means of future payment, and no schedule of future payment. Indeed, the ledger was signed solely by the seller, clearly indicating that the only future obligations belonged to the seller. This transaction must therefore have been a cash transaction. The only liability it imposed was a promise of delivery on the part of the seller in the middle of the next spring, as the bulbs are dug up from the ground and physically delivered to the purchaser.

Similarly, on the 9th of December, Posthumus (1929, p. 456) reports the sale of a Gel en Rot van Leijen for the apparently surprising low price of 70 guilders for a 578-aas flower, or an indexed value of 12.2. Here again, as it was for the November 12th transaction above, the broker's book is signed only by the seller since the sale is a cash transaction reflecting the true futures price of the bulb in question. Indeed, the next sale, the following entry in Gaergoedt's records, displays an altogether different type of transaction in that, unlike the December-9th sale which was succinctly recorded and signed only by the seller, the later sale has both the seller and the buyer sign the transaction record and identifies the buyer's alternative means of payment in case cash is not delivered in the future.

By mid-December, the nature of the call option contract must have been widely understood by the traders. Indeed, Dash (p. 165) describes in detail a deal made toward the end of December 1636 which plainly defines the terms of the option, as a planter "Henricus Munting was able to complete a lucrative deal to sell a handful of his tulips for 7000 guilders to a man from Alkmar only by promising his nervous customer that if prices fell before the summer of 1637 he could cancel the purchase and pay no more than 10 per cent on the agreed price" (p.176).[3]

Appendix III

Figure 3 above puts the "mania" in perspective by looking at the evolution of the Dutch tulip market over the two-year period which led to the Tulipmania. The earliest prices from December 1634 to July 21st, 1636 are to be found in Krelage. On page 49 and 50, he

[3] We excluded two kinds of price observations. One was a very high per-aas price, extremely small, 7 aas Gouda. The other, low-price Switsers that traded early in the mania, before these bulbs came to attract speculative interest.

Regarding the former, Posthumus (1927, p. 41) describes a January 29th, 1637, sale to a baker from Haarlem of a 7-aas Gouda for the contract price of 100 guilders. Although this represents a sale at 14 guilders per aas, or an unadjusted index value of 228, such a small bulb would probably, in just a year become at least a 200 aas bulb with the proper amount of nurturing and care. The other bulbs in our index were at least 200 aazen. Ignoring the prospective cost of care, risk, and interest, the contract price would have been around 2,000 guilders. To make this baby bulb comparable, we would have add the prospective care, risk, and interest costs to the 100 guilders price and then compute a per-aas price as if the small bulb actually weighed 200 aazen, in which case the per-aas price would have been a lot lower than 14 guilders. So the price should have probably been adjusted downward to account for the small size of the bulb. However, if we adjusted it down by more than 15%, we would contradict the statements of Posthumus (1929, pp. 444, 455) and essentially all others that contract prices were rising in late December and January and declined from their peak during the three days preceding the February 5th suspension. We would also contradict the February 1 index value of 199. Having no real grounds for the 15% discount, we simply omitted the observation from our sample.

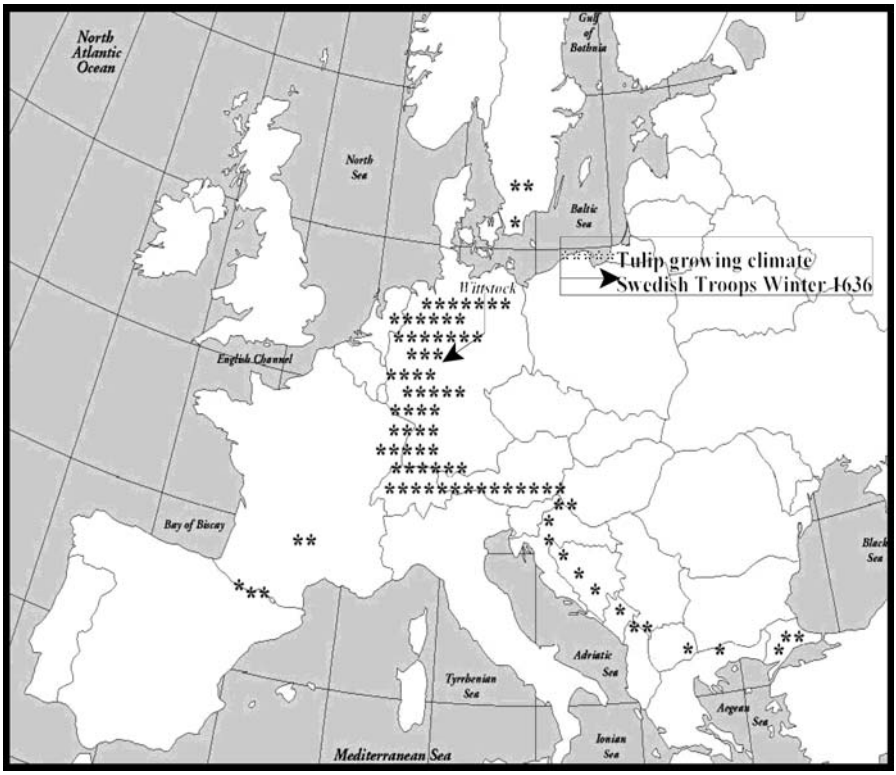
Regarding the low-priced Switsers, the inferior status of these bulbs as a speculative asset is indicated not only by their absence from Cos' tulip catalogue despite their great abundance but also by the fact that, prior to the tail end of the mania, sales were in heterogenous pound lots whereas sales of the speculative quality bulbs were on a per-bulb basis (Posthumus, 1929, p. 454).

mentions Gouda prices in December 1634 at 30 stuivers per aas (or 1.35 guilders per aas), which represented an index volume of 22. The next Gouda is priced at 2.1 guilders per aas (index 34) during the winter of 1635/36. In May 1636, Krelage lists bulbs of the same variety being exchanged for 3.75 guilders per aas, thus yielding an index value of 61. Then, the discussion moves to an Admiral Liefken been sold in June 1636 for 6 guilders and 12 stuivers per aas, or an index value of 38. A bulb of Admiral van der Eijck was sold at 2 guilders and 10 stuivers on July 21st, 1636, giving us an index value of 51. By the closing of the summer 1636, on August 29, the prices have again risen, reaching the index value of 61, as we see, in Garber (2000, p.139), a Gouda being sold for 3.75 guilders per aas.

Appendix IV

The map shows the areas of the European continent that have been traditionally accepted to be prime tulip growing regions (*Tulipworld.com*), from the first bulbs' birthplace in Constantinople to their European springboard in Vienna to the propitiously cold but welcoming plains of Western Germany in the latter half of the 16th century (Dash, pp. 31–35). It also illustrates the Swedish troop movements immediately following the battle of Wittstock on the Northern coast of Germany.

The popularity of tulips among the German aristocracy of the 1620's and 1630's is attested to in various early 17th century castle drawings collected by Hogenberg and a painting of Anna Margareta Von Haugwitz by Anselm van Hulle (Bussman and Shilling).



The 1632–1636 rise in tulip prices corresponded with the Empire's success in pushing the Swedish forces out of western Germany, and finally into small parts of Northern Germany, from 1632 to 1636, which ended in a new German unity under the intra-German Peace of Prague signed and confirmed by the end of September (e.g. Wedgwood, p. 359). But the Peace, by ending the official support of Sweden by Germany's Protestant Northern provinces, created an opportunity for Sweden to attack her previously supportive allies, who were largely unaided by Imperial troops, the latter being preoccupied in preparations to engage the newly combative France (e.g., Wedgwood, p. 351; Maland, p. 155). This produced Sweden's sudden success in the Battle of Wittstock, thereby ushering in a new, political rather than religous, phase of the Thirty Years' War.

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References

Bussmann, K., & Shilling, H. (1648). *War and Peace in Europe*, Munster: Osnabruck. 1998.

Cos, P., *Verzameling van een meenigte tulipaanen, naar het leven geteekend met hunne naamen, en swaarteder bollen, zoo als die publicq verkogt zijn, te Haarlem in den jaare A. 1637,* door P. Cos, bloemist te Haarlem. – Haarlem : [s.n.], 1637. – 75 pi. (See http://www.bib.wau.nl/tulips.)

Chancellor, E. (1999). *Devil Take the Hindmost* (p. 17). New York: Farrar.

Dash, M. (2000). *Tulipomania*. New York: Three Rivers Press.

De La Vega, J. (1688). *Confusion de Confusions,* Harvard, Cambridge, pp. 35.

Garber, P.M. (1986). *The Tulipmania Legend*. New York: Center for the Study of Futures Markets, Columbia Business School, Columbia University.

Garber, P.M. (1989). Tulipmania. *Journal of Political Economy*, *97*(3), 535–557.

Garber, P.M. (2000). *Famous First Bubbles: the fundamentals of early manias*. Cambridge: Mass MIT Press.

Hogenberg, Abraham and Franz (1983). *Geschichtsblatter*, Alfons UHL, Nordlingen, 448,449, and A.4.

Krelage, E.H. (1942). *Bloemenspeculatie in Nederland*, P.N.Van Kampen and Zoon, Amsterdam, 49–52.

Mackay, C. (1841). *Extraordinary Popular Delusions and the Madness of Crowds,* London, Ch. 3.

Maland, D. (1980). *Europe at War, 1600–1650*, Manchester: Macmillan.

Posthumus, N.W. (1926). De Speculatie in Tulpen in de Jaren 1636 en 1637, 1. *Economisch-Historisch Jaarboek*, Martinus Nijhoff, Gravenhage.

Posthumus, N.W. (1927). De Speculatie in Tulpen in de Jaren 1636 en 1637, II. *Economisch-Historisch Jaarboek*, Martinus Nijhoff, Gravenhage.

Posthumus, N.W. (1929). The Tulipmania in Holland in the Years 1636 and 1637. *Journal of Economic and Business History,* Cambridge, May, Vol I.

Posthumus, N.W. (1934). De Speculatie in Tulpen in de Jaren 1636 en 1637 III, *Economisch-Historisch Jaarboek*, Martinus Nijhoff, Gravenhage.

Tulipworld.com, Planting and Care/Climate Zones. Currently, the web address is: http://www.tulipworld.com/tulip.asp?contentloc=/info/bulbcare/climatezone.shtml

Wedgewood, C.V. (1999). *The Thirty Years War*. London: The Folio Society.