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A la Recherche du Temps Perdu : Legal and Quantitative Analysis of the First Documented Option Market - Paris 1844-1939

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A la Recherche du Temps Perdu:

Legal and Quantitative Analysis of the First Documented Option Market Paris 1844-1939

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Abstract

We provide the first ever quantitative analysis of pricing and profitability of option trading in Paris from 1843 to 1939 based on a data source featuring more than 75,000 option prices. Using a special case of the Black (1976) option pricing model, we show that, albeit options were consistently undervalued, the market was still profitable for all the parties. We prove that the exceptional longevity of the Paris options market was based on a 4-pillars market microstructure: (1.) systematic underpricing of cheap options to attract gamblers, (2.) administration of settlement price by the brokers' syndicate, (3.) parimutuel-like betting operation and safety thanks to (4.) a sophisticated risk management in the position-taking style which minimized actual clearing price manipulation.

Keywords

Option pricing, financial risk management, betting markets, alternative investments.

JEL Codes : G12, G14, N23, N24.

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Introduction

For the period before the Second World War, only two papers provide a quantitative analysis of option business on rather marginal markets. Kairys and Valerio (1997) show that the sale of over-the-counter options in New York in the 1870s was not attractive to investors because the options were clearly overvalued and therefore offered no prospect of profit. Moore and Juh (2006) showed in the case of the South African market that while over-the-counter options were also overpriced, warrants were commonly used by gold mines to raise capital at a price reasonably close to the prediction of a properly adjusted Black-Scholes model. These authors also mention that Bachelier (1900) found "that observed prices on the bourse [were] close to his model's prices". However, it should be remembered here that Bachelier's (1900) study is limited to the 1894-1898 period on the one hand, and on the other hand to the French government bonds (the so-called *rentes*), which were certainly the most intensely traded securities on the Paris market, but still there was a host of other securities which deserve our attention: at the beginning of the twentieth century, the market capitalization for stocks in Paris is comparable to the London and New York stock exchanges (Kuvshinov-Zimmermann (2020)). Moreover, Paris attracted many emerging bond issuances, notably from the Russian and Ottoman issuers. We propose to go beyond conventional wisdom to embrace all the aspects of Paris option contracts, trading and stakeholders over a century (1844-1939) by providing a quantitative analysis of a novel database.

As Rajan and Zingales (2003) have shown, many "countries were more financially developed in 1913 than in 1980". These authors noticed in particular that "France's stock market much bigger as a fraction of its gross domestic product (GDP) than markets in the United States in 1913, even though the per capita GDP in the United States was not any lower than France's", asking why it could have been the case. One obvious answer is that the French market had been offering advanced features such as derivative trading for more than a century, while the US were plagued by adverse Supreme Court rulings (see e. g. Irwin v. Williar, 1884) and infamous bucket shop activity. Deutsch (1910) p. 223 wrote "... the ordinary option business in Paris is of far greater importance than all the various kinds of option business in London put together"; Higgins (1902) p. 58 already mentioned that "the largest individual transactions have been done in Paris, where speculators occasionally deal in amounts which are almost unheard of" in London, and we are going to show that those speculators were only the tip of the iceberg. Being the only legal betting venue for the whole country between 1832 and 1891, the "marché à terme" attracted a crowd of bettors, from the poorest who "come, literally in rags, to compete for the

last shreds of their misery"[1] (Pollin 2007 p. 103) to the "members of Parliament, generals, colonels and high ranking civil servants"[2] (ibid p. 97). Dumas, Zola, many other authors were fascinated by the Bourse, a central fixture of the Paris city life of the *Second Empire* and the *Belle Epoque* (Bellet 1983).

Until now, scholars have studied derivative trading in Paris from various points of view: legal scholars studied the legal aspects (Hissung-Convert 2009) and mathematicians the work of Bachelier in comparison with contemporary developments of financial mathematics , without confronting these theories with facts; those who studied the facts adopted a socio-historical perspective highlighting a formal institutional opposition between market segments (*i. e. parquet* vs. *coulisse*), without a legal analysis of the option contract nor a quantitative analysis of pricing and listing practice (Hautcoeur-Riva 2012, Lagneau-Ymonet and Riva 2018). In particular, the very nature of the option contract itself remained in the shadows. The first thing to be said here is that the Paris option contract remained the same at least from 1819 until 1939: such stability contrasts sharply with the political instability of France, which experienced no less than 14 different forms of government[3] from 1789 to 1877. The first step of any serious study of option trading in Paris is to clarify the precise legal nature of the option contract. Our inquiry is not only legal since we provide the first ever quantitative analysis of pricing and profitability of option trading in Paris over more than a century. Such a quantitative analysis is made possible by the availability of an exceptional data source featuring a sample of more than 75,000 options prices from 1844 to 1939, from which more than 44,000 feature a standard deviation making them amenable to valuation by financial mathematics. Contrary to the common opinion, the Black and Scholes formula is not fit for Paris options, which were options on forwards. We use a special case of Black's (1976) formula, where the discount rate is zero to show that, albeit options appear consistently undervalued, the market is still profitable for all the parties: this provides a strong rationale for the outstanding longevity of the Paris option trading business. Where Kayris and Valerio (1997) show that the attempt to set up an options market in NY was stillborn because of overvalued options, we prove that the exceptional

[1] Les nécessiteux « qui viennent, littéralement en haillons, disputer au jeu les derniers lambeaux de leur misère ».
[2] « Des députés, des généraux, des colonels des employés supérieurs d'administration »
[3] Namely: 1. the Ancien Régime monarchy (before 1789), 2. the constitutional monarchy (1789-1792), 3. the National Convention (1792-1794), 4. the Committee of Public Safety during the Terror years (1794-1795), 5. the Directoire (1795-1799), 6. the Consulate (1799-1804), 7. Bonaparte's First Empire (1804-1814), 8. the first Restoration (1814-1815), 9. the Hundred days (1815), 10. the second Restoration (1815-1830), 11. the July Monarchy (1830-1848), 12. the second Republic (1848-1851), 13. the second Empire (1851-1870), 14. the Third Republic (1870-1940).

longevity of the Paris options market was based on a 4-pillars market microstructure: (1.) systematic underpricing of cheap options to attract gamblers, (2.) an administered settlement price, (3.) a sophisticated risk management involving position-taking and book-balancing in order to achieve (4.) parimutuel-like betting performance and sustainability for the operator.

The rest of the paper proceeds as follows: section 1. describes the Paris option contract, section 2. introduces the database and provides some descriptive statistics, and section 3. establishes the correct valuation model for the Paris option contract, section 4. provides original findings of pricing anomalies, section 5. exhibits the microstructure of options trading to give account for the underpricing pattern of options.

1. The Paris option contract: legal analysis

The Paris option contract originates in Amsterdam (1.1.). It was an **un-securitized, cash-settled American call option on forward prices**. The following sections will provide detailed explanation of each of these features (1.2.) before picturing the actual operation of the options (1.3.).

1.1. Origins of the Paris option contract

It is well-known that there has been option trading in the Ancient World, since Aristotle reports how Thales of Miletus bought options on the use of olive mills to corner the market[4]. Medieval examples of widespread put options trading exist, as the papal interdiction of bottomry (1236) led to development of insurance contracts as put options on the ship and cargo (Briys et al. 2006). The modern option history begins with the Amsterdam (Gelderblom and Jonkers 2005) and London markets (Murphy 2009), but stock options of that time were physically settled (*i. e.* by the delivery of the security) and were more a kind of *repurchase agreement* to provide the holder of a security with money for a while. It seems though, that the Barnard Act (1734)

[4] See Aristotle, Politics (1259a), from Aristotle in 23 Volumes, Vol. 21, translated by H. Rackham. Cambridge, MA, Harvard University Press; London, William Heinemann Ltd. 1944, available on-line on http://www.perseus.tufts.edu/: "Thales, so the story goes, because of his poverty was taunted with the uselessness of philosophy; but from his knowledge of astronomy he had observed while it was still winter that there was going to be a large crop of olives, so he raised a small sum of money and paid round deposits for the whole of the olive-presses in Miletus and Chios, which he hired at a low rent as nobody was running him up; and when the season arrived, there was a sudden demand for a number of presses at the same time, and by letting them out on what terms he liked he realized a large sum of money, so proving that it is easy for philosophers to be rich if they choose, but this is not what they care about."

prevented the development of the London market, which eventually moved to Amsterdam where it flourished (Neal 1987). Evidence about the Amsterdam option contracts are scarce, but Ricard (1722) and Pinto (1771) provide direct and indirect material. In particular, Ricard provides a full template for both put and call options *on commodities*. It must be noted here that this template exactly matches the template provided by Bizet (1821) for the Paris market one century later, but the Paris market we consider was a *securities market* (see Table in Appendix A).

One can ask how the Amsterdam customs eventually flourished in Paris. This story remains to be written, but it is remarkable that the first comprehensive work dedicated to the Amsterdam market was written by a French man in French as soon as 1721 (Ricard 1721). Then, the most detailed book on the trading of options in Amsterdam, Isaac de Pinto's "Jeu d'actions en Hollande" (1771) was again written in French and contains a description of options, contango (*report* in French, Pinto called it *prolongation*, p. 292) and what we called complex strategies in section 1.2[5]. There were some elements of option trading as early as the eighteenth century in France, though the market was a weakly regulated over-the-counter operations on public debt securities. This trade became mainstream only when France moved to annex Amsterdam as soon as 1795 (first as capital of the Amstel province of the Batavian Republic, and from 1806 to 1814 of the Zuyderzee French department), under the leadership of Napoleon Bonaparte who simultaneously organized the Paris financial market as it will work until 1985. It seems thus that the options trading in Paris is the direct continuation of the Amsterdam Beurse.

1.2. Distinctive features of the Paris option contract

1.2.1. An American in Paris

The literature usually considers the Paris options to be European-style options[6], but the wording of the Paris option template was actually American:

> *"On the 31st of August, fixed date,* or sooner at will*, upon 24 hours notice, I will be provided by Mr. Dumont, agent de change 10,000 fr. [worth of yearly*

[5] See for instance how Pinto described the combination of short selling and selling puts as "mousser sa contrepine en avant" p. 298.
[6] See e. g. Poitras [1994] p. 353 :"The origins of the European and American features in options contracts are obscure, though early sources such as Bachelier (1900) indicate that the European feature predates the American."

coupon] of 5% consolidated bonds issued on march the 22nd 1814, for a 130,000 fr. cash payment[7] *"*

While the settlement date is fixed to the end of a given month, the call option may be exercised on any prior date, which defines the American option, albeit there is a one-day notice. This early example in Bizet [1819] is followed by later mentions in Bresson [1826] p. 21, Peuchet [1829] pp. 161-162 etc. up to Buchère [1892] p. 357. Eventually these terms were written in the Regulations of the Stockbrokers Association (*règlement de la compagnie des agents de change*), and lastly into a decree[8] (which stayed in force until WW2). Hissung-Convert [2009] p. 352 suggests the clause was not intended to be actually exercised, it was merely featured to escape the legal qualification of gambling, which would have made the contract unenforceable by the courts: by explicitly mentioning physical delivery, the contract did not appear as a wager on uncertain events but as an outright purchase of securities. According to this interpretation, the continuity with the Amsterdam option contract might be more formal than actual.

Upon closer reading the contemporary literature, the American-style clause was not just formal. Market players were well aware that there is usually no reason to exercise an American call before settlement, as Bizet [1819] p. 46 wrote:

"One may observe options are very rarely exercised before maturity for two reasons: first, because prices including the option are always higher than forward prices, hence only a sharp increase in prices can overcome this difference; second, it not in the buyer's interest to exercise the option since by doing so he terminates the option before the settlement date, while between the current date and the settlement date the option could offer gain opportunities that would be annihilated[9] *"*

[7] Bizet 1819 p. 44 : « Le 31 août prochain, *ou plutôt à volonté*, en me prévenant 24 heures à l'avance, il me sera livré par M. Dumont, agent de change 10,000 fr. de rentes, 5 pour % consolidés, jouissance du 22 mars 1814, contre le paiement de la somme de 130,000 fr. »

[8] Décret du 7 octobre 1898 portant règlement d'administration publique pour l'exécution de l'article 90 du Code de Commerce et de la Loi du 28 mars 1885 sur les marchés à termes. Voir l'art. 63 : « L'acheteur a toujours la faculté de se faire livrer par anticipation, au moyen de l'escompte, les valeurs négociées, soit qu'il ait traité ferme, soit qu'il ait traité à prime. Les escomptes donnent lieu à une liquidation anticipée… »

[9] "On observera cependant qu'il est très-rare de voir escompter les marchés libres ; par deux raisons: la première, parce que les rentes à prime étant toujours à un cours plus élevé que les rentes fermes , il faut une grande hausse pour trouver un intérêt à le faire; la seconde, parce qu'il n'est pas dans les intérêts de l'acquéreur d'escompter, puisque par l'escompte il termine un marché avant le jour fixé, et que du jour de l'escompte à ce jour fixé, son marché libre peut lui offrir des chances de gain qu'il annulerait."

Bizet here makes two points. The first argument refers to an "option price" that must be understood as *all-inclusive*, in particular by including transaction costs that increase sharply when the option is exercised before maturity, since transactions are then carried out on a spot basis, with fees that are on average four times higher (see below). Therefore, authors from the 1820's mentioned early exercise was only profitable in order to corner or squeeze short sellers (Bresson 1821 p. 176). The second one is from the same confounding modernity since it shows that the market operators of the 1810's already understood that an American call option will not be exercised before expiry, as it has been understood a century and half later.

Eventually, the standard option template featured an American-style possibility of early exercise. For reasons of both opportunity and transaction cost, options were usually not exercised before maturity, unless exceptional circumstances (such as a corner leading to a squeeze) make it possible to pay the additional transaction costs. Hence, French options were American option contracts, but most of time were exercised as cash-settled European options on forward prices.

1.2.2. An Option on Forwards

The Paris option is a wager on the *forward price of securities*, not on their *spot price*. In standard notation, assume a European call for expiry date T with strike price K on a stock whose forward price in t for T is F_t^T will produce a payout $F_t^T - K$ if $F_t^T > K$, for a cost of c. In the Paris practice, F_t^T is the *forward price* of the underlying, and settlement date T is called the *réponse des primes* (options settlement day), usually this day is the penultimate of every month (every fortnight for stocks) and F_t^T is then called *cours de la réponse des primes* (options settlement price). Being an option on forward, the Paris option is paid in T, not in t when the contract is concluded. Hence, everything[10] is settled on the *réponse des primes* (settlement day), which occurs once a month for bonds and twice a month for stocks. According to a royal decree of September 22nd 1786, the farthest legal maturity for option contracts is set to two months, that is to say, one can only buy options for the next two settlements in case of bonds (monthly settlement), or next three settlements in case of securities settled twice a month.

[10] Everything, as long as one does have an account with a stockbroker. Very low price options – some options were as cheap as a penny – were paid cash. This does not change much for pricing purpose since a 3% interest on a month does not makes a large difference.

1.2.3. A Non-securitized Option

The Paris option contract offered a right, which was personal and could not be sold on a secondary market. Hence the Paris option market was a primary market only. This differed from the present practice, since options can now indefinitely be re-sold on a secondary market. The reason for the non-resaleability of those options is that they were framed as *insurance premiums*[11], hence the term *primes* (prime d'assurance being the French term for insurance premium, both terms originating in the dutch *premie*). This being said, it was possible to short the listed options by "selling on prime" (*vendre à prime*), which meant everyone could *sell a call*. More accurately, as the options did not have a securitized form, "selling on prime" meant taking a cash-settled position *equivalent* to selling a call. Non-securitized options implied it was not possible to exit the market, but we will show that dynamic strategies could be implemented by buying and selling *new* call options (see below 2.2.3). The next paragraph shows why it was impossible to resell the options except on zero measure sets.

1.2.4. "Only the spread is priced" (Bachelier 1900)

While in the contemporary practice, the market lists option prices for various strikes, the Paris practice was to list options with *fixed* prices, and display $K + c$, where $K + c - F_t^T$ was called the spread. With this spread, people could figure out instantly the distance between the current forward price F_t^T and the break-even price of the option $K + c$. The French called "c" (the option price) the "dont", which litterally means "from which", hence a 1 franc call option with strike at 99 francs was listed as "100 francs dont 1 fr." (or "100 fr. /1 fr."), i. e. 100 francs break-even price from which option price = 1 franc.

This way of listing and pricing options made it impossible to re-sell option rights, as an example will show. Assume I bought yesterday the rente at "100 francs dont 1" (*i. e.* a 1 franc call on the rente at a strike price of 100 – 1 = 99 francs), what is the probability that the same strike is listed today so that I can sell back the option I bought yesterday? Since there are only three options listed on the rente (25, 50 centimes and 1 franc), three different strike prices are available, from a wide range of possible alternatives. Hence the probability that a given strike price is listed every day is infinitesimal. In modern words, it is impossible to re-sell an option

[11] See e. g. Pinto (1771) p. 294: "We call premium for receiving, when Paul gives Peter a premium for Peter to oblige himself to receive on settlement day a thousand pounds of annuities or other securities at a given price: by means of which *Peter becomes like Paul's insurer* [emphasis added], & undertakes to make good to him all that this fund may diminish, decrease, or lose in the meantime beyond the agreed price."

once it has been bought except on zero-measure sets. Consequently, the Paris options were closer to a *contract for differences* than to modern, resealable options.

Since the terminology of the Paris option contract seems idiosyncratic, there has been errors in interpreting the Paris Bourse slang[12]. The following table will provide a summary at a glance:

Table 1 – terminology and notations

Usual Notation	**Name (today)**	**In French ca. 1840-1940**	**Remarks**
	Perpetual annuity Bond	Rente	See below
F_t^T	price of the underlying asset	= prix à terme	
	Maturity	= jour de la réponse des primes	
$V(F_t^T, t)$	price of the option (premium) as a function of the underlying asset F,t	= « dont »: to be understood literally as « from which »	In Paris, possible option price are 25 c., 50 c., 1 fr., 2 fr., 5 fr. and some higher multiples of 5 fr.
in particular, $C(F_t^T, t)$	price of a call option	prime à délivrer or prime à livrer	only call options were exchanged
$P(F_t^T, t)$	price of a put option	prime à recevoir	not available on the official Paris market
K	strike price (set constant today, variable in the past)	« Pied de la prime » (Bachelier)	
$K + C\left(F_t^T, t\right)$	Option break-even point (transaction fees and tax are not taken into account)	**cours à prime**	
$K + C(F_t^T, t) - F_t^T$		**Ecart**	

[12] For instance, Walker 2001 p. 197 quotes Boissière 1908 pp. 237: "A 1700 dont 20 je prends 50 Rios" meaning "I buy (je prends) 50 20 francs options on Rio at 1680 strike price" translating erroneously "At 1,700 and a commission of 20 centimes, I will take 50 Rios". Walker confuses francs with centimes and option prices with "commissions" (= fees). "Commission" is mentioned p. 189 as being charged by the stockbroker "at a rate fixed by law, for acting as an intermediary": Walker then confuses option price with brokers' fees. Then again p. 196, he quotes Boissière "Dont 40, j'ai l'ex", translating by "At a commission of 40 centimes, I have Ex bonds". Here again, option prices are confused with "commissions" (*i. e.* fees), francs with centimes and more: "j'ai" translated as "I have" actually means "I do sell you".

In the following, we will use the contemporaneous English vocabulary and means of accounting, but we will mention the French habit every time it is necessary, so that we constitute a (nineteenth century) French - (modern) English dictionary of derivative contracts. We shall mention in particular that the word "rente" is tricky since rente often describes *both* the income and the asset which produces this income. There can thus be a confusion between the *income* and the *price of the underlying asset*, which is the *capital.* This is the case especially in classical French literature (Balzac), but also in the way it is reported by financial analysts. Formally, "cent francs de rente" means an income of hundred francs derived from sovereign bonds. We might think today of "cent francs de rente" as being a hundred francs' worth of bonds, which were called "rente". This latter interpretation is a misunderstanding (in French, *un abus de langage*), not entirely uncommon in the Belle Epoque Paris. Most commonly, "cent francs de rente" meant "the capital which produces hundred francs of rente", that is to say 100:5% (by 1814) = 2,000 francs. "Cent francs de rente" then actually meant "two thousand francs of capital" invested in (perpetual annuity) securities. By the end of the 19th century, the same "cent francs de rente", now at 3%, meant 3,333.33 francs. It must be mentioned that meanwhile, the value of the franc germinal stayed at 290.25 mg of pure gold.

1.2.5. There is no put

While put options existed on the Amsterdam beurs ("primes à livrer"), French politics induced specific developments which distinguished *de facto* the Paris options from their Dutch ancestors. In particular, the emergence of options trading in Paris is to be linked with the war of American independence, since this event made the French government debt become unsustainable. Sophisticated trading then appeared as a way to attract liquidity and ease up the price discovery process for public securities. The Crown was particularly concerned by short selling for 'attacking the public credit', since the price of the *rente* revealed the interest rate at which the State borrowed. As a consequence, as soon as August 7th of 1785, a royal decree prohibited the Dutch "primes à livrer" or put options in the following terms:

> *"His Majesty declares null and* void the contracts and compromises of royal and other securities of any kind, which would be made at term and without delivery of the said securities or without the actual deposit of the said securities, established by a duly controlled deed, at the very moment of the signature *of the undertaking" (Mollot 1841 p. 143)*

By this decree, the King Louis XVI forbade short selling of government bonds, both on the spot and forward market. In that time, and up to 1985 in France, the options market was considered to be part of the forward market, hence forbidding forward short sales implied forbidding as well the sale of put options on forward prices. The same decree set a high penalty for non-compliance: 24,000 francs fine for the benefit of the whistleblower plus a lifetime ban from both the stock exchange and removal of banking license, if applicable.

This ban on short sales in general and put options in particular was continued during the French history. Bonaparte himself made clear the reason for the stringent regulation:

> *"I wonder whether the man who offers to deliver in a month's time at 38 francs French rente at 5%, which is sold today at 40, is not proclaiming and preparing for discredit, whether he is not announcing that personally he does not have confidence in the Government, and whether the Government should not regard as its enemy the one who declares himself to be such." (Mollien t. 1 p. 253)*

Bonaparte added later:

> *"I do not want to hinder anyone's industry; but as head of the present government of France, I must not tolerate an industry for which nothing is sacred, whose usual means is fraud and lies, whose aim is an even more immoral profit than that sought in games of chance, and which, for the most mediocre profit of its kind, would sell the secrecy and honour of the government itself, if it could dispose of it." (Mollien t. 1 p. 262)*

For Bonaparte, the government should act to raise the price of state-bonds. The quotation below appears to be a French-style definition of interventionism:

> *"Since you agree that it is important for its [the Government's] internal and external consideration that the price of his debt should be maintained in a progressive state, the natural consequence of your confession is his right to police and supervise those who, speculating only on the variation of that price, often have an interest in imprinting a retrograde movement on him." (Mollien t. 1 p. 259)*

One would think that the monarchs' obsession with short selling and its prohibition would have been crippling to the options market in general. This was not the case, on the contrary, this situation encouraged the development of complex operations that made it possible to effectively sell short via *synthetic* puts, without revealing the implicit rate of the *rente*. A French mind would observe that legislation is made to be circumvented[13], hence notwithstanding these prohibitions. In particular, a synthetic call can be obtained by selling short and buying a call. More complex trading, involving dynamic strategies are detailed in Appendix B. Dynamic strategies should not be confused with dynamic *hedging* in the modern sense. Market organization prevented modern option management, as we show in the next section.

1.3. Market organization

Modern option theory and modern option sellers usually hedge option risks by continuously adjusting spot and forward positions. This was not possible on the Paris market for two reasons:

- No compensation is possible between the underlying and the option, since the underlying (i. e. forward price of the security) is settled on the last day of the month and the option is settled on the day before at a different price. Thus there is an unhedgeable basis risk.
- Moreover, market opening hours were extremely limited in time. François-Marsal (1931) has listed the texts that regulated the opening hours of the stock exchange between 1801 and 1931. This survey shows that the opening hours of the stock exchange range from 1 to 3 hours per day at most, with no definite trend (i. e. no steady increase in time). Continuous-time hedging was of therefore out of reach.

Since the assumptions of modern theory, and notably the ability to replicate by a portfolio the option, were not met, the market operation should have been very different from what we observe today. How could this option market effectively operate? This is what we will show in the following. Before we move toward a quantitative analysis of option trading, let us introduce the database we used for this analysis.

2. The database

[13] This obviously fits Churchill's observation: "In England, everything is permitted except what is forbidden. In Germany, everything is forbidden except what is permitted. In France, everything is allowed, even what is prohibited. In the USSR, everything is prohibited, even what is permitted. "

2.1. Source

The data for this study comes from the DIFH database. The DFIH database collects data on firms and securities prices listed on the Paris stock exchange from 1795 to 1976. For our matter, the options market was listed from May 1844 on. From the daily publication of the price of listed securities by the Stockbrokers Association, DFIH has extracted and stored two samples per month, usually corresponding to settlement days (15th and last day of the month, except for Sundays and holidays). One important feature of this record of prices is that it was "official", that is to say, the prices published were binding for the brokers and could be relied upon by a court. Therefore, the error rate in the original document is extremely low[14].

Appendix C illustrates the price listed for the 15th of December 1881. The first line features the "fonds d'Etat français 3%", that is, 3% French government perpetual bond. The "au comptant" column features the *spot* prices (between 85fr50 and 85fr65), then the "à terme" columns feature both the *forward* and *option* prices. Here the forward price opened at 85fr80 ("premier cours"), oscillated between 85fr75 (lowest = "pl. bas") and 85fr85 (highest = "plus haut") to close at 85fr82 ("dernier cours"). Two options were listed for the 31st of December[15], the first one opened at "86fr05 dont 25", the other one reached a lowest at "86fr dont 50". In modern terms, the first one is a (fr0.25 worth) call option with a strike of 86fr05-0fr25=85fr80 while the other (worth fr0.50) has a strike of 86-0.50=85.50. When we examine the *moneyness* of these options, we can see that both options feature a strike price below the closing (*i. e.* 85.80 and 85.50 < 85.82), thus both options are sold *in the money*. Moreover, the strike price for the pricier option is lower than for the less expensive one, and thus the pricier option has a better probability of winning. This is fully in accordance with the theory.

[14] We found merely one error during our study, on February the 15th, 1870, where the Suez Canal stock was listed at 840 spot, while the opening price was 342.5 for both spot and forward.

[15] the price list here mentions "Pr. fin c." for "prime fin courant" i. e. "option for the end of current (month)". The coding of the expiry date was a bit complex since the notation varies. The possible values of the "expiry" field in the raw file are:
"en liqu." or "en liquidation" means this is the settlement price;
"au 15" means "settlement date end is the 15th of current month"
"au 15 pr." means "settlement date end is the 15th of next month"
"Pr fin c." (or "Pe fin c.") means "end of month settlement date"
"Pr fin pr." (or "Pe fin pr.") means "settlement date end of next month"
"Pr au 28" (alt. "Pr 28", "Pe au 28", "Pe 28"), "Pr au 29", "Pr au 30", "Pr au 31" mean "settlement date equal [28, 29, 30 or 31]", the corresponding month had to be determined according to the number of days in the current and next month (since options could not be sold for more than two month, except after 1930 when options could be extended to three months), but sometimes "pr." is added to indicate next month.
Alternatively, most often after 1930, the month of the settlement date can be more or less explicitly indicated.
Because of the very large number of acronyms and of their variability across time, coding the raw DFIH data into the database took a considerable amount of working time.

Albeit the original data, as published in the official listing, is almost error-free, there are some transcription errors in the DFIH database, notably misplaced quotes (*i. e.* opening prices reported as minimum prices and closing prices reported as maximum, leading sometimes to minimum being above the maximum). Assuming that moneyness is increasing with option price, we discarded every observation that contradicted this rule. This led to discard 5.66% of raw observations. In the following, our analysis is performed only on these consistent option prices.

2.2. Descriptive statistics

The raw DFIH database features approximately 80,000 options prices listed between May 1844 and May 1940. Table 2 features general descriptive statistics, such as the number of unique securities listed during that decade on the spot, forward and option markets. Not every listed security enjoyed a daily 'fixing', *i. e.* the official market was not active every day for every listed security[16]. As it can be seen from columns 1, 2 and 4, securities trading forward were only a subset of the general market, and options were traded on a subset of the securities trading forward. While before WWI, around 80% of securities listed in the base were available on the forward market and 70 to 90% of them had options traded on them; after WWI, only 58 to 72% of the securities were traded forward, with options theoretically available, but not every trading day. Spot prices were listed on average around every two day on average: there was a clear difference though between securities that were traded on a daily basis and those who enjoyed only discontinuous trading, since the brokers were intermediaries without a market making duty. The availability of forward prices was comparable except during the 1900s where forward was more sustained than spot trading, then the forward declined with the war and never recovered fully.

Table 2 — descriptive statistics of securities listing

decade	number of securities listed (spot)	number of securities listed (FWD)	% of spot	number of securities listed (options)	% of forward	% days without price (spot)	% days without price (FWD)	% days without price (options)

[16] Settlement days were the most active trading days and the DFIH database contains settlement days for the spot and forward markets (the option market is settled on the eve of forward settlement day). Nevertheless, the trading volumes are unknown and will remain so since options were cash-settled (in the most material meaning, *i. e.* paid with cash, no cheque, no bank transfer).

1840	26	22	84.6%	20	90.9%	51.1%	59.5%	76.4%
1850	70	62	88.6%	54	87.1%	45.1%	52.0%	78.2%
1860	91	79	86.8%	65	82.3%	59.7%	53.8%	83.8%
1870	130	105	80.8%	81	77.1%	47.3%	44.9%	83.9%
1880	166	133	80.1%	93	69.9%	45.8%	55.5%	82.6%
1890	204	163	79.9%	126	77.3%	48.2%	66.7%	83.0%
1900	260	207	79.6%	170	82.1%	47.7%	28.8%	80.5%
1910	257	219	85.2%	161	73.5%	52.8%	73.5%	91.3%
1920	275	161	58.5%	161	100.0%	39.8%	54.3%	67.3%
1930	272	197	72.4%	197	100.0%	44.4%	59.2%	53.8%

Option prices are fixed and range from 0.25 franc to 2000 francs. We broke down our sample into five option price categories and four time periods. The rationale for cutting the sample obeys institutional concerns: the implementation of the financial transaction tax (July 1893), then the start of the WW1 (1914) and the "Poincaré Stabilization", *i. e.* the 80% devaluation of the Franc in late 1926. The distribution of option prices is indicated in the table 3:

Table 3 — distribution of option prices in the raw DFIH data

dont	**1844-1893**	**1894-1914**	**1919-1926**	**1927-1939**
$x \leq 1$	37.6%	21.0%	5.4%	14.4%
$1 < x \leq 4$	1.0%	11.3%	1.0%	1.8%
$4 < x \leq 25$	59.0%	**63.3%**	62.3%	49.3%
$25 < x \leq 100$	2.5%	4.4%	26.6%	24.5%
$x > 100$	0.0%	0.0%	4.7%	10.0%
Total	24.4%	**26.2%**	8.6%	40.8%
listed options/yr	445	692	940	2399
Average price	7.88	8.55	42.15	49.01

The table reads as follow: between 1894 and 1914, 63.3% of options listed were priced between 4 and 25 francs. Overall, options listed during that period amount to 26.2% of all options listed in the total database. The table also features two rows, one with the average number of options listed every year in each of the 4 subperiods, showing an clear increase in the number of quoted options. The average option is on average 6 times higher after the WW1.

Options moneyness

Scholars interested in the workings of the option market usually look for moneyness of options. Table 4 below list the proportions of options that are sold deep out-of-the money, out-of-the money, slightly out-of-the money, at-the-money, slightly in-the-money, etc.

Table 4 – options degree of moneyness

moneyness	1844-1893	1894-1914	1919-1926	1927-1939
deep out-of-the money	0.2%	0.0%	0.1%	0.1%
out-of-the money	1.3%	0.8%	4.2%	10.9%
slightly out-of-the money	59.7%	65.3%	71.3%	70.0%
at-the-money	5.8%	4.3%	2.2%	1.9%
slightly in-the-money	32.5%	29.3%	22.1%	17.0%
in-the-money	0.2%	0.2%	0.1%	0.1%
deep in-the-money	0.3%	0.2%	0.0%	0.0%
total	100.0%	100.0%	100.0%	100.0%

We consider here usual definition of degrees of moneyness, viz.
deep out-of-the money applies when strike price is above 135% of the underlying price,
out-of-the money applies when strike price is between 110 and 135% of the underlying price,
slightly out-of-the money applies when strike price is between 100 and 110%,
at-the-money when strike price is exactly equal to the prince of the underlying security,
slightly in-the-money applies when strike price is between 90 and 100%,
in-the-money applies when strike price is between 75 and 90%, and
deep in-the-money applies when strike price is below 75% of the underlying price.

We will now insist on a specificity of the Parisian options market that contrasts with modern usage. Today, several distinct strikes are frequently quoted. In Paris, a single option on an underlying asset is often quoted for a given maturity. The following table shows the degree of multiplicity of listed options.

Table 5 – moneyness according to the multiplicity of listed options

	1844-1893	1894-1914	1919-1926	1927-1939
no moneyness info	44%	46%	34%	39%
only one option listed	38%	35%	44%	41%
more than one option listed, all with the same degree of moneyness	7%	8%	12%	12%
more than one option listed with different degree of moneyness	11%	11%	10%	9%
total	100%	100%	100%	100%

This pattern of option listing is highly unusual by modern standards. We will give account for it in section 5.

2.3. Volatility estimation

Looking at volatility now, we need continuously and consistently priced securities to extract volatilities. Unfortunately, many securities do not offer continuous series of closing, minimum nor maximum prices: the most consistent price series are the series of *opening forward prices*. We compute yearly volatility based on either 8, 15 or 30 14-day periods[17] using the formula:

$$\sigma_n = \sqrt{26} \times \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(r_i - \bar{r})^2}$$

where $r_i = \ln\left(\frac{c_i}{c_{i-1}}\right)$ and $\bar{r} = \frac{\sum_{i=1}^{n} r_i}{n}$ for n=8, n=15 or n=30, on the opening forward prices, we could obtain slightly more than 43,000 volatility measurements with 8 observations, slightly less that 42,000 with 15 observations and around 39,000 with 30 observations. It should be emphasized that the changing n, the sample duration of observation (either 8, 15 or 30 14-day periods) may serve as a robustness check[18]. In order to both extend robustness check and take advantage of information contained in minimum and maximum *spot* prices of the underlying, we computed, as well Parkinson volatilities using the formula:

$$\sigma_{parkinson} = \frac{26}{4n\ln(2)}\sum_{i=1}^{n}\ln\left(\frac{H_{t+i}}{L_{t+i}}\right)$$

Where H_{t+i} is the maximum price for the $t+i$ market day and conversely, L_{t+i} is the minimum price for the same day. Any contemporary analyst would be worried about taking into account dividend distributions and corporate actions (like stock split), since failure to do so, may have an upward effect on the volatility estimates. In our sample, no options were found to be sold around coupon or dividend payments or other notable corporate actions. This is easily explained by the very short life of the options sold in Paris. Eventually, all the estimation procedures bear consistent results as tables 6a and 6b show.

Table 6a – average volatility per decade for bonds

Opening prices	#obs	Parkinson (min-max fwd prices)	#obs

[17] The computed volatility relies on 26 records per year on average, hence the reference period is 365:27 = 13.52 or 14 calendar days. We multiplied our volatility estimates by $\sqrt{26}$ to get the yearly volatility. The data is likely to exhibit serial correlation, this issue will be discussed in section 4.

[18] For the sake of simplicity, we only present results for 8-days volatilities. Using 15 or 30-days based volatilities does not substantially impact the result. Complete results are available upon request.

1840	n. a.	0.0%	26.1%	0.6%
1850	n. a.	0.0%	17.0%	2.0%
1860	n. a.	0.0%	11.1%	3.5%
1870	6.8%	0.8%	15.7%	8.0%
1880	7.7%	0.7%	8.8%	10.2%
1890	11.8%	4.1%	8.0%	14.7%
1900	7.6%	27.9%	4.2%	16.8%
1910	6.1%	8.8%	2.4%	10.4%
1920	34.9%	14.8%	12.2%	12.9%
1930	20.3%	42.9%	18.7%	20.9%

Table 6b – average volatility per decade for bonds

	Opening prices	#obs	Parkinson (min-max fwd prices)	#obs
1840	48.2%	0.1%	31.5%	0.7%
1850	37.4%	0.3%	15.7%	2.0%
1860	n. a.	0.0%	22.0%	3.7%
1870	29.6%	0.3%	24.6%	5.4%
1880	25.0%	0.5%	23.8%	8.3%
1890	19.1%	1.3%	18.4%	9.0%
1900	18.3%	19.8%	16.9%	13.2%
1910	16.0%	14.0%	15.6%	12.3%
1920	28.4%	27.4%	25.0%	20.7%
1930	**35.2%**	**36.3%**	**34.2%**	**24.7%**

The tables read as follow: the average yearly volatility of stocks during the 1930s was 35.2% when volatility is computed on opening prices and 34.2% when computed from min and max forward prices. Volatilities computed during 1930s represent 36.3% of all volatilities computed on opening prices and 24.7% of volatilities computed on min/max forward prices of the underlying. The are occasionally some differences between the averages of results given by both methods, either because of the unavailability of one method or (this is especially relevant for options on bonds during the interwar period) because options were often quoted on very speculative underlying which were not even traded on the forward market (*e. g.* defaulted Russian bonds). It is worthwhile to mention that our volatility estimates are consistent with those of Le Bris & Hautcoeur (2010), who report a volatility of 22.8% for the CAC40 index during the period 1919-1946, and 7.78% during the period 1854-1918. Obviously, our volatility

estimates are higher since we consider individual stocks rather than an index as Le Bris & Hautcoeur (2010).

3. How shall the Paris options be priced?

The Paris options were cash-settled American call options on forward prices, but as we mentioned in 1.2.1., these options were usually not exercised before maturity, for reasons of both opportunity and transaction cost. Hence, Paris options are nearly always exercised on expiration, and Bachelier thus disregarded the exceptional cases when the forward price made it profitable to "discount" the option (*i. e.* exercise it before maturity at the cost of additional fees) to price the Paris options as *European* options. The Bachelier model is very much like the Black (1976) model, as Schachermayer W. Teichmann J. (2008) rightly pointed out. But there are two important differences between the Bachelier (1900) and the Black (1976) models: first, the schedule of payment of the option, second, the nature of the price process.

schedule of payment of the option

Haug and Taleb (2011) noticed after Sprenkle (1961) that "The first identifiable [option pricing formula] was Bachelier (1900) […] [who] avoids discounting". Discounting was not required for Bachelier since he considers options on forwards cash *settled on expiry*: all differences were paid on maturity, *including the option price* (with one already mentioned exception: "discounted" options, *i. e.* options exercised before maturity; for the sake of simplicity we neglect these cases, for which no empirical examples were found). This peculiar feature made the market understandable for the most cognitively modest investor, who just had to compare the forward price to the "prime" (*i. e.* strike + option price quoted together) in order to figure out the result of his investment. The modern reader must understand that here lies the genius simplicity of this option contract, however exotic it appears now. So far for the schedule, now let us look at the underlying price process.

underlying price process

Whereas Bachelier assumes the price S_t^B of the underlying security to follow a differential process $dS_t^B = \sigma^B dW_t$, where changes in price are proportional only to the volatility, Black considers the variation of the price of the underlying to be proportional to that price as well: $dS_t^{BS} = S_t^{BS}\sigma^{BS}dW_t$. The reason for this difference is simple: Bachelier only considered options on *rente*, *i.e.* on (perpetual) bonds that fluctuate inversely with the interest rate. This

model is *a priori* not suitable for the valuation of options insofar as the underlying has a trend component that involves a drift in the stochastic process. The Black model incorporates such a drift term, which is absent in Bachelier's original model.

As Schachermayer and Teichmann (2008) pointed out, the difference between prices provided by either modelling alternative is rather small since the Paris options have a short life span, while the difference is comparable to a difference between simple and compound interest. But Bachelier's model did not lead to a closed pricing option formula, while Black's does.

Black-Scholes describes options on spot, Black describes options on forward paid at the moment of buying the option, and Bachelier priced options paid on expiry but he considered trendless underlying, excluding stocks. We need a model with features of both the Bachelier's (option paid on expiry) and Black's (underlying may have non-zero trend) models. To correctly value Parisian options on both bonds (as Bachelier already does) *and equities*, we consider a special case of Black's model with zero discount rate since the option payment is made at maturity, according to the Paris custom.

Eventually, table 7 summarizes the subtle differences in time value of prices:

Table 7 — differences between the Black-Scholes, Black and Paris option

Theoretical model	option price paid on…	Underlying price	Strike price relative to…	Stochastic process for prices	Option formula
Black and Scholes 1972	Current date	Spot	Future date	$dS_t^{BS} = S_t^{BS}\sigma^{BS}dW_t$	$S_t\mathcal{N}(d_1) - Ke^{-rT}\mathcal{N}(d_2)$
Black 1976	Current date	Forward	Future date	$dS_t^{BS} = S_t^{BS}\sigma^{BS}dW_t$	$e^{-rT}\big(F\mathcal{N}(d_1) - K\mathcal{N}(d_2)\big)$
Bachelier 1900	Future date	Forward	Future date	$dS_t^{B} = \sigma^{B}dW_t$	No closed formula
Undiscounted Black	Future date	Forward	Future date	$dS_t^{GB} = S_t^{GB}\sigma^{GB}dW_t$	$F\mathcal{N}(d_1) - K\mathcal{N}(d_2)$

We now have a benchmark model to test whether Paris options were correctly priced.

4. Were Paris options correctly priced?

The undiscounted Black model introduced in the previous section allows us to compute for each option in the database a model price using volatilities computed in section 2. The pricing error is then given by the formula

$$pricing\ error = \frac{market\ price - model\ price}{market\ price}$$

Table 8 summarizes the pricing errors by subperiod and by degree of moneyness:

Table 8 – option pricing errors by subperiod and by degree of moneyness

	1844-1893	1894-1914	1919-1926	1927-1939
deep out-of-the money	-40.8%	n. a.	-39.3%	-13.3%
out-of-the money	-26.2%	-21.6%	-10.7%	-4.8%
slightly out-of-the money	-22.3%	-5.7%	-5.6%	-9.9%
at-the-money	-12.7%	-1.3%	-1.4%	-0.7%
slightly in-the-money	-9.4%	-0.9%	-1.0%	-0.8%
in-the-money	n. a.	-0.3%	n. a.	0.0%
deep in-the-money	-29.2%	n. a.	n. a.	n. a.
Total	-17.8%	-4.6%	-4.9%	-4.7%

This table provides the first survey of option pricing correctness in the Paris bourse over a century. Three main stylized facts can be extracted from this data:

- Options appear consistently undervalued over the whole range of our study[19];
- Before the Belle Epoque, undervaluation is very significant; from 1894 on it stays at a steady level around 5% *on average*;
- Out-of-the-money options are more strongly undervalued than in-the-money options. In particular, deep out-of-the-money options are the most undervalued options. This is strongly counter-intuitive, since put options were not traded in Paris, and one would expect that deep out-of-the-money calls (together with selling forward, see 1.2.5. and Appendix B) could be used to carve synthetic in-the-money puts.

Let us give account for these stylized facts.

[19] Only 21.5% of listed options were not undervalued.

Stronger initial mispricing

Modern readers who have read Bachelier (1900) usually believe that the options on *rente* were correctly priced on the time period described by Bachelier (1894-1898). We show that the previous time period exhibited strong pricing anomalies across the range of options. Haug and Taleb (2011) have shown that market operators developed pricing heuristics in absence of robust theories, we can infer from our data that pre-1890 heuristics were unsatisfactory.

Underpricing of deep out-of-the-money calls

Modern market operators would have expected option sellers to manage the risk emerging from the sale of out-of-the-money calls by raising their prices. Our data obviously contradicts this intuition. Since only very few deep out-of-the-money calls were offered by stockbrokers, we can infer that their sellers managed their risks not by raising the price but by refraining from selling these instruments. In section 5, we will provide a more comprehensive view of option sellers risk management techniques, at the moment we have a hint that option sellers managed their risks not by adjusting prices but quantities (*i. e.* the mere fact of not *listing* options).

Systematic options underpricing

This is in stark contrast with Kairys and Valerio (2012), who showed the option prices in New York were overvalued and thus, uninteresting for the public, therefore the New York option market did not take off in the 1870's. We give evidence that Paris is the exact opposite of this failed attempt to establish an options market in New York City, since Paris options were undervalued and thus very appealing to the public.

One may ask whether this major result is not simply an error. One may think that the returns in Paris are based on illiquid prices, which would likely cause serial correlation and Franke *et al.* (1999) have shown that autocorrelation in volatility may lead to underpricing of options. Is it the case here? To examine this hypothesis, we consider the distribution of the autocorrelation parameter for strongly undervalued options and weakly undervalued options: in both cases, the distribution has the same moments (mean, variance, skewness, kurtosis)[20]. Hence undervaluation is *not* linked to autocorrelation.

[20] The following table compares the estimations of the first four moments of the distribution of the autocorrelation parameter of the volatility:

	strongly undervalued options (<-20%)	correctly valued options (>-1%)
Mean	-0.1334269	-0.133816
Variance	0.1209501	0.1273599
Skewness	0.7952675	0.6715413

Since autocorrelation does not give a hint about mispricing, one may wonder whether there are consistent cross-sectional patterns of mispricing on the whole data sample. Modern market intuition would certainly be deceived since the institutional specificities of the Paris market have to be taken into account in order to understand by what miracle the sale of *undervalued* options was sustainable for so long for the brokers.

*

5. From institutions to microstructure

The apparent undervaluation of options on the Paris stock exchange does not make sense of the sustainability of the brokers' business model. Three mechanisms allowed brokers to regain control: additional costs (5.1.), the setting of settlement prices (5.2.), and risk management techniques similar to that of bookmakers (5.3.). Eventually, we describe the payoffs of the stakeholders (5.4) and the wider welfare implications of the microstructure.

5.1. The role of additional costs

First, brokerage fees ("le courtage") on option trading were due only when the operation was "profitable" for the buyer, that is to say, when the option was actually exercised. Bozerian (1859) makes this point very clearly:

> *"brokerage fees for securities not paid in full are due only on the net profit of negociation.*
>
> *Jurisprudence of the Marseilles commercial court, 27 of January 1847*
>
> *(…) it cannot be that brokerage is charged on a nominal and fictitious value, but rather on the real amount of the thing conveyed by the negotiation…*[21]*"*
> *(p. 51-52)*

Kurtosis	3.895405	3.527222

Consequently, there is no significative difference in autocorrelation between correctly priced (i. e. market price > 99% model price) and undervalued options (market price < 80% model price).

[21] « Les droits de courtage pour des valeurs non libérées ne sont dus que sur le net produit de la négociation. Jurisprudence conforme — Trib. com. de Marseille, 27 janvier 1847 (…) il ne peut être que le courtage soit perçu sur une valeur nominale et fictive, mais bien, au contraire, sur le montant réel de la chose transmise par la négociation »

This ruling of the Marseilles court in 1847 does not modify previous practices; on the contrary, it reflects the custom of the Paris stock exchange, from which Marseilles brokers had sought to deviate (*i. e.* they wanted to cash in fees even when options were not exercised). Thus transaction fees actually *raised the strike price for exercised options*, which lowers the probability of the call being exercised. When an investor buys "a premium at 100 from which one", *i. e.* a one franc option with a strike price of 99, he expects to be at the money if the settlement price is at 99 on expiry. At 100, he will have paid back the option, and above he will be earning a profit. In Paris, things are slightly different since at 99, if the investor exercises his option, the fees and tax will be due. Those fees amount to 0.25 and, after 1893, a 0.05 tax was added (see below section 5 for complete account)[22]: additional costs amounted to 0.30 francs overall for every security (except for rente options, which featured only 0.10 francs of additional costs). Hence, the option is really at the money when the fees and tax can be paid, *i. e.* the strike is effectively raised by the amount of the fees plus tax (in our example the investor will begin to profit when the settlement price is above 100.30, which is thus the "true" break-even point).

The investor who paid a low price option might think he has been cheated since he thought he was in the money while he is actually not. Moreover, the fees are usually higher for low transaction volumes, which typically correspond to the cheapest options. Hence a recurring complaint about brokers' fees: as fees where due every thousand francs, those who bought only one option were bitterly disappointed, not just to pay the same amount as those who bought a thousand francs of options, but even to lose their bet when they thought they had won. This may seem a rather bad marketing plan, as deception should deter the cheated investor from coming back… Except that the stockbroker's salesman could explain at 100.10: "if you had bought four options, you would have paid the same amount of fees overall and would have won 10 centimes". Psychologists have shown that such "near-miss", *i. e.* the feeling to have "almost" won is one of the strongest leverages of gambling addiction, as documented in Pisklak et al. (2019). Bachelier would have advised to buy the more expensive options rather than buying more of the same, since the probability of winning on options was increasing with option value. Appendix D provides evidence that the average return on call options was increasing with option prices for every category of underlying (*i. e.* bond and shares) and every period, starting from the cheapest, most popular options. So albeit cheap 0.25fr options were appealing but more rarely won, they lured the unsophisticated investor into buying *more* of them.

[22] See below section 5. Table XX for a complete account of transaction fees and taxes.

The role of the 1893 financial transaction tax

When the French government created a financial transaction tax (1893), in the wake of the Panama stock market related scandal, the stockbrokers protested that they were going to lose their customers due to rising costs. Moreover, as the public was complaining about rising additional costs, the government announced the stockbrokers fees would be consequently reduced[23]. This looked apparently as blatant financial repression. But, given the nature of the option contract we explained in the previous paragraph, the additional tax only raised the investor's break-even point, reducing the probability for the public to win. And, when the option buyer does not win, the option money is profit for the broker, *who did not pay the tax on unexercised options*[24]. This is where lies the trick: while the financial transaction tax is usually perceived as detrimental to securities trading, *in this very special case, it profited to the option sellers since it raised the proportion of unexercised options*. And for the sake of comedy, the stockbrokers were shamelessly complaining about a tax that was actually profitable for them on the short run.

Nobody ever noticed this trick, neither among contemporaries nor historians. Nevertheless, this trick strongly reduced the undervaluation of the cheapest options, especially between the implementation of the tax and the WWI, as the tables 16, 17 & 18 show. We distinguished between the pre-tax, pre-war and the interwar periods since the undervaluation of options is stronger on average during the latter. Albeit the latter period is a bit more troubled in all respects, the same pattern is visible across time: the undervaluation of options is reduced while the option price grow; this relation is not monotonous across the range of option prices but in a given category, *i. e.* among bond options under one franc then among stock options above one franc. It is thus worthy to note that the underpricing of options inversely correlates with the probability of making profit: the expensive options were more likely to win and less undervalued. Still, even taking into account additional costs the options were undervalued: another trick was required for the brokers not to lose money on a regular basis.

[23] Buloz 1893 p**. 238 :** « On a dit à la chambre, et le ministère en a fait en quelque sorte la promesse, que le courtage officiel serait prochainement réduit en proportion telle que les agens de change se trouveraient assumer pratiquement toute la charge de l'impôt. »

[24] See e. g. Faure (1900) talking about the financial transaction tax: "an exception is made for options when the option is not exercised"; in French: p. 26 (774) : « Exception est faite pour les opérations à primes, dans le cas où la prime est abandonnée. »

Table 9 – option pricing errors when *actual* strike price is raised by fees + taxes

	1844-1893*	1844-1893 ft	1894-1914*	1894-1914ft	1919-1926*	1919-1926ft	1927-1939*	1927-1939ft
deep out	-40.8%	-40.2%	n. a.	n. a.	-55.5%	-55.2%	-13.3%	+11.2%
out	-26.2%	-23.6%	-21.6%	-20.3%	-10.7%	-3.7%	-9.9%	+4.2%
slightly out	-22.3%	+0.4%	-5.7%	-0.5%	-5.6%	-3.3%	-4.8%	+12.5%
at-the-money	-12.7%	+33%	-1.3%	+21.3%	-1.4%	+31.3%	-0.7%	+11.6%
slightly in	-9.4%	-0.1%	-0.9%	+2.66%	-1.0%	+0.4%	-0.8%	+4.6%
in	n. a.	n. a.	-0.3%	+0.8%	n. a.	n. a.	0.0%	+3.1%
deep in	-29.2%	-28.4%	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.
Total	-17.8%	+0.9%	-4.6%	+0.3%	-4.9%	-2.5%	-4.7%	+10.3%

Columns with a star provide the pricing error for apparent strike price (excluding fees and taxes), colums with ft provide the pricing error for the maximum applicable fees and taxes.

The table reads as follows: between 1894 and 1914, slightly out-of-the-money options appear underpriced by a 5.7% margin; applying fees and taxes raises the actual strike price so that the model price of the option is lower and the final underpricing is only 0.5%.

5.2. The penultimate[25] resort: twisting the settlement price

The ultimate trick of the brokers was as simple as this: options on forwards were not cleared on the basis of an observed market price, such as spot options are today, but on the basis of a price determined by the brokers themselves[26]. This price was called “cours de la réponse des primes”. This price is decided one day before the clearing (*liquidation*) of the forward market itself. Since the settlement price (cours de réponse des primes) is decided one day before the clearing, the brokers may avoid using the spot price as an anchor for the forward price on the day before the end of the term. On the forward market, brokers did not continuously balance supply and demand, they waited for the settlement day to match supply and demand over the whole time since the last settlement. *The price-discovery mechanism in the Paris options market, as it has operated for a century, instead of matching instantly supply and demand, was in fact an ex post balancing mechanism adjusted by brokers every fortnight.*

[25] Only in 1882, had the Banque de France to lend in *last* resort to the stockbrokers.

[26] See e. g. Martin M. J. D. 1789, p. 66 : « les agens de change ont à la bourse un certain cabinet où ils se réunissent tous après la bourse, pour se recorder sur les cours » (brokers do have at the stock exchange a certain closet where they all meet after the closure of the stock exchange, to agree on the prices [that will be printed in the official list]) ; Décret du 7 octobre 1890 portant règlement d'administration publique pour l'exécution de l'article 90 du code de commerce et de la loi du 28 mars 1885 sur les marchés à terme., art. 77. : « les agents de change se réunissent à l’issue de la Bourse pour vérifier et arrêter la cote des cours pour les valeurs, le change et les matières métalliques » (the stockbrokers meet after the closure of the stock exchange to check and decide on the quotation of prices for securities, foreign exchange and metals).

The prohibition on proprietary trading was sufficient to ensure that there was no conflict of interest with customers on the spot market. On the other hand, this prohibition was insufficient to limit conflicts of interest on the forward markets, including options, since the brokers themselves set the settlement prices. We should then expect that the counterparties would have been vocal about price-fixing by the brokers in some controversial cases. Jean Bouvier (1960) gives a particularly remarkable example of political escalation: after the crash of 1882, the settlement price (*cours de réponse des primes*) set by the Parisian brokers decided the collective bankruptcy of the Lyons brokers who traded against them: "Although the bulls lobbied hard for high prices, neither François Allain-Targé, the Finance Minister nor his successor, Léon Say, supported them; and the Paris Bourse chose the February 2 price of 400 francs for its settlement price" (as quoted by White (2007)). From this example we can conclude that even the government could not change the settlement prices decided by the Paris stockbrokers.

It should be noted here that, were the Paris options call on spot prices, it would be impossible to set the settlement price because the market would provide a market price. Since the Paris options were options on forward prices, and since the forward prices were not listed for the same day, the stockbrokers had some margins in setting the settlement prices of both options and forward contracts without market reference. In other words, if the options were on the spot, a manipulation would have been visible whereas on the forward there was no reference price. The stockbrokers could therefore manipulate the settlement price and that is how they were sure to earn money: a 1% price manipulation on exit would have rendered 99% of options worthless. This is not to say that such manipulations were carried out on a regular basis, since the stockbrokers did not require every option to be profitable for them: this would have made the options uninteresting for investors, as was the case in New York, according to Kairys and Valerio (1997). The brokers only needed *some* options buyers to lose or, to be more precise, enough options buyers to lose to pay for the wins of those who won.

An example will show how settlement price-fixing actually provided a last-resort insolvency protection to the stockbrokers. Assume for instance a stock listed at fr. 100, with two calls being supplied, one at 105/1 (i. e. fr. 1 call, strike price = fr. 104) and a more expensive one at 104/5 (i. e. a fr. 5 call with strike price = fr. 99). Assume 1m francs worth of options have been sold: 60% of sales volume is on /1 call, 30% on /5 call and another 10% of customer sell the /1 call. The latter just clear as many call buyers so the net volumes are fr. 500,000 of 105/1 option and fr. 300,000 of 104/5 option. On maturity, if the spot price of stock is 104 (plus fees, plus taxes)

or below, then the brokers pocket the 800,000. If the spot price of the stock is somewhere between 104 and 105 (plus fees, plus taxes), then we have 500,000 of stakes from smaller gamblers to pay at most 300,000 to higher rollers. When the stock ends up at more than 105 (plus fees, plus taxes), things start to be fishy for the brokers. At 106, they can still set the settlement price at 105.55 for instance, in which case they actually pay (105.55-105.3)x500,000 = 125,000 to /1 option buyers (because of tax and fees) and (105.55-104.3)x300,000 = 375.000 to /5; this would still leave the stockbrokers with comfortable fees. This example shows how the options can appear undervalued. To make a long story short: since the brokers were mainly selling calls, they were not exposed to losses from a bearish speculation. A steep rise in prices could bring all the calls in the money, but this could be ultimately mitigated by adjusting the settlement price. In doing so, the brokers did not aim at making money on all options, they actually used the losses on inexpensive options to pay the wins on more expensive ones. Interestingly, this is exactly how a pari-mutuel betting scheme works.

In setting settlement prices, the stockbrokers not only guaranteed their profit, they also decided who won and who lost among the investors, just as in a pari-mutuel betting system. Another contribution of this paper is to allow the understanding of the sustainability of options trading on the Paris stock exchange by showing the mechanisms that decided the distribution of profits and losses between the stakeholders: these are the same mechanisms as those of pari-mutuel operation. This technique was backed by a more general expertise on betting operations.

5.3. le marché de Paris est un marché de paris[27]

In the twenty-first century, betting is a remarkable feature of English-speaking countries, who have both high spending per capita and expertise in operations, while France has nothing special in this area (Rodriguez 2017). However, France made a significant contribution to the development of betting during the times we are concerned with: as soon as the 1860's, Paris was the first city where a pari-mutuel betting scheme on horse racing was operated, as opposed to UK-style fixed odds betting. Pari-mutuel came to the English-speaking world few decades later, with great success (Pradier 2019). Parimutuel betting means that the stakes of the punters are pooled, and the winners' prizes are taken from that pool, without any risk for the betting operator to lose. In comparison, operating a fixed odds betting scheme exposes the bookmaker

[27] In French, *Paris* is the capital of France but the plural of *wager* as well: hence "le marché de Paris" with a capital letter means "the Paris market" while "un marché de paris" in lower case only means "a betting market", hence the title overall means "the Paris market is a betting market".

to the risk of the punters outguessing her probabilistic prediction of future events, and winning against her. Usually, selling options is risky and close to taking fixed odds bets; here the ability to decide the settlement price made the sale of options by the Paris stockbrokers close to the management of a pari-mutuel betting system, since the settlement price divided up between low-price losing options and higher price winning options, in other terms, the buyers of expensive options won what the buyers of cheap options lost. With the ultimate guarantee of an adjustment of the settlement price, options trading operated very much like a parimutuel system.

In order to minimize the probability of a settlement price fix, the stockbrokers resorted to techniques that prefigure betting risk management, as described by Oikonomidis (2013). This author describes different styles of bookmaking as operators can be either *position-takers* or *book-balancers*[28]. The position-takers strategy involves "filtering to avoid skilled bettors", viz. attracting losers and deterring winners. One obvious method is the provision of "comps" to high rollers by casinos in order to attract them: nineteenth century stockbrokers could as well reduce the fees charged to their best customers, *i. e.* those who lost consistently. But they could as well charge maximum legal fees to winning speculators, or force them to pay cash for their options. This looks very much like risk-management of contemporary bookmakers as described in Betmonitalert (2017 p. 133): the techniques usually involve limiting the amounts bet by the most skillful bettors, so that they ultimately prefer betting with some other operators. Additional filtering was provided by the *selection of options* supplied to the public, as we mentioned above in section 4, citing the scarcity of deep out-the-money options. Moreover, when more than one option for a given underlying and maturity are listed, a clear pattern underpricing emerges.

When option pricing error is broken down according to the number of simultaneously listed options with the same underlying and maturity (for a given market day), a very clear and consistent pattern appears: the cheaper the option, the more undervalued it is. We unveil for the first time the actual pricing pattern of the Paris option market: the pricing policy of the stockbrokers is targeting the unsophisticated investors by offering them very cheap options with

[28] "book-balancing bookmakers act in the same manner to market makers in financial markets, effectively matching buyers with sellers by adjusting their odds according to the amounts traded on different game outcomes. As a result, their profit is a function of the generated turnover and their prices reflect a volume-weighted average of the public's opinion, potentially dominated by 'smart-money'. Position-taking bookmakers on the other hand, attempt to maximize their profit margin rather than minimize exposure against a large customer base, deliberately filtered to avoid 'skilled bettors'." (Oikonomidis 2013 p. 87)

a chance of winning which is *apparently* very high. Option undervaluation is thus focused on a definite market segment, as illustrated by contemporary witnesses.

Table 10 – underpricing pattern for multiple options listing

	1 option listed	2 options listed	3 options listed	4 options listed	5 options listed
cheapest option	-3.40%	-8.41%	-16%	-23.30%	-36.70%
2nd cheapest option	n.a.	-1.57%	-4.04%	-7.72%	-18.70%
3rd cheapest option	n.a.	n.a.	-0.54%	-1.38%	-7.48%
4th cheapest option	n.a.	n.a.	n.a.	-0.09%	-2.40%
5th cheapest -option	n.a.	n.a.	n.a.	n. a.	-0.21%
observations count	17239	20063	5379	1103	36

Today, position-taking betting operators manage their risks by avoiding skilled bettors, which are then nudged into placing their bets with the competitors. The Paris stockbrokers of the *Belle Epoque* had the same expectations: they knew the curbstone market and bucket shops offered "better" deal, albeit these were not enforceable by the courts, and they were certainly satisfied to direct the most proficient investors toward these specialized dealers. There is no doubt an aggressive commercial policy of underpricing options, together with a tightened risk management implies accrued competition with the marginal competitors, as some authors have noticed (Hautcoeur Riva 2012). Our analysis of option trading and risk management now gives a rationale to the patterns of both options listing and pricing that was not rationalized so far.

It is very important to understand that option trading was not just a small fancy segment in a large market. On the contrary, options were absolutely necessary for the brokers to balance the overall (*i. e.* including options) forward market, which, according to contemporary authors, amounted to more than 95% of the transactions in Paris. Since markets were cleared every fortnight, the risks for the stockbrokers were considerable: brokers today hedge a significant proportion of their net forward exposition on the spot market. The Paris stockbrokers did not, as the spot market was weak. Instead of hedging forward transactions with spot positions, the Paris stockbrokers used options to eventually balance their forward positions. Levitt (2004) has shown how asymmetry simplified bookmaking, and the analogy with Paris operations is striking:

> *"Bettors exhibit a systematic bias toward favourites and, to a lesser extent, towards visiting teams. Consequently, the bookmakers are able to set odds*

> *such that favourites and home teams win less than 50% of the time, yet attract more than half of the betting action. By choosing these prices, it appears bookmakers increase their gross profit margins by 20–30% over a price-setting policy that attempts to balance the amount of money on either side of the wager"* (Levitt 2004 p. 226)

Replace "favourites and visiting teams" by "bullish strategies" and you have the Paris market. The asymmetry between bullish and bearish strategies is guaranteed since puts could not be bought, hence the (unsophisticated) speculator had the choice between buying a call with a risk limited to the value of the call and selling the same call with an unlimited risk. Of course, a more sophisticated punter could create a synthetic put by selling short forward and buying the call (see above § 2.2.1.), but that required opening an account with the stockbroker, and was thus not the layman's business, plus the brokers then got two degrees of freedom against these strategies as they can eventually fix both the settlement price of the call *and* the clearing price of the forward. Levitt shows that the bookmakers usually profit just by predicting the bias of the gamblers; if they exclude the most skilled bettors they will moreover get a cognitive edge and thus raise their profit. Levitt's theory thus offers a rationalization of the Paris market as a betting market where, as Levitt said, "bookmakers announce a price, after which adjustments are small and infrequent". More precisely, the prices are set on a daily basis and published in the daily listing (*cote officielle*); by contrast, Wall Street operated with the much faster *stock tickers* since the 1870's. The reference to Levitt (2004), contrasting financial markets with betting markets shows that the Paris financial market had all the characteristics of a *betting* market. Overall, the Paris brokers were sophisticated bookmakers, they organized a market in which all the stakeholders found their profit, as the next section shows.

5.4. The distribution of payoffs among the stakeholders and welfare implications

Typically, a capital market involves three or four parties: (1.) intermediaries who bring together (2.) investors with financing capacity and (3.) issuers in need of financing, possibly (4.) speculators to act as counterparties and facilitate the price discovery process. In Paris, the role of a fifth party has been described in the previous section: (5.) gamblers, who by their gambling losses provided the income of the intermediaries, thus lowering the costs of trading for investors, issuers and speculators. These five categories of stakeholders did not meet by chance, since the French authorities have put in place effective incentives on the stakeholders: taxes,

particularly on options, were very low until the 1890's, while the supply of alternative gambling was almost inexistent. The brokers' syndicate has taken advantage of these opportunities to encourage the trading of options.

	Possess	Find in Paris	Strategy	Side effect
1. intermediaries	Monopoly on trading	Trading volumes	Long term: market development; Short-term: profit maximization by position-taking bookmaking with (5.)	Require low fees from (2.), (3.) and (4.)
2. investors	Funds, risk aversion	Large investment universe	Risk-return arbitrage	Attract (3.)
3. issuers (incl. the French state)	Future income	Credit, Trading volumes, 'speculation-proof' market (no put)	Use Paris as a lead issuance place	Provide return to (2.) and underlying to (4.) and (5.)
4. speculators	Funds, skill, moderate risk aversion	Trading volumes, complex instruments	Arbitrage, possibly international	Enhance the price-discovery process
5. gamblers	Low funds, low skill, risk love	Options as gambles	Gamble	Provide income to (1.)

This table sheds light on the organization of a market where the losses of the gamblers finance the cost of the infrastructure, *i.e.* the income of intermediaries. The least sophisticated agents therefore unknowingly finance the other activity of the brokers, i.e. the financing of the

economy. This cross-subsidy offered by the gamblers to the financing of the economy is the key to welfare analysis of the *overall* Paris financial market. This state of affairs can result in two very different equilibria linked to brokers' own strategies: in the high equilibrium, the brokers attribute the entire income they derive from the gamblers to the financing of the economy; in the low equilibrium, brokers focus on betting operations, to the detriment of the financing of the economy. These two equilibria constitute the stylized facts underlying the reality of the Paris financial market over a century.

6. The Splendors and Miseries of a Securities Market

Drawing on the typology of stakeholders on the Paris Bourse, our model allows for endogenizing the shift from a state policy embracing long-term growth objectives and international openness to a short-term domestic orientation.

Obviously, the French state gradually changed its strategy for the financial markets, from using them to issue long-term (even perpetual) debt to taxing them so heavily as to crowd out their activity. Market intermediaries followed the trend and adapted. While during most of the nineteenth century, the stockbrokers adhered to a long-term strategy balancing short term profit (viz. betting operations) and market development with a significant welfare impact, they opted for a short-term strategy in the interwar period. This short-term strategy consisted of introducing much riskier securities, which allowed for options trading but compromised the credibility and sustainability of the market[29]. We propose to formalize the rise and decline of the Paris bourse as a repeated prisoner's dilemma that worked well for many turns, before the commitment of the parties collapsed. The formalization of a cooperation model is then straightforward. Assume the following notations:

Let T be the current volume of option business.

The brokers derive a revenue δT from this option business: in the Long-Term strategy, they spend εT to subsidize the funding of the economy, which would bring a growth of the domestic produce at rate $\tilde{g}$. In the Short-Term strategy, they keep the money and the welfare effect is nil.

[29] For instance, stockbrokers introduced options on Serbian sovereign bonds in 1934, right after the assassination of the king Alexander (average yearly volatility of the bond: 75%) or Russian bonds in 1933-1934 (with an average yearly volatility above 100%), which were defaulted in 1917!

Conversely, the Government car either raise an additional τT worth of taxes (inflation, in this respect, is a kind of tax since it lowers the cost of repaying debt), at the cost of halting growth of T: this is the Short-Term strategy. Alternately, the Long-Term strategy is to let growth at a rate $\tilde{g}$ increase T: this would in turn bring in some tax return at rate t. Of course $\tilde{g}t < \tau$.

Eventually, growth is achieved only if both players commit to their Long-Term strategy. The matrix of payments for any turn n is:

Government Brokers	ST	LT
ST	$(\delta T, (t+\tau)T)$	$(\delta T, tT)$
LT	$((\delta - \varepsilon)T, (t+\tau)T)$	$((\delta - \varepsilon)T, tT)$

On turn n+1, if both players chose the LT strategy on turn n, then all payoffs are multiplied by $(1+\tilde{g})$. When we consider the repeated game with players sticking to the same strategy, the infinite-horizon payoff matrix would look like:

Government Brokers	ST	LT
ST	$(\frac{\delta T}{r_B}, \frac{(t+\tau)}{r_G})$	$(\frac{\delta T}{r_B}, \frac{t}{r_G})$
LT	$(\frac{(\delta-\varepsilon)T}{r_B}, \frac{(t+\tau)}{r_G})$	$\left(\frac{(\delta-\varepsilon)T}{r_B-\tilde{g}}, \frac{tT}{r_G-\tilde{g}}\right)$

Where r_B is the discount rate of the brokers (and conversely, r_G is the discount rate of the government).

As a practical example, consider the case where

$$\delta = 0.05\%, \tau = 0.02\%, r_B = r_G = 5\%, \tilde{g} = 3\%, t = 0.03\%$$

Then, obviously

$$\frac{\delta}{r_B} = 1\% < 1.5\% = \frac{\delta - \varepsilon}{r_B - \tilde{g}}$$

And

$$\frac{\tau + t}{r_G} = 1\% < 1.5\% = \frac{t}{r_G - \tilde{g}}$$

Hence the government is better off with the 0.03% tax than with adding a 0.02% tax since this would break market growth and would eventually yield less. Now, if the Government believes it can extract a higher tax from the market, hence pass a law where $\tau = 0.05\%$, which would imply $\frac{t+\tau}{r_G} = 1.6\% > 1\% = \frac{t}{(1+\tilde{g})(r_G-\tilde{g})}$, it would choose the Short-Term strategy. This, in turn, would imply the brokers to switch to the short-term strategy.

One can imagine a further generalization of this game with the investors as a third player: obviously, significant inflation imply for them a tax several orders of magnitude above direct taxation, hence investors would react to inflation by exiting the market. This is exactly what happened from the beginning of WW1. While FTT had a moderate impact on them and gradually induced the brokers into the short-term strategy, inflation had a more dramatic impact: the investors no longer bought financial assets; the issuers had to go to another place to look for funding, and the market was left with only intermediaries acting as betting operators, gamblers losing money to them and the government levying taxes (including inflation tax). Eventually, the operations on the financial market declined to the point where only "hairdressers and servants"[30] remained. The market was then crowded with cheap (0.5 to 2 francs) options on junk underlying and no serious international issuer used Paris as a place for raising capitl.

While the French Government and brokers had chosen the long-term strategy favoring slow but virtuous growth until the 1880s, the Government ended an era of moderation in the 1890s. The result was a headlong rush for taxes then inflation, that ended up in the market losing its domestic and international appeal. In the meantime, the signature stakeholders of the Paris market disappeared: the "pères de famille" ("good fathers") who used to invest their wealth as well as the most sophisticated market participants who were able to produce a fully-fledged theory of options trading and pricing in the 1900s. On the trading floor remained only gamblers and brokers. The game matrix of § 1. evolved into :

[30] Droz in Boverat et al. 1898 p. 130 : « C'est qu'en réalité il y a toujours des joueurs. Il faut bien reconnaître qu'en abolissant l'exception de jeu, on n'a pu empêcher que sous la forme du marché à terme se déguisât le jeu ou le pari. Quand on voit des garçons coiffeurs acheter 5.000 quintaux de blé ou des domestiques vendre 5.000 pipes d'alcool, il est bien clair que le contrat ne correspond à aucune marchandise à livrer ou à prendre en livraison. Certes, les gens qui engloutissent dans ces opérations le fruit de leurs économies ne sont pas fort intéressants. Mais enfin nos lois civiles et nos lois de police ne sont pas jusqu'ici affranchies de l'idée qu'il faille priver de toute protection les faibles et les imbéciles. »

	Post-WWI Strategy	Side effect
1. intermediaries	Profit maximization by position-taking bookmaking with (5.)	Adverse selection deters sophisticated speculators
2. investors	Exit the market	0
3. issuers (incl. the French state)	The French state has a higher preference for present → inflation + taxation	Adverse selection deters investors
4. speculators	Exit the market	0
5. gamblers	Gamble	The market becomes a pure gambling market

Not only was the magic of the Paris bourse lost for decades: the role of Paris as an international financial place vanished.

*

Conclusion

Today, commentators misunderstand both the nature of the Paris option contract and the market in which it was traded. Under the appearance of a bizarre and archaic curiosity, the Parisian option contract is a wager of an amazing subtlety: the gambler sees it as a bet on the forthcoming *spot price*, where in fact settlement price (*cours de réponse des primes*) was a *forward price* decided by the stockbrokers. Only the professional speculators understood the mysteries of a play in which brokers pull the strings. Under the appearance of a hemiplegic market where put was prohibited, the exceptional institutional conditions favored the development of strategies circumventing the prohibition: complex option strategies, both static and dynamic, have been in place on the Paris stock exchange since the nineteenth century.

We have revealed the mechanism that allowed the Paris stock exchange to trade options for over a century. Success of this trade relied on a microstructure arranged around four pillars,

which were: (1.) underpricing of cheap options to attract the gamblers, (2.) an administered clearing price to achieve a (3.) guaranteed parimutuel-like betting operation and (4.) sophisticated risk management in the position-taking style to minimize actual clearing price manipulation.

In its golden age, the market brought together five categories of parties who could find their interest in it: (1.) the stockbrokers whose business model was significantly based on the sale of options; (2.) investors with funding capacity; (3.) the issuers, notably the French government, as well as large international issuers (e. g. the Ottoman and Russian Empires) found both a supply of capital and among the best characteristics of liquidity and depth at the time; (4.) the professional speculators efficiently traded options, contributing to the price discovery mechanism; eventually smaller gamblers (5.) only satisfied their passion for gambling and this contributed to funding the whole financial sector.

The modern reader will be struck by the similarity between the popular success of the Paris derivatives markets and the current craze for alternative assets and trading platforms. As we have seen, the Paris options had no secondary market, so there were literally *contracts for differences*, like those offered by alternative trading platforms operating not only in traditional financial assets, but also in cryptoassets. Like Parisian stockbrokers, these operators offer low or zero transaction costs but administered exit prices. Like Parisian stockbrokers, these operators do not manage their positions by continuous replication, but by balancing their betting book. This parallel leads to the identification of two significant differences between the historical Paris market and contemporary alternative platforms: on the one hand, as alternative financial operators are in competition, their manipulations are visible (for example, when eToro arbitrarily closed its clients' positions to cut its own losses); on the other hand, the interest of the Parisian market is to have been able to exploit the risk appetite of gamblers for the benefit of other stakeholders, which at the time were thought to represent the "general interest". Eventually, the general interest collapsed, and the reason of the decline of the Paris market needs to be investigated. This will be carried on in future research.

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Comparison of the Amsterdam with the Paris option contracts

	Ricard 1722 p. 57	Bizet 1821 p. 75
Counterparty	« Je soussigné reconnais avoir acheté de Monsieur N. N.	Acheté par M. DUMONT, agent de change, par mon ordre et pour mon compte,
Underlying	(commodity) quatre mille Livres Café du Levant sain & livrable & cela au prix de vingt-neuf sols argent courant, chaque livre, étant ce marché ferme,	(security) cinq mille francs de rentes, 5 p. % consolidés, jouissance du 22 mars 1821,
Expiry	pour recevoir au premier Mai mille sept cent dix	livrables fin d'août fixe,
American-style clause « right to discount »	mais à condition que si je soussigné demande lesdites 4000 l. de Café *avant ledit jour* [n. i.] le Vendeur sera prêt à me les livrer,	ou plutôt à volonté,
Payment on exit	& moi à les payer en me les livrant, en argent courant	contre le paiement de la somme de soixante-six mille cinq cents- francs.

Comparison of the Amsterdam with the Paris option contracts

	Ricard 1722 p. 57	Bizet 1821 p. 75
Counterparty	I, the undersigned, acknowledge having purchased from Mr N. N.	Purchased by Mr. DUMONT, stockbroker, by my order and on my behalf,
Underlying	(commodity) four thousand pounds of coffee from the Levant, sound & deliverable, at the price of twenty-nine s. of current money, each pound, being this contract firm,	(security) five thousand francs in annuities, 5 p. % consolidated, effective 22 March 1821,
Expiry	to receive on the first of May one thousand seven hundred and ten	deliverable at the end of August, fixed date,
American-style clause « right to discount »	but on condition that if I, the undersigned, request the said 4000 l. of Coffee *before the said day* [e. a.] the Seller will be prepared to deliver it to me,	or sooner at will,
Payment on exit	and up to me to pay for them on delivery, in cash	for payment of the sum of sixty-six thousand five hundred francs.

Appendix B – Unfolding more complex operations

Albeit only calls were directly available on the Paris market, the contemporaries were aware of replication techniques which allowed to create synthetic puts, straddles and develop complex dynamic hedging strategies. Bachelier 1900 devotes 6 pages (pp. 65-70) to what he calls "complex operations":

- Buying forward + selling a call option, which amounts to selling a (synthetic) put,
- Selling forward + buying a call option = buying a (synthetic) put,
- Buying forward + selling twice as much call options = selling a (synthetic) straddle,
- Selling forward + buying twice as much call options = buying a (synthetic) straddle,

Eventually various kinds of option spreads:

- Buying an expensive call option + selling an inexpensive call option
- Selling an expensive call option + buying an inexpensive call option
- Buying an expensive call option + selling twice as much inexpensive call options
- Selling an expensive call option + buying twice as much inexpensive call options

In the following sections we recall three such strategies: synthetic put (1.), synthetic straddle (2.) and more generally dynamic hedging (3.).

1. synthetic put (prime à recevoir)

As early as 1771, Pinto mentioned that "...while having a long call, all one need to do is short sell […] to convert by this process the call into a put[31]". Along the 19th century, many French authors from Bresson (1820) p. 80 to Bigot (1881) pp. 86-87 presented this "complex strategy" to benefit from an expected fall in security price while limiting the loss to a fixed amount, which we would call the put price. Jovanovic (2006) already mentioned that Lefevre (1873) p. 234 was apparently the first to feature a "profit chart" (see figure). In 1900, Bachelier gave a comprehensive account of how to build synthetic puts using short sale on the forward market featuring "profit charts" (Bachelier 1900 p. 66-67) or conversely, selling synthetic puts by buying forward and selling the call option. It must emphasized that, since options were options on forwards, they could be sold short, hence the Paris market enabled short trading of options: this enabled the building blocks of complex trading strategies that contributed to the attractivity of the Paris options market.

[31] Pinto (1771) p. 300 : « on n'a qu'à vendre en marché ferme à la faveur de cette prime pour le même rescontre 1000 Liv. à 150 pour %, & l'on convertit par ce procédé la prime, qui étoit à délivrer, en prime à recevoir »

Figure 1 — profit chart for a synthetic put from Lefevre (1873)

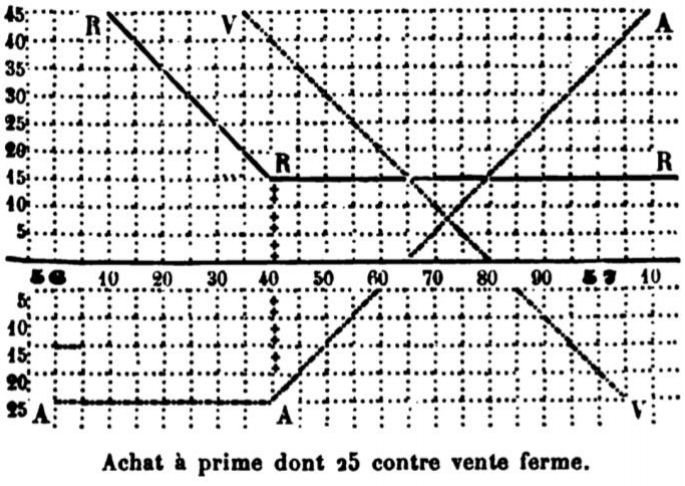
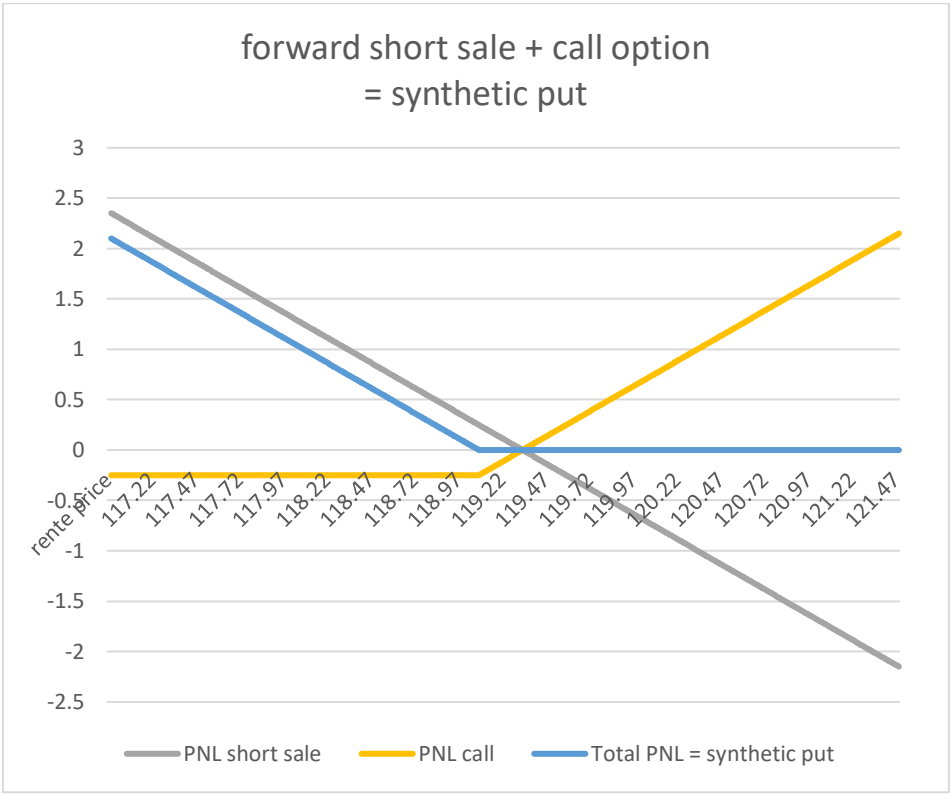


Figure 2 — a synthetic put from Bigot 1881 pp. 86-87

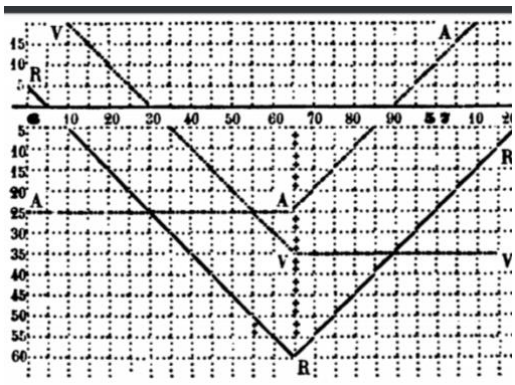


« Vous vendez à 10,000 ferme à 119,35 et vous achetez en même temps 10,000 à prime /25c à 119,70 par exemple »

2. straddles

Since put were not directly available, straddle were replicated by buying two calls and shorting forward (Bachelier 1900 pp. 67-68) or conversely selling the straddle by buying forward and selling two calls. Lefevre (1873) already featured profits charts for buying/selling of straddles (fig. 3) and most authors comment on the circumstances in which to buy/sell those straddles.

Figure 3 — a straddle from Lefevre (1873) p. 242



For instance, Bigot (1881 pp. 88-89) recommended to buy a straddle: "whenever one assumes or foresees a strong change in prices, either rising or falling; weak changes or *statu quo* would be fatal to this operation". But as soon as 1820, Bresson wrote:

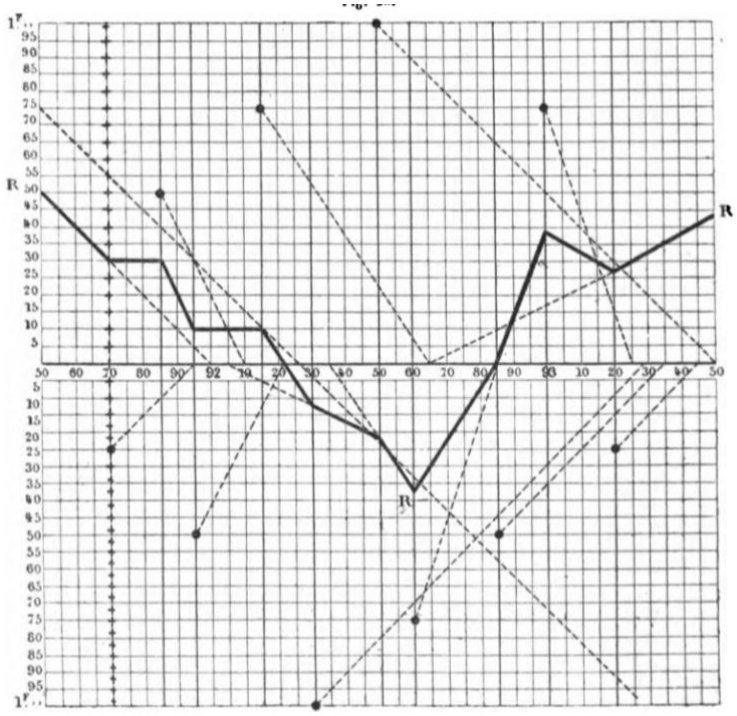
> *"When you foresee that as yet undecided events are expected to produce large movements on the annuity, either up or down, buy a call on government annuities, and sell forward one half of the same amount." (Bresson 1820 p. 83)*

Both authors featured numerical examples, and Bigot takes into account the transaction fees, so that the benefit of the operation can be correctly reckoned.

Many French authors of the nineteenth century thus presented "complex operations" combining buying and selling call options as means to implement trading strategies. Lefevbre (1873) offered the most complex "option ladders" (*échelles de primes*), with a combination of buying six calls and selling four plus a short sale, which leads to a partition of the outcomes in 11

different states of nature (figure 4)[32]. Such diagrams can be interpreted in a static or more dynamic way, as a precursor of dynamic hedging.

Figure 4 — complex "option ladders" from Lefevre (1873) p. 248



[32] Lefebvre commented the graph as follows :
Supposons qu'on ait fait sur l'emprunt français 5 pour 100 les opérations ou marchés suivants :

Acheté	5000 à 91,95 /25.	Vendu	10000 à 92,10 /25.
	10000 à 92,20 /25.		5 000 à 92,25 ferme.
	10000 à 92,85 /25.		7500 à 92,65 /50.
	5000 à 93,30 /1.		15000 à 93,25 /25.
	5000 à 93,35 /50.		5000 à 93,50 / 1.
	5000 à 93,45 /25.		

Si la réponse des primes tombe :

Au-dessous de 91,70,	on reste vendeur de 5000 au cours de 92.
De 91,70 à 91,85,	on reste liquidé avec un bénéfice de 0,30.
De 91,85 à 91,95,	on reste vendeur de 10000 au cours de 92.
De 91,95 à 92,15,	on reste liquidé avec un bénéfice de 0,10.
De 92,15 à 92,30,	on reste vendeur de 7500 au cours de 92,22 ½.
De 92,30 à 92,50,	on reste vendeur de 2500 au cours de 92,05.
De 9h50 à 92,60,	on reste vendeur de 7500 au cours 92,35.
De 92,60 à 92,80,	on reste acheteur de 7500 au cours 92,80.
De 92,80 à 93,00,	on reste acheteur de 12 500 au cours 92,80.
De 93,00 à 93,20,	on reste vendeur de 2 500 au cours 93,75.
Au-dessus de 93,20,	on reste acheteur de 2 500 à 92,65.

3. dynamic strategies

As soon as 1821, Bresson describes "how to convert a bullish strategy into a bearish strategy":

> *"Let us suppose that I bought 5000 fr. of rente at 84 fr. (...) and that the rente has fallen to 83 fr. 05 c., if I sell (...) I will have a deficit (...). But if I think the rente is likely to suffer a further sharp fall, instead of selling 5,000 fr. of rente, I will sell 10,000 fr. so that, on the one hand, being a buyer of 5,000 fr. of rente, and on the other hand a seller of 10,000 fr., I will remain a short seller (p. 159) of 5,000 fr., and I will be able to take advantage of the whole fall to regain, and beyond, the loss I might have suffered.*
>
> *How one can convert a bearish strategy into bullish one.*
>
> *For example, if I sold [short] 5,000 fr. of rente at 83 fr., and the rente has risen to 83 fr. 6o c., I buy back twice the amount, i.e. 10,000 fr. of rente at this price. Since I am on the one hand selling 5,000 fr. of annuity, and on the other hand buying 10,000 fr. of annuity, it follows that I remain the buyer of 5,000 fr. of rente at 83 fr. 6o c.; so that the increase, however high it may be, will cover me either in part or in full of the loss I might have initially experienced in my downward transaction, and, moreover, will produce an unspecified profit for me."* (Bizet 1821 pp. 158-160) [33]

This narrative involves outright forward transactions rather than options. But Bizet also describes a synthetic put which can be expressed in the same dynamic terms. In fact, most

[33] « Supposons que j'aie acheté 5000 fr. de rente à 84 fr. (…) et que la rente soit descendue à 83fr. 05 c., si je revends (…) j'aurai un déficit (…). Mais si la rente me paraît devoir encore subir une baisse assez forte, au lieu de vendre 5000 fr. de rente, j'en vendrai 10,000 fr.; en sorte que, d'un côté, étant acheteur de 5000 fr. de rente, et de l'autre vendeur de 10,000 fr., je resterai vendeur (p. 159) de 5000 fr. à découvert, et je pourrai profiter de toute la baisse pour regagner, et au-delà, la perte que j'aurai pu faire.

Comment l'on peut convertir une opération, à la baisse en une opération à la hausse.
Par exemple, si j'ai vendu 5 000 fr. de rente à 83 fr., et que la rente soit montée à 83 fr. 6o c., je rachète le double, c'est-à-dire 10000 fr. de rente à ce prix. Or, étant d'une part vendeur de 5000 fr. de rente, et de l'autre, acheteur de 10000 fr. de rente, Il en résulte que je reste acheteur de 5 000 fr. de rente à 83 fr. 6o c.; en sorte que la hausse, tant élevée qu'elle arrive, me couvrira, soit en (p. 160) partie, soit en totalité, de la perte que j'aurais pu éprouver primitivement dans mon opération à la baisse, et, en outre, me produira un bénéfice indéterminé »

nineteenth century authors describe dynamic strategies, for instance Bozerian mentions explicitly "complex operations" (as described later by Lefebvre, Bachelier and other later authors):

> *"Since it is very difficult, at the beginning of a month, to predict with certainty whether rise or fall will prevail in the interval from one settlement to the next, some speculators, instead of operating in one direction or the other (p. 140), begin with a* ***complex transaction*** *(emphasis added), i.e. they operate in both directions, even if they take advantage of the movement which has just occurred, to direct the course of their operations in this direction"* [34] *(Bozerian 1859 t. 1 pp. 139-140)*

Such dynamic narratives can be interpreted in two very different ways. Most contemporary readers were interested by stock market stories as we now watch sport events: the stock market itself was on the edge of the entertainment district of Paris, the so-called "boulevards", not far away from the theaters and cafés. The show offered by the Paris bourse was free, and vintage engravings from the 1840s to the 1900s show the building crowded with onlookers that bought low priced options just as there is now live betting on sport events. On weekends, such public would read the descriptions of stock market raids and speculation in similarly low priced newspapers: Bozerian provides a sample from l'*Estafette* in a style reminiscent of the forthcoming radio sportscasting[35]. Such were dynamic narratives for the lay people. On a higher level, speculators trained in mathematics were obviously interested in unfolding dynamical trading strategies: unfortunately, we only found sketchy allusions rather than a general presentation of the concept and practice. In Paris as everywhere, no one would expose a truly winning strategy…

[34] Comme il est fort difficile, au début d'un mois, de prévoir sûrement laquelle, de la hausse ou de la baisse, l'emportera dans l'intervalle d'une liquidation à l'autre, certains spéculateurs, au lieu d'opérer dans un (p. 140) sens ou dans un autre, commencent par une *opération complexe* [n. i.] , c'est-à-dire qu'ils opèrent dans les deux sens, quitte à profiter du mouvement qui vient à se déclarer, pour diriger de ce côté la marche de leurs opérations.
[35] See e. g. p. 145: "All securities are attacked in turn. The *rente* itself, which up to now had energetically resisted and, in the midst of the general weakness, had kept a relatively very firm capacity, the *rente* itself gives way to the drag of the other securities and slips away. (…) The fortnightly settlement starts under a bad sign, and it is feared that, as a result of the deliveries of securities and despite the moderation of the contango rate, the securities will be shaken again."

Appendix C - Cours authentique

COMPAGNIE DES AGENTS DE CHANGE

COURS AUTHENTIQUE

SEUL OFFICIEL

PARAISSANT TOUS LES JOURS DE BOURSE

BOURSE DE PARIS

Jeudi 15 Décembre 1881

PRIX D'ABONNEMENT : Paris : un an, 32 fr. ; six mois 16 fr. ; trois mois, 8 fr. — Départements : un an, 42 fr. ; six mois, 21 fr. ; trois mois, 11 fr. — Étranger : frais de poste en sus.

REPORTS Comptant liq.	REPORTS Liq. pr	REPORTS Liq. à l'autre	Taux d'émiss.	DÉSIGNATION DES VALEURS	Jouissance	AU COMPTANT	A TERME 1er cours	A TERME Plus haut	A TERME Pl. bas	A TERME Dernier cours	Derniers cours cotés précédemment Compt.	Derniers cours cotés précédemment Terme	Intérêts et dividendes
				FONDS D'ÉTAT FRANÇAIS									
.25	...	...	Divers	**3 %**	1er octob. 81.	85f60 65 60 50	en liq...	... ...	... ...	... ...			
...	...	...	...				fin cour.	85 80	85 85	85 75	85 85½	85 55	85 85	3f
							Pr. fin c.	... ...	... ... d 3f	... ...	... ...			
							Pr. fin c.	... ...	... ... d 1f	86 ..	... ... d 50			
							Pr. fin c.	86 05	... ... d 25	... ...	... ...			
							Pr. fin p.	... ...	... ... d 1f	... ...	... ... d 50			
							Pr. fin p.	... ...	... ... d 3f	... ...	... ...			
							Pr. fin p.	... ...	... ... d 25	... ...	... ... d 3f			
...	...	...	...	**3 %** amortissable, annuités finissant en 1958	16 octob. 81	86f20	en liq...	... ...	... ...	... ...	... ...			
							fin cour.	86 35	86 35	86 20	86 25	85 75	86 25	3f
							Pr. fin c.	... ...	... ... d 1f	... ...	... ... d 50			
							Pr. fin c.	... ...	... ... d 25	... ...	... ...			
							Pr. fin p.	... ...	... ... d 1f	... ...	... ... d 50			
							Pr. fin p.	... ...	... ... d 25	... ...	... ...			
...	...	...	83 25	**3 %** amortiss. 1881, annuités finissant en 1953, 66 fr. 60 payés	16 octob. 81	85f35 70	en liq...	... ..	... ...	86 ..	... ...			
							fin cour.	86 ..	86 05	... ...	86 02½	85 65	86 07½	3 %
							Pr. fin c.	... ...	... ... d 1f	... ...	... ... d 50			
							Pr. fin c.	... ...	... ... d 25	... ...	... ...			
							Pr. fin p.	... ...	... ... d 1f	... ...	... ... d 50			
							Pr. fin p.	... ...	... ... d 25	... ...	... ...			
...	...	...	...	**4 %**	22 sept. 81.	... ...	en liq...	... ...	... ...	... ...	... ...			
							fin cour.	... ...	... ...	... ...	... ...	103 50	87 ..	4f
...	...	...	...	**4 ½ %**	22 sept. 81.	113f25 113f	en liq...	... ...	... ...	... ...	... ...			
							fin cour.	... ...	... ...	... ...	... ...	113 ..	111 ..	4f50
...	...	...	Divers	**5 %**	16 nov. 81..	115f25 115f 115f25 30 35	en liq...	... ...	... ...	... ...	... ...			
							fin cour.	115 80	115 80	115 65	115 75	115 35	115 80	5f
							Pr. fin c.	... ...	... ... d 3f	... ...	... ...			
							Pr. fin c.	... ...	... ... d 1f	... ...	... ... d 50			
							Pr. fin c.	116 15	... ... d 25	... ...	... ...			
							Pr. fin p.	... ...	... ... d 1f	117 10	... ...			
							Pr. fin p.	... ...	... ... d 3f	... ...	... ... d 50			
							Pr. fin p.	... ...	... ... d 25	... ...	... ... d 2f			
...	...	...	...	Répartition Marmesins, promesse de rentes	....	... ...						0 20	... ..	
...	...	...	...	d° bulletins négociables	....	... ...						13 ..	... ..	
...	...	...	...	Bons du Trésor	....	... ...						3½ à 1 an	... ..	
...	...	...		d° 4 %, éch. 1er mars 1883 (coup. de 500 f.)	septemb. 81.	... ... Coup. de 5000f.						505 ..	... ..	4 ½
...	...	...		d° d° d° (coup. de 1000 f.)	....	... ...						1010 ..	... ..	
...	...	...		d° d° éch. 1er sept. 1884 (coup. de 500 f.)	septemb. 81.	5050 .. ... Coup. de 10000f.						505 ..	... ..	4 %
				d° d° d° (coup. de 1000 f.)	....	... ... Coup. de 5000 f.						1010 ..	... ..	
				d° d° éch. 1er mars 1885 (coup. de 500 f.)	septemb. 81.	... ... Coup. de 10000 f.						500 ..	... ..	4 %
				d° d° d° (coup. de 1000 f.)	....	... ... Coup. de 10000 f.						1021 ..	... ..	
				d° d° éch. 1er sept. 1885 (coup. de 1000 f.)	septemb. 81.	... ...						1020 ..	... ..	
...	...	...	440	Obligations du Trésor, int. 20 f., r. à 500 f. (annuités finiss. en 1889), t. p.	20 juillet 1.	518	en liq...	... ...	... ...	... ...	... ...			
							fin cour.	... ...	... ...	... ...	... ...	518 ..	435 ..	20f
			470	d° (annuités finiss. en 1907), t. p.	16 juin 81..	517	fin cour.	... ...	... ...	... ...	... ...	520 ..	477 50	20f
...	...	...	500	Bons de liquid. 5 % (ém. 1874-1875), r. 500 f.	15 juillet 81.	528 530	fin cour.	... ...	... ...	... ...	... ...	530 ..	480 ..	25f
				EMPRUNTS (Seine et Villes)										
			205	Dép. de la Seine, obl. 1857 4 %, r. 225 f., t. p.	juillet 1881.	227						229 ..	... ..	9f
...	...	...	...	Obl. 1855-1869, 3 %, remb. à 500 f., t. p	septemb. 81.	505 503	fin cour.	... ...	... ...	... ...	... ...	503 ..	330 ..	12f
...	...	...	450	d° 1865, 4 %, remb. à 500 f., t. p.	août 1881...	515	fin cour.	... ...	... ...	... ...	... ...	518 ..	417 50	20f
...	...	...	345	d° 1869, 3 %, remb. à 400 f., t. p.	31 juil. 81..	401 403	fin cour.	... ...	... ...	... ...	... ...	402 50	400 ..	12f
				Ville de Paris.			en liq...	... ...	... ...	... ...	... ...			
			377	d° 1871, 3 %, remb. à 400 f., t. p.	juillet 1881..	398	fin cour.	... ...	... ...	... ...	... ...	398 ..	398 75	12f
...	...	...	69 75	d° d° quarts 3 %, remb. à 100 f.	juillet 1881.	112 111 50 ... ... Hier 112						111 25	... ..	
			..	d° d° séries sorties (unités)	....	... ...						200 ..	... ..	
			..	d° séries sorties (série entière).	....	... ...						10000 ..	... ..	
...	...	...	..	d° 1875, 4 %, remb. à 500 f., t. p.	15octobre 81	509 510	en liq...	... ...	... ...	... ...	... ...			
							fin cour.	... ...	... ...	... ...	... ...	508 50	526 25	20f
			465	d° 1876, 4 %, remb. à 500 f., t. p.	15octobre 81	510 509 508	en liq...	... ...	... ...	... ...	... ...			
...	...	...	500	Bons de liquid. 5 % r.500f., t. p. (*garantis et payables par l'État, exempts d'impôt*)	29 oct. 81...	525 523	fin cour.	... ...	... ...	... ...	... ...	506 ..	477 50	20f
							Pr. fin c.	... ...	... ...	... ...	... ...	523 ..	496 25	25f
...	...	...					fin cour.	... ...	... ...	... ...	... ...			
...	...	...	252 50	Ville de Marseille 1877, 3 %, remb. à 400 f., tout payé	31 juil. 81..	366	en liq...	... ...	... ...	... ...	... ...			
							fin cour.	... ...	... ...	... ...	... ...	366 ..	383 75	12f
							Pr. fin c.	... ...	... ... d 5f	... ...	... ... d 10			
				VALEURS FRANÇAISES										
...	...	...	500	La Foncière (Cie d'assurances mobilières et immobilières), act. 500 f. 125 f. p. (nominatives)	23 mai 1877.	580	en liq...	... ...	... ...	... ...	... ...			
							au 15...	580 ..	... ...	... ...	... ...	580 ..	580 ..	.....
							Pr. au 31	... ...	... ... d 20	... ...	... ... d 10			
							Pr. au 15	... ...	... ... d 5f	... ...	... ... d 10			
...	...	...	500	La Grande Compagnie d'assurances, act. 500 fr., 125 fr. p. (nominatives)	25 février 81.	710 714 25 712 50 713 75 715	en liq...	... ...	... ...	... ...	... ...			
							au 15...	715 ..	... ...	... ...	720 ..	715 ..	720 ..	
							Pr. au 31	... ...	... ... d 5f	... ...	... ... d 10			
							Pr. au 15	... ...	... ... d 5f	... ...	... ... d 10			
...	...	...	500	La Métropole (Cie d'assurances mobilières et immobilières), act. 500 f., 125 f. p. (nominatives)	....	425	en liq...	... ...	... ...	... ...	... ...			
							au 15...	... ...	... ...	... ...	... ...	625 ..	625 ..	.....
							Pr. au 31	... ...	... ... d 20	... ...	... ... d 10			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	Divers	Banque de France (nominatives)	juillet 1881	5990 5950	fin cour.	5990 ..	... ...	5950 ..	5950 ..	5925 ..	5960 ..	ex. 1886, 154f63 h-c. 1881, 118f50
							Pr. fin c.	6100 ..	... ... d100	6150 ..	6250 .. d 50			
							Pr. fin p.	... ...	... ... d100	... ...	... ... d 50			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	Divers	Banque d'Escompte de Paris, a. 500 f. 125 f. p. (nominatives)	juillet 1881.	880 877 50	au 15...	877 50	880 ..	875 ..	880 ..	880 ..	880 ..	ex. 80. 31f25
							Pr. au 31	... ...	... ... d 40	895 ..	... ... d 10			
							Pr. au 15	... ...	... ... d 20	... ...	... ... d 10			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	500	Banque hypothéc^re de France, a. 500f. 125 f. p. (nominatives)	1er juill. 81	670	au 15...	670 ..	... ...	... ...	... ...	670 ..	670 ..	ex. 79-80. 6f25
							Pr. au 31	... ...	... ... d 5f	... ...	... ... d 10			
							Pr. au 15	... ...	... ... d 20	... ...	... ... d 10			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	500	Banque de Paris et des Pays-Bas, a. 500 f. tout payé (ex-coup. 18)	juillet 1881.	1332 50 1335 1340 1332 50 1331 25 1330 ...	au 15...	1340 ..	... ...	... ...	1337 50	1335 ..	1335 ..	ex. 80. 60f..
						.... Hier au 31. 1380 d. 10	Pr. au 31	1380 ..	... ... d 20	... ...	... ... d 10			
							Pr. au 15	... ...	... ... d 20	... ...	... ... d 10			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	500	Banque Transatlantique, act. 500 f., 125 f. p. (nominatives)	25 août 1881.	560 565	au 15...	560 ..	... ...	... ...	550 ..	570 ..	560 ..	.....
							Pr. au 31	... ...	... ... d 5f	... ...	... ... d 10			
							Pr. au 15	... ...	... ... d 5f	... ...	... ... d 10			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	Divers	Cie Algérienne, act. 500 fr., t. p. (ex-c. 6).	juin 1881..	630	au 15...	... ...	... ...	... ...	... ...	630 ..	640 ..	ex. 80. 35f ..
							Pr. au 31	... ...	... ... d 5f	... ...	... ... d 10			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	500	Cie Foncière de France et d'Algérie, a. 500 f., 125 fr. p. (nominatives)	20 août 1881	550 540	au 15...	545 ..	550 ..	542 50	545 ..	558 75	545 ..	
							Pr. au 31	... ...	... ... d 5f	... ...	... ... d 10			
							Pr. au 15	... ...	... ... d 5f	... ...	... ... d 10			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	Divers	Comptoir d'Escompte, act. 500 f. t. p.	août 1881...	1045	au 15...	... ...	... ...	... ...	... ...	1050 ..	1050 ..	ex. 80. 46f..
							Pr. au 31	... ...	... ... d 10	... ...	... ... d 10			h-c. 81, 20f.
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	500	Crédit Algérien, act. de 500 fr. 250 f. p.	26 janvier 81	... ...	au 15...	... ...	... ...	... ...	... ...	535 ..	535 ..	.....
							Pr. au 31	... ...	... ... d 5f	... ...	... ... d 10			
							Pr au 15	... ...	... ...	... ...	... ... d 10			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...	Divers.	Crédit de France (anc. Soc. Gén. Française de Crédit), act. 500 fr., 250 fr. payés	21 nov. 1881	900	au 15...	900 ..	... ...	... ...	897 50	905 ..	900 ..	ex. 80. 50f. h-c. 1881, 15f...
							Pr. au 31	... ...	... ... d 50	... ...	... ... d 10			
							Pr. au 15	... ...	... ... d 20	... ...	... ... d 10			
							en liq...	... ...	... ...	... ...	... ...			
...	...	...		Crédit Foncier et Agricole d'Algérie, act. 500 fr., 125 fr. p. (nouvelles)	9 déc. 1880	650 655	au 15...	650 ..	... ...	... ...	... ...	650 ..	650 ..	.....
							Pr. au 31	... ...	... ... d 5f	... ...	... ... d 10			
							Pr au 15	... ...	... ... d 10	... ...	... ... d 10			
...	...	...	500	Crédit Foncier Colonial, act. 500 f. 300 f. p. (nominatives)	juillet 1881.	... ...	au 15...	... ...	... ...	... ...	... ...	390 ..	380 ..	ex. 80. 10f.

Appendix D – increasing profitability of options

There are too few options amenable to profitability computation before 1894. The breakdown of the sub-periods proposed below corresponds to the change in tax rates: implementation of a financial transaction tax in 1894, in 1898 brokers are supposed to issue a bill for every transaction, in 1907 the tax rate is doubled. The probability of profiting from the call is the minimum probability when only one call is bought (since fees are due every 1,000 francs of options, the actual probability of winning raises slightly with every additional option up to a thousand francs worth of options).

Table 11 — probability of profit for call on stocks 1894-1898

Option value	maturity	Actual probability (DFIH)	Number of observations
10 francs	30 days	0.27	82
10 francs	20 days	0.29	231
5 francs	30 days	0.22	69
5 francs	20 days	0.27	181

Table 12 — probability for call on bonds (B) stocks (S) 1907-1914

Option value	maturity	Actual probability 1907-1914	Number of observations	Actual probability 1894-1898	Number of observations
40 francs (s)	30 days	0.29	63	0.57	7
40 francs (s)	20 days	0.31	120	0.50	4
20 francs (s)	30 days	0.23	116	0.38	34
20 francs (s)	20 days	0.25	254	0.36	89
10 francs (s)	30 days	0.21	163	0.27	82
10 francs (s)	20 days	0.25	428	0.29	231
5 francs (s)	30 days	0.29	194	0.22	69
5 francs (s)	20 days	0.29	567	0.27	181
50 centimes (b)	30 days	0.35	55	0.46	85
50 centimes (b)	20 days	0.41	180	0.46	179
25 centimes (b)	30 days	0.35	26	0.32	50
25 centimes (b)	20 days	0.36	170	0.36	170

Table 13 — probability of profit on call options 1922-1938

Option value	maturity	Actual probability 1922-1926	Actual probability 1927-1931	Actual probability 1934-1938
50 centimes	30 days	n. a.	n. a.	0.16
50 centimes	20 days	n. a.	n. a.	0.14
1 franc	30 days	n. a.	n. a.	0.18
1 franc	20 days	n. a.	n. a.	0.21
10 francs	30 days	0.12	0.64	0.31
10 francs	20 days	0.09	0.51	0.26
20 francs	30 days	0.10	0.57	0.27
20 francs	20 days	0.10	0.46	0.28
40 francs	30 days	0.13	0.65	0.28
40 francs	20 days	0.15	0.49	0.27
100 francs	30 days	0.15	0.72	0.14
100 francs	20 days	0.15	0.51	0.14
200 francs	30 days	0.24	0.65	0.12
200 francs	20 days	0.28	0.54	0.12
500 francs	30 days	n. a.	0.65	n. a.
500 francs	20 days	n. a.	0.48	0.11

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