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ABSTRACT

This paper aims to test the role of gold quoted in Paris in the diversification of French portfolios from 1949 to 2012 using the stochastic dominance (SD) approach. The advantage of this method is that the returns do not have to be normally distributed. The results show that *stock* portfolios *with gold* stochastically dominate those *without gold*. Including gold will thus maximize the utility of French investors in stocks (mostly during unstable and crisis periods). However, including gold in *bond* or *risk-free* portfolios is not advantageous as portfolios *without gold* dominate those *with gold*. Therefore, our results indicate that investors can use gold to improve their utility with stock portfolios in France.

JEL Classification: G11
Key words: Gold, French portfolios, portfolio diversification, stochastic dominance

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1. INTRODUCTION

Gold markets have been very volatile in the last few years, especially since 2007 when the financial crisis began. Gold prices have been greatly affected by financial, economic, political, and social conjunctures and, on September 6, 2011, the price reached 1,895 USD, the highest price in the history of gold. This price rise has prompted the following question: Why does the price of gold increase during crises and unstable periods? Intuitively, we think that it's because gold was a *currency* for a very long time[1], and this "precious metal" therefore continues to be considered to be a *real, tangible, and secure value*. In periods of instability, investors thus prefer secure assets like gold. Moreover, gold is very liquid and universal: It can easily be sold anywhere in the world.

In this paper, we are interested in another reason for this price rise, which is *the favorable role of gold in the diversification of portfolios* in crisis times. Indeed, if including gold increases the value of portfolios, investors will surely invest more in gold. Thus, gold prices increase as demand rises.

In our study, this hypothesis will be tested on the French stock exchange. We chose the French market for at least two reasons. First, there are very few studies about the Paris gold market, and, second, the Paris Stock Exchange is important both in Europe and in the world. Thus, the results of this research can provide interesting information for investors and fund managers.

According to the literature, gold is a good factor for diversifying portfolios because it is not *positively correlated* with other assets. Thus, when the prices of other assets decrease, gold prices may still increase, and this can maintain the portfolio's value even in crisis times. Following the portfolio theory of Markowitz (1952), a low or negative correlation between the assets composing a portfolio can reduce risk. This point has already been studied by several authors such as Sherman (1982), Jaffe (1989), and Baur and Lucey (2010)[2]. However, most of these authors were only interested in gold quoted in the London Bullion Market[3], the biggest gold market in the world. To our knowledge, there has been no study on gold quoted in Paris and the diversification of French portfolios.

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[1] See Hoang (2010b) for more information about gold standards.
[2] A literature review is presented in section 2.
[3] Website: http://www.lbma.org.uk

In the studies mentioned above, mean-variance (MV) methods, following the Markowitz theory, are commonly used. However, if the distribution of returns is not normal, the results can be misleading. To circumvent this limit, we use *the non-parametric stochastic dominance (SD) method*, which does not set any conditions on the distribution of returns and uses the whole distribution (not only the first two moments). Another advantage of SD is that it sets only minimum conditions on the investor's risk preference or utility function. To our knowledge, this is the first paper to employ SD techniques to analyze gold investment.

The SD approach consists of maximizing the utility function of investors. In order to determine whether gold should be included in a portfolio, we compare the cumulative distribution functions (CDF) of returns of portfolios with gold and those without gold. If the CDF of portfolios with gold *stochastically dominate* those without it, gold is preferred for utility maximization and hence wealth maximization (Wong *et al.*, 2008).

The results of our study show that stock portfolios with gold dominate stock portfolios without gold. This implies that French investors can increase their utility by including gold in their *stock* portfolios. However, for bonds and risk-free portfolios, including gold is not preferable except if the proportion of gold is very small (from 1% to 2%).

To demonstrate these results, our article is organized as follows. Section 2 presents a literature review on the role of gold in portfolio diversification. Section 3 explains the methodology. Section 4 presents the database and its descriptive statistics. The final section analyses the results obtained and answers the question: Is gold quoted in Paris good for the diversification of French portfolios?

2. DIVERSIFY PORTFOLIOS WITH GOLD: A LITERATURE REVIEW

In this literature review, we present articles on the role of gold in portfolio diversification published between 1977 and the present. Gold is usually assumed to be a good asset for diversifying financial portfolios thanks to its weak correlation with other assets. This is due principally to the difference between the determinants of gold prices and those of other financial assets[4].

[4] Many studies analyze the determinant factors of gold prices; for example, Lipschitz and Otani (1977), Jastram and Leyland (2009), Sherman (1983), Koutsoyiannis (1983), Sjaastad and Scacciavillani (1996), Cai *et al*. (2001), Levin and Wright (2006), and Cheng *et al*. (2009). The principal determinants of gold prices can be presented in three groups: political factors, monetary factors (like inflation or the USD), and the price of other financial assets and precious metals. For a literature review of these articles, see Hoang (2010b).

The first study that we found on this subject was conducted by McDonald and Solnik (1977).[5] The authors were interested in the relationship between gold prices in London and the S&P 500 index using monthly data from 1948 to 1975. They also studied the relationship between gold prices and gold mining stocks using a linear two-factor model. Their results showed no relationship between gold prices and stocks, but there was a positive relationship between gold and gold mining stocks. They thus concluded that both gold and gold mining stocks would be profitable for portfolio diversification. In addition to McDonald and Solnik (1977), other authors were also interested in both physical gold and paper gold (gold mining stocks or gold mutual funds). Jaffe (1989) studied the period from 1971 to 1987 with monthly data on gold prices in London, gold mining stocks and gold mutual funds[6]. This author calculated correlation coefficients and linear regressions and also measured the return and the risk of portfolios with and without gold. He concluded that both physical gold and paper gold were good for portfolio diversification but that physical gold was more efficient. Chua *et al.* (1990) used the same approach as Jaffe (1989), calculating correlation and beta coefficients between physical gold prices and gold mining stocks in London. These authors drew the same conclusions as Jaffe (1990). Blose (1996) and Faff and Chan (1998) also examined this problematic.

Other articles have dealt more directly with the role of gold in the diversification of portfolios. Sherman (1982) studied the effect of gold in portfolios composed of stocks and bonds using London monthly data from 1976 to 1981. He used a classical mean-variance approach with the Capital Asset Pricing Model (CAPM) and correlation coefficients. The author showed that gold had a weak beta, a positive alpha, and a weak correlation with other assets. Thus, it was profitable to add gold in portfolios. Smith (2002) studied the relationship between gold prices in London and 17 European stock indexes from 1991 to 2001. The author found that the correlation between gold and stock indexes was very weak or even negative. Moreover, there was no cointegration between them. He thus concluded that gold was a good factor for portfolio diversification. Lucey *et al.* (2006) also studied gold prices in London from 1980 to 2003 with the Nasdaq and FTSE indexes. Instead of using the classical mean-variance framework of the above-cited articles, these authors chose the mean-variance-skewness approach. Their results showed that gold was profitable for portfolio diversification. Michaud *et al.* (2006), Ratner and Klein (2008), and Wozniak (2008) used

[5] Before 1971, the gold standard was still applied and gold prices were fixed at $35 per ounce (about 31.1 grams). Thus, gold was not considered as a financial asset but as a currency before 1971. For more information about gold under the Bretton-Woods system, see Hoang (2010c).

[6] These are mutual funds that invest in gold mining stocks and not in physical gold, as mutual funds cannot invest directly in physical gold.

mean-variance approaches and found the same results. Baur and McDermott (2009) used the GARCH model and concluded that gold quoted in London was favorable in the diversification of portfolios for major European and American stock markets. However, this was not the case for Australia, Canada and some emerging countries. Baur and Lucey (2010) used linear regressions and also concluded that gold had a favorable role in a portfolio.

Still other authors have compared gold with other precious metals (like silver and platinum). Hillier *et al.* (2006) used daily London data from 1976 to 2004 and three stock indexes, S&P 500, MSCI and EAFA (Europe, Australia and Far East). They used a mean-variance approach with correlation coefficients and CAPM. They also measured the performance of portfolios with the reward-to-risk ratio[7]. Their results showed that including one of these precious metals improved portfolio performance. Barisheff (2006) used the New York Spot Precious Metals Index (SPMI) from 1972 to 2004 and found the same results as Hillier *et al.* (2006). Conover *et al.* (2007) studied the period from 1973 to 2006 and confirmed these previous results.

To summarize, we found nearly twenty articles on the subject. Most of them used gold prices quoted in London. They studied either the relationship between gold prices and other assets (stocks and bonds) or the performance of portfolios before and after including gold. Some others compared "physical gold" (ingots or coins) and paper gold (gold mining stocks or gold mutual funds). Some others compared gold with other precious metals like silver or platinum. All of these studies found that gold was favorable for the diversification of portfolios because it reduced their risk and improved their return. Some authors also concluded that physical gold was more efficient than paper gold in portfolio diversification. Most of these articles used the mean-variance approach with measures like correlation coefficients, efficient frontier, CAPM, and multi-factor regressions. Some authors also used GARCH models or the mean-variance-skewness approach. However, we found no papers using the stochastic dominance approach based on the entire distribution of the return and not only on its first orders. Moreover, we found no research on the French financial market. Our study thus adds value to this literature, in both the methodology and the data.

The next section presents the stochastic dominance approach.

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[7] The "*reward-to-risk*" ratio is calculated as follows: $\lambda = \dfrac{\overline{R_i} / \sigma_i^2}{\overline{R_m} / \sigma_m^2}$, with $\overline{R_i}$ the average return, σ_i the standard deviation, $\overline{R_m}$ the average return of the market portfolio, and σ_m the standard deviation of the market portfolio.

3. STOCHASTIC DOMINANCE APPROACH

Let F and G be the cumulative distribution functions (CDFs) and f and g the corresponding probability density functions (PDFs) of the returns of two assets Y and Z, respectively, with common support of $[a, b]$ ($a < b$). Define

$$H_0 = h \text{ and } H_j\left(x\right) = \int_a^x H_{j-1}\left(t\right)dt \text{ for } h = f, g\,,\; H = F, G \text{ and } j = 1,2,3\,. \qquad (1)$$

Y will dominate Z by the first-order SD (FSD) if and only if $F_1\left(x\right) \le G_1\left(x\right)$; by the second-order SD (SSD) if and only if $F_2\left(x\right) \le G_2\left(x\right)$; and, last, by the third-order SD (TSD) if and only if the mean of Y is not less than the mean of Z and $F_3\left(x\right) \le G_3\left(x\right)$ for all x, and the strict inequality holds for at least one value of x (Chan *et al.*, 2012).

The existence of SD implies that *the expected utility* of investors is always higher when they hold the dominant asset rather than the dominated asset and, in addition, investors' expected *wealth* increases if the dominance is at *the first order* (Wong *et al.*, 2008). Consequently, the dominated asset should not be chosen. Under the FSD, investors will exhibit non-satiation (more is preferred to less); under the SSD, investors will have an additional characteristic of risk aversion; and under the TSD, they have added decreasing absolute risk aversion (DARA)[8]. We note that a hierarchical relationship is observed in SD (Levy, 1992, 1998). This means that the FSD implies the SSD, which in turn implies the TSD. However, the converse is not true. Thus, only the lowest dominance order of SD is reported in practice.

Recent advances in SD techniques allow the statistical significance of SD to be determined. To date, the SD tests have been well developed; for example, see Davidson and Duclos (2000), Barrett and Donald (2003), Linton *et al.* (2005), and Bai *et al.* (2012). Since the DD test was found (Tse and Zhang, 2004; Lean *et al.*, 2008) to be powerful and yet less conservative in size, we employ the DD test in our study.

For any two assets Y and Z with CDFs F and G, respectively, and for a grid of pre-selected points $x_1, x_2 \ldots x_k$, the order-j DD statistic, $T_j\,(x)$ (j = 1, 2, and 3), is:

$$T_j\,(x) = \frac{\hat{F}_j\,(x) - \hat{G}_j\,(x)}{\sqrt{\hat{V}_j\,(x)}} \qquad (2)$$

where $\hat{V}_j(x) = \hat{V}_Y^j(x) + \hat{V}_Z^j(x) - 2\hat{V}_{Y,Z}^j(x),$

[8] DARA means that the more wealth *increases*, the more the degree of risk aversion *decreases*. For example, if an investor is DARA and if he/she experiences an increase in wealth, he/she will choose to invest *more* in risky assets.

$$\hat{H}_j(x) = \frac{1}{N(j-1)!}\sum_{i=1}^{N}(x-h_i)_+^{j-1},$$

$$\hat{V}_H^j(x) = \frac{1}{N}\left[\frac{1}{N((j-1)!)^2}\sum_{i=1}^{N}(x-h_i)_+^{2(j-1)} - \hat{H}_j(x)^2\right], H = F, G; h = y, z;$$

$$\hat{V}_{Y,Z}^j(x) = \frac{1}{N}\left[\frac{1}{N((j-1)!)^2}\sum_{i=1}^{N}(x-y_i)_+^{j-1}\left(x-z_i\right)_+^{j-1} - \hat{F}_j(x)\hat{G}_j(x)\right]$$

in which F_j and G_j are defined in (1).

It is empirically impossible to test the null hypothesis for the full support of the distributions. Thus, Bishop *et al.* (1992) proposed to test the null hypothesis for a pre-designed finite number of values *x*. Specifically, the following hypotheses are tested:

$H_0 : F_j(x_i) = G_j(x_i)$, for all x_i, $i = 1, 2, ..., k$;

$H_A : F_j(x_i) \neq G_j(x_i)$ for some x_i ;

$H_{A1} : F_j\left(x_i\right) \leq G_j\left(x_i\right)$ for all $x_i, F_j\left(x_i\right) < G_j\left(x_i\right)$ for some x_i;

$H_{A2} : F_j\left(x_i\right) \geq G_j\left(x_i\right)$ for all $x_i, F_j\left(x_i\right) > G_j\left(x_i\right)$ for some x_i.

We note that in the above hypotheses, H_A is set to be exclusive of both H_{A1} and H_{A2}, which means that if either H_{A1} or H_{A2} is accepted, this does not mean that H_A is accepted. Bai *et al.* (2011) suggested using a simulation approach to generate the simulated critical value. In this paper, we follow their recommendation to obtain simulated critical values in our analysis.

The DD test compares the distributions at a finite number of grid points, and various studies have examined the choice of these points. For example, Tse and Zhang (2004) showed that an appropriate choice of *k* for reasonably large samples ranges from 6 to 15. Too few grids will miss information on the distributions between any two consecutive grids (Barrett and Donald, 2003) and too many grids will violate the independence assumption required by the SMM distribution (Richmond, 1982). To make more detailed comparisons without violating the independence assumption, we follow Fong *et al.* (2005), Lean *et al.* (2007), and others to make ten major partitions with ten minor partitions within any two consecutive major partitions in each comparison. We make the statistical inference based on the simulated critical value suggested by Bai *et al.* (2011).

4. DATA AND ITS DESCRIPTIVE STATISTICS

In this section, we present our database and its descriptive statistics. In order to better understand the database, we first present a brief history of the Paris gold market.

The Paris gold market opened officially in *February 1948* under the authority of the Paris Stock Exchange. Before this date, gold trade was forbidden in France and a clandestine market functioned regularly in Paris between 1940 and 1948[9]. In 2004, the Paris Stock Exchange decided to suspend the quotation of gold. Since this date, the Paris gold market is in over-the-counter trading, which means that trade rules are established freely by the buyers and sellers themselves. Nowadays, the Paris gold market is relatively small compared with the London gold market. Yet despite this small size, the French are known for their preferences for gold hoarding (Hoang, 2012c). Thus, answering the question about the role of gold in portfolio diversification should provide important information to investors.

Our data begin in December 1949 and end in September 2012. We begin only in December 1949 (even if the Paris gold market opened in February 1948) because French stock and bond index data are available only from this date. The periodicity of our data is *monthly*. In fact, when we began this study, there was no complete database for the Paris gold market. Thus, we had to collect gold prices by hand from different sources. We used the Archives of the Bank of France for the period from 1948 to 1968. From 1968 to 1993, we collected the data from the Official Listing of the Paris Stock Exchange. From 1994 to 2012, gold prices in Paris are available on the website of the *Compagnie Parisienne de Réescompte*[10]. To constitute different portfolios, our database was also composed of the French bond index, the French stock index and the French risk-free asset. The details of our database are presented in the following table.

The first two lines of Table 1 concern the monthly prices of the two principal gold assets of the Paris Stock Exchange: Napoleon coins and ingots. Napoleons are old 20 franc coins that were used as money during the gold standard in France from 1803 to 1914 (6.4 grams with 5.8 grams of fine gold)[11]. This coin was chosen because it is the most popular gold coin in France. Thus, its prices are representative for the Paris gold market. The second gold asset is the 1-kilo ingot, which represents fine gold. From 1949 to 1960, the currency of quotation was in old French francs. From 1961 to 1998, it was in new French francs (1 new franc = 100 old francs)[12]. Since 1999, it has been in euros (1 euro = 6.5597 new francs). Finally, we decided

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[9] For more information about the clandestine Paris gold market (1940-1948) and the history of the Paris gold market from 1948, see Hoang (2011) and Hoang (2012a).
[10] The *Compagnie Parisienne de Réescompte* (CPR) is the biggest gold trading house in France today. It organizes a daily price fixing at 1 pm. The price thus determined is the reference for gold trading in France.
[11] For more information about the gold standard in France, see Hoang (2012c).
[12] The objective of this operation was to reduce inflation in France (see Hoang 2010b for more information).

to keep new francs as the common currency because of its long quotation period (37 years over 62 years).

Table 1: Data sources

Data	Sources
Napoleon coin prices	OL, BOF, CPR
Ingot prices	OL, BOF, CPR
Stock index	Insee, Euronext
Bond index	Insee, EuroMTS
Risk-free asset	Insee, BOF

OL = Official Listing of the Paris Stock Exchange, BOF = Bank of France, CPR = Compagnie Parisienne de Réescompte, INSEE = National Institute of Statistics and Economic Studies of France, EuroMTS = A European company that provides services for European fixed income markets.

The stock index that we use is composed of three indexes. From 1949 to 1992, the French stock index was called the French Index of Variable Incomes Securities[13]. This index was built by the French National Institute of Statistics and Economic Studies (INSEE) using the 300 highest capitalization French stocks. In 1993, this index was replaced by the SBF 250[14], which was built with the 250 highest capitalization stocks. In March 2011, the SBF 250 index became the *CAC All Tradable Index*. In order to take into account these changes, we converted these three indexes into the same base[15] of 100 in December 1949.

The bond index is also composed of three indexes. From 1949 to 1990, the bond index was built by INSEE and was called the "French Index of Fixed Incomes Securities"[16]. From 1991 to 1998, this index became the CNO[17]. From 1999, with the introduction of the European common currency, the CNO index became the EuroMTS index. This latter is calculated on sovereign bonds of the euro zone. In order to take these changes into account, we needed to fix a new base, which was 100 in December 1949. For the stock and bond indexes, we included the revenues (dividends for stocks and coupons for bonds).

For the risk-free asset from 1949 to 1998, we used the French 1-month interest rate fixed by the Bank of France. From 1999, we use the 1-month Euribor[18] interest rate, which is the reference for the euro zone. This change is due to the introduction of the common currency (euro) into Europe in 1999.

[13] In French: Indice des Valeurs Françaises à Revenu Variable (IVFRV).
[14] SBF = Société des Bourses Françaises = French Stock Exchange Company
[15] The details of these calculations are presented in Hoang (2010b).
[16] In French: Indice des Valeurs Françaises à Revenu Fixe (IVFRF).
[17] In French, CNO = Comité de Normalisation Obligataire = Standardization Committee for Bonds.
[18] Euribor = European Interbank Offered Rate.

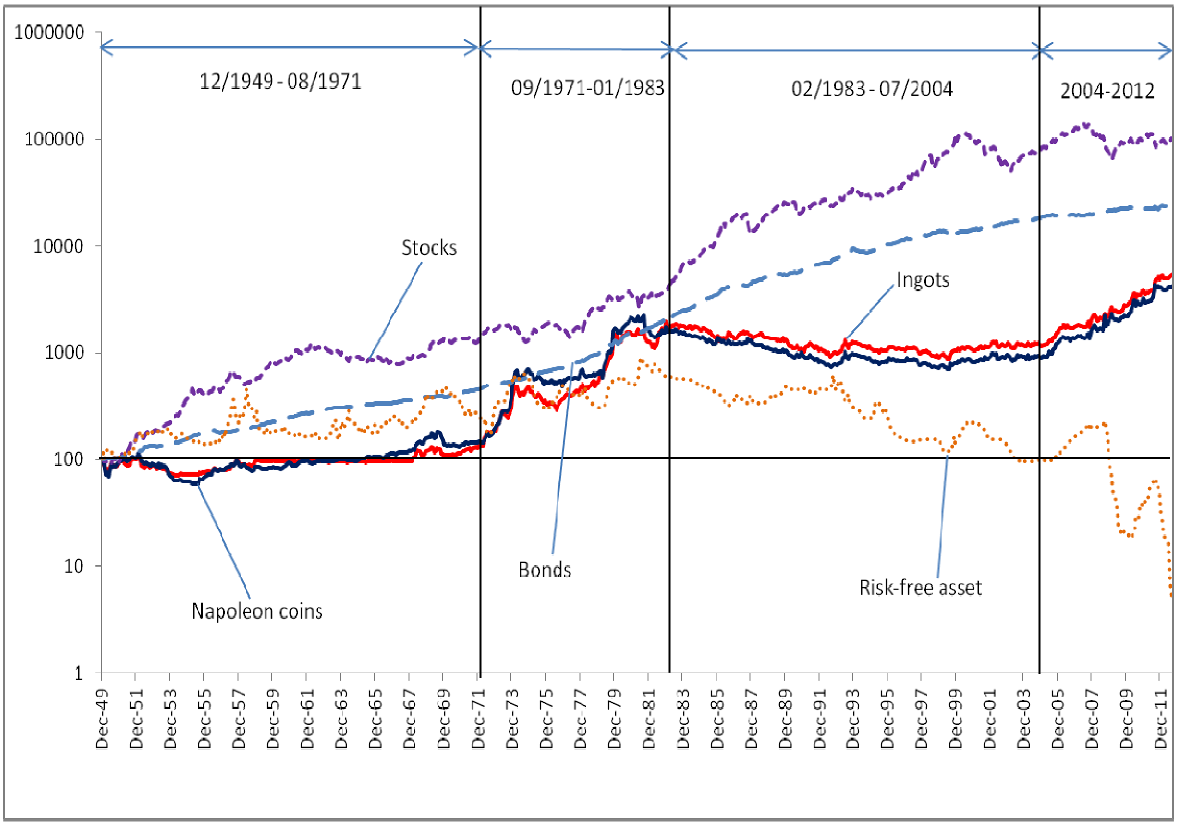
In order to compare the evolution in these series, all indexes have the same base of 100 in December 1949. For gold prices, we also transformed them into indexes with this same base.

The following graph presents the time series plots of data used in this article.

As a function of the evolution in Paris gold prices, we can divide the whole period into four sub-periods.

- *Sub-period 1, from February 1948 to August 1971*: This period preceded the announcement of the American President that the US dollar was no longer pegged to gold. The price of Napoleon coins was stable around 40 new francs during this 1st sub-period. The Bank of France intervened often in the Paris gold market to keep the price of gold stable around the official parity of $35 an ounce (for more information, see Hoang 2010b).

Graph 1: Data



- *Sub-period 2, from September 1971 to January 1983*: This was the most eventful and volatile period for gold markets. The most important event was the abandonment of USD-gold parity in August 1971. This was followed by the official end of the Bretton-Woods fixed exchange system in 1973, two oil shocks in 1973 and 1979, and the opening of the free gold market in the United States in January 1975. This period was also marked by the soaring gold price in London, which reached $666 an ounce for the first time in its history. In France, the election of François Mitterrand in May 1981 raised the price of Napoleon coins to 940 francs (about 143 euros). This was the highest price ever reached.

- *Sub-period 3, from February 1983 to July 2004*: This period was characterized by a downward trend in the Paris gold market (a decrease of 47% between the beginning and end of the period). However, the London gold market was characterized by a stable tendency with a price drop of only 8.3%. In July 2004, the Paris Stock Exchange decided to stop gold trade. Since then, the Paris gold market has been in over-the-counter trading where rules are determined freely between the buyers and sellers themselves. The reference price is calculated by the *Compagnie Parisienne de Réescompte* every day by a fixing at 1 pm. In parallel, other prices are determined continuously all day as a function of buy and sell orders.
- *Sub-period 4, from August 2004 to September 2012*: This last period was marked by the rise in gold prices, notably in September 2011 when the price of one gold ounce reached $1895, the highest level ever attained.

These observations for sub-periods were also confirmed by our tests comparing the distribution of returns between sub-periods[19]. The objective of these sub-periods was to see how the role of gold in the diversification of French portfolios *changes over time*.

Table 2 presents descriptive statistics of our database. In this table (following page), we present the average return, standard deviation, skewness, kurtosis and also tests for the normality of the distribution.

For the average return, we see that stocks were more profitable than gold and bonds most of the time, except in sub-periods 2 and 4. During these two periods, gold prices increased very strongly while stocks decreased, especially during the recent financial crisis. This shows the safe-haven characteristic of gold. Bonds were more profitable than gold most of the time, except in sub-periods 2 and 4 when the rate of return of gold was very high. Contrarily to what one believes, investments in gold are not always profitable.

For the standard deviation, most of the time gold returns were more volatile than stocks and bonds, except in sub-periods 1 and 3 when gold prices were very stable. Bond returns were the least volatile.

Table 2: Descriptive statistics of the data

[19] In order to simplify the text, the results of these tests are available on request.

	Average	SD	Skewness	Kurtosis	JB	KS
Whole period, 12/1949 - 09/2012 (753 months)						
Ingots	0.53% ***	4.70%	0.54 ***	3.38 ***	395.99***	0.11***
Napoleon coins	0.50% ***	5.02%	1.08 ***	8.57 ***	2451.95***	0.11***
Stocks	0.92% ***	4.87%	-0.53 ***	1.26 ***	83.39***	0.06***
Bonds	0.73% ***	1.16%	0.26 ***	2.49 ***	202.94***	0.06***
Risk-free asset	0.50% ***	0.30%	0.82 ***	0.23	86.39***	0.13***
Sub-period 1, 12/1949 - 08/1971 (260 months)						
Ingots	0.08%	2.96%	0.02	4.86 ***	255.97***	0.18***
Napoleon coins	0.14%	3.63%	-0.64 ***	6.20 ***	434.67***	0.13***
Stocks	1.02% ***	4.12%	0.00	0.07	0.05	0.04
Bonds	0.57% ***	0.91%	0.67 ***	5.90 ***	396.81***	0.08***
Risk-free asset	0.39% ***	0.15%	1.42 ***	1.50 ***	111.84***	0.13***
Sub-period 2, 09/1971 - 01/1983 (137 months)						
Ingots	2.02% ***	7.26%	0.34	0.86 **	6.98**	0.07
Napoleon coins	1.82% ***	7.36%	0.89 ***	4.45 ***	131.31***	0.09***
Stocks	0.74% *	4.88%	-0.20	1.11 ***	7.9**	0.06
Bonds	1.12% ***	1.36%	-0.12	4.03 ***	92.89***	0.11***
Risk-free asset	0.83% ***	0.29%	0.50 **	- 0.26	6.13**	0.09***
Sub-period 3, 02/1983 - 07/2004 (258 months)						
Ingots	-0.20%	3.86%	-0.34 **	1.30 ***	23.11***	0.05
Napoleon coins	-0.25%	3.57%	0.63 ***	2.32 ***	75.08***	0.08***
Stocks	1.14% ***	5.43%	-0.82 ***	1.56 ***	54.9***	0.08***
Bonds	0.83% ***	1.19%	0.15	0.28	1.78	0.04
Risk-free asset	0.56% ***	0.27%	0.17	- 1.26 ***	18.31***	0.14***
Sub-period 4, 08/2004 - 09/2012 (98 months)						
Ingots	1.56% ***	5.33%	-0.01	0.51	1.08	0.09*
Napoleon coins	1.57% **	6.69%	0.81 ***	5.23 ***	124.41***	0.12***
Stocks	0.30%	5.11%	-0.74 ***	0.83	11.8***	0.08*
Bonds	0.35% ***	1.17%	0.00	0.93 *	3.53	0.09*
Risk-free asset	0.18% ***	0.12%	0.38	- 1.21 **	8.36**	0.12***

Notes: *** means that the value is significantly different from 0 at a 1% threshold; ** at a 5% threshold. No asterisk means that the value is not significantly different from 0. JB (Jarque-Bera) and KS (Kolmogorov-Smirnov) are tests for the normality of the distribution. *** means that it is not normal at a 1% threshold; *: at 10% threshold. No asterisk means that it is normal.

For skewness, the asymmetry coefficient of the distribution in most cases was significantly different from 0[20]. This means that the distribution was not symmetric around the average value. Negative skewness means that most rates of return are lower than the average. Positive skewness means that most rates of return are higher than the average.

[20] For a normal distribution, the skewness equals 0.

For kurtosis, the flattening coefficient of the distribution was in most cases significantly different from 0[21]. This means that the tails of the real distribution graph are thicker than the ones of the normal distribution. Financially, this means that there are more extreme rates of return (negative or positive ones) than a normal distribution.

The results of the normality tests (Jarque-Bera and Kolmogorov-Smirnov) confirmed the results of the skewness and kurtosis coefficients: the distribution of returns of French assets is not normal. This means that MV methods should not be used to analyze the performance of portfolios. Therefore, our choice to use the SD approach is more suitable since it is based on the whole distribution, and not only on the first two moments (mean and variance).

5. IS GOLD GOOD FOR FRENCH PORTFOLIO DIVERSIFICATION?

To answer this question, we built two kinds of portfolios: ones *with* gold and ones *without* gold. The following table shows the way that we built our portfolios.

Table 3: The portfolio composition

Asset 1 **Gold** **(Ingots or Napoleon coins)** *The common asset in all portfolios*	**Asset 2** *Portfolios 1* **Stocks**	**Asset 2** *Portfolios 2* **Bonds**	**Asset 2** *Portfolios 3* **Risk-free asset**
1%	99%	99%	99%
2%	98%	98%	98%
5%	95%	95%	95%
10%	90%	90%	90%
15%	85%	85%	85%
20%	80%	80%	80%
30%	70%	70%	70%
40%	60%	60%	60%
50%	50%	50%	50%

We created three groups of portfolios. Group 1 was composed of gold and stocks; group 2 of gold and bonds; and group 3 of gold and risk-free asset. In each group, the percentage of gold varied from 1% to 50%. Thus, the proportion of the second asset (stocks or bonds or risk-free asset) varied from 99% to 50% (see Table 3). In total, we had 54 portfolios (27 for ingots and 27 for Napoleons). We performed pairwise comparison between a pure asset 2 (100% stocks or 100% bonds or 100% risk-free asset) and a portfolio with a portion of gold. The analysis was conducted for one whole period and the four sub-periods defined above. This means that we performed SD analysis for 270 pairwise comparisons in total. We recall that our objective was to compare portfolios *without* gold (0% of gold) to portfolios *with* a

[21] For a normal distribution, the kurtosis (or the surplus of the kurtosis over 3 exactly) equals 0.

portion of gold (from 1% to 50%). If the portfolio including gold stochastically dominates the portfolio without gold, gold is preferred for maximizing the utility of investors.

Before presenting the results of our analysis, we briefly recall the meaning of each SD order. First-order stochastic dominance (FSD) implies that non-satiation (more is preferred to less) investors can increase their expected wealth *and* expected utility if they switch from the dominated portfolio to the dominating portfolio. Second-order stochastic dominance (SSD) means that risk-averse investors would prefer the dominating portfolio to the dominated portfolio in order to maximize their *utility*. Third-order stochastic dominance means that decreasing absolute risk aversion (DARA) investors would prefer the dominating portfolio to the dominated portfolio to maximize their utility. With the SSD and TSD, risk-averse investors can maximize their expected utility but not their expected wealth (Lean *et al*., 2013). We also recall that the FSD implies the SSD, which in turn implies the TSD – but the converse is not true.

For maximal clarity, we present the results of the whole period first and then those of the sub-periods.

5.1. Whole period (1949 to 2012)

Table 4 presents the results of the DD tests for the three groups of portfolios.

Table 4: Results of the DD tests for the whole period (1949-2012)

Portfolios	*Stock portfolios*		*Bond portfolios*	
	With ingots	*With Napoleon coins*	*With ingots*	*With Napoleon coins*
1%	$\succ^{2,3}$	$\succ^{2,3}$	*ND*	$\succ^{2,3}$
2%	$\succ^{2,3}$	$\succ^{2,3}$	*ND*	$\succ^{2,3}$
5%	$\succ^{2,3}$	$\succ^{2,3}$	*ND*	*ND*
10%	$\succ^{2,3}$	$\succ^{2,3}$	*ND*	*ND*
15%	$\succ^{2,3}$	$\succ^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
20%	$\succ^{2,3}$	$\succ^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
30%	$\succ^{2,3}$	$\succ^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
40%	$\succ^{2,3}$	$\succ^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
50%	$\succ^{2,3}$	$\succ^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$

Portfolios	*Risk-free portfolios*	
	With ingots	*With Napoleon coins*
1%	*ND*	$\succ^{2,3}$
2%	*ND*	$\succ^{2,3}$
5%	*ND*	*ND*
10%	*ND*	*ND*
15%	$\prec^{2,3}$	$\prec^{2,3}$
20%	$\prec^{2,3}$	$\prec^{2,3}$

30%	$\prec^{2,3}$	$\prec^{2,3}$
40%	$\prec^{2,3}$	$\prec^{2,3}$
50%	$\prec^{2,3}$	$\prec^{2,3}$

Note: 1%, 2%,…, 50% means the percentage of gold in the portfolios. $\succ$ means that the portfolio with gold stochastically dominates the portfolio without gold. $\prec$ means that the portfolio with gold is stochastically dominated by the portfolio without gold. ND means that there is no SD. ^{2,3} means SSD and TSD.

Stocks and gold portfolios: Stochastic dominance at orders 2 and 3

There were SSD and TSD for portfolios composed of both stocks and gold over portfolios composed of only stocks. This means that risk-averse investors and DARA investors would prefer portfolios with gold to the ones without gold to maximize their expected utility. These results were true for all percentages of gold and both types of gold in portfolios.

Bonds and risk-free portfolios: Including only 1% or 2% of Napoleons

With ingots, the results show that there was no SD at the first three orders with 10% or less of ingots in the portfolios. With more than 15% of ingots, bond or risk-free portfolios *without* gold dominated those *with* gold at the SSD and TSD.

With Napoleon coins, including between 5% and 10% of gold did not create any preference in portfolios as there was no SD found. The portfolios that contained more than 15% of gold were dominated by portfolios without gold at the SSD and TSD. However, risk-averse and DARA investors would prefer including less than 2% of Napoleons in their bond or risk-free portfolios to maximize their expected utility.

We thus conclude that for bond and risk-free portfolios, investors prefer them without gold than with gold. Gold can increase the utility of investors only when they include 1% or 2% of Napoleons in the portfolios. For more than 15%, *not including gold* in portfolios would increase their utility. Last, for the whole period from 1949 to 2012, gold quoted in Paris increased the utility of French investors only if they included it in stock portfolios. This was true for both ingots and Napoleon coins. For bonds and risk-free portfolios, the utility of investors would be improved only if they included a very small portion of Napoleon coins (less than 2%).

5.2. Is gold good for portfolio diversification in sub-periods from 1949 to 2012?

The results for the sub-periods are presented in three different tables: Table 5 for stock portfolios, Table 6 for bond portfolios and Table 7 for risk-free portfolios.

Table 5: Portfolios composed of gold and stocks in sub-periods

	Sub-period 1, from 12/1949 to 08/1971 *Gold price stability*	*Sub-period 2, from 09/1971 to 01/1983* *Gold price increase*

Portfolios	With ingots	With Napoleon coins	With ingots	With Napoleon coins
1%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
2%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
5%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
10%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
15%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
20%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
30%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
40%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
50%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$

	Sub-period 3, from 02/1983 to 07/2004 Gold price decrease		*Sub-period 4, from 08/2004 to 09/2012 Gold price increase*	
Portfolios	*With ingots*	*With Napoleon coins*	*With ingots*	*With Napoleon coins*
1%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
2%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
5%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
10%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
15%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
20%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
30%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
40%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$
50%	$\succ^{3}$	$\succ^{3}$	$\succ^{2,3}$	$\succ^{2,3}$

Note: 1%, 2%,…, 50% means the percentage of gold in the portfolios. $\succ$ means that the portfolio with gold stochastically dominates the portfolio without gold. ND means that there is no SD. $\prec$ means that the portfolio with gold is dominated stochastically by the portfolio without gold. ^{2,3} means SSD and TSD.

Stock portfolios

In all sub-periods, portfolios with gold dominated those without gold at the TSD (see Table 5 above). This means that DARA investors could maximize their expected utility by including gold in their stock portfolios in all sub-periods. We noted that there was SSD only when gold prices increased strongly (in the 2nd and 4th sub-periods). This means that risk-averse investors would prefer portfolios with gold during periods when gold prices increase and stock prices decrease (like during the financial crisis in the 4th sub-period). There was no FSD in all cases. This means that including gold in stock portfolios did not allow non-satiation investors to increase either their utility or their wealth.

Bond portfolios

The following table presents the results for portfolios composed of bonds and gold in the four sub-periods.

Table 6: Portfolios composed of gold and bonds in sub-periods

	Sub-period 1, from 12/1949 to 08/1971 Gold price stability		*Sub-period 2, from 09/1971 to 01/1983 Gold price increase*	
Portfolios	*With ingots*	*With Napoleon coins*	*With ingots*	*With Napoleon coins*
1%	*ND*	*ND*	*ND*	*ND*
2%	*ND*	*ND*	*ND*	*ND*
5%	*ND*	*ND*	*ND*	*ND*
10%	$\prec^{2,3}$	*ND*	*ND*	*ND*
15%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
20%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	*ND*
30%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
40%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
50%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$

	Sub-period 3, from 02/1983 to 07/2004 Gold price decrease		*Sub-period 4, from 08/2004 to 09/2012 Gold price increase*	
Portfolios	*With ingots*	*With Napoleon coins*	*With ingots*	*With Napoleon coins*
1%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
2%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
5%	$\prec^{2,3}$	$\prec^{2,3}$	$\succ^{2,3}$	$\succ^{2,3}$
10%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
15%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
20%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
30%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
40%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
50%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*

Note: 1%, 2%,…, 50% means the percentage of gold in the portfolios. $\succ$ means that the portfolio with gold stochastically dominates the portfolio without gold. *ND* means that there is no SD. $\prec$ means that the portfolio with gold is dominated stochastically by the portfolio without gold. ^{2,3} means SSD and TSD.

For bond portfolios, the situation is clear: *Investors prefer portfolios without gold*. In most cases, there was no SD and in many cases, portfolios without gold dominated portfolios with gold. Nevertheless, there was an exception in the 4th sub-period when gold prices increased very strongly: If investors include 5% of gold in their bond portfolios, risk-averse and DARA investors increase their utility (SSD and TSD). This is true for both ingots and Napoleon coins.

Risk-free portfolios

The results for portfolios composed of risk-free asset and gold in the four sub-periods are presented in the following table.

Table 7: Portfolios composed of gold and risk-free asset in sub-periods

	Sub-period 1, from 12/1949 to 08/1971	*Sub-period 2, from 09/1971 to 01/1983*

	Gold price stability		*Gold price increase*	
Portfolios	*With ingots*	*With Napoleon coins*	*With ingots*	*With Napoleon coins*
1%	*ND*	*ND*	*ND*	*ND*
2%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
5%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	*ND*
10%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
15%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
20%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
30%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
40%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$
50%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{2,3}$

	Sub-period 3, from 02/1983 to 07/2004 Gold price decrease		*Sub-period 4, from 08/2004 to 09/2012 Gold price increase*	
Portfolios	*With ingots*	*With Napoleon coins*	*With ingots*	*With Napoleon coins*
1%	$\prec^{2,3}$	$\prec^{2,3}$	*ND*	*ND*
2%	$\prec^{3}$	$\prec^{3}$	*ND*	$\prec^{2,3}$
5%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{3}$	$\prec^{2,3}$
10%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{3}$	$\prec^{2,3}$
15%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{3}$	$\prec^{2,3}$
20%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{3}$	$\prec^{2,3}$
30%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{3}$	$\prec^{2,3}$
40%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{3}$	$\prec^{2,3}$
50%	$\prec^{2,3}$	$\prec^{2,3}$	$\prec^{3}$	$\prec^{2,3}$

Note: 1%, 2%,…, 50% means the percentage of gold in the portfolios. $\succ$ means that the portfolio with gold stochastically dominates the portfolio without gold. *ND* means that there is no SD. $\prec$ means that the portfolio with gold is dominated stochastically by the portfolio without gold. ^{2,3} means SSD and TSD.

These results show that *gold is not a good factor for the diversification of risk-free portfolios*. In most cases, pure risk-free portfolios dominated portfolios *with* gold at the 2nd and 3rd orders. So, for risk-averse and DARA investors, their expected utility cannot be maximized by including gold in their portfolios.

CONCLUSION

Using the SD approach, we show how to use gold quoted in Paris to diversify French portfolios. From our empirical results, we can draw the following conclusions. First, gold is really good only in stock portfolios and mostly in periods where gold prices increase significantly (like from 1971 to 1983 or from 2004 to 2012). These periods correspond to unstable conjunctures: for example, from 1971 to 1983, there were two oil shocks in 1974 and

1979; and from 2004 to 2012, there were successive financial crises worldwide and in Europe in particular. In these conjunctures, stock portfolios with gold dominated those without gold at the second and third orders. This means that risk-averse and decreasing absolute risk aversion (DARA) investors prefer including gold in stock portfolios to maximize their utility. For the choice of gold assets, our study shows that ingots and Napoleon coins give the same results. Therefore, individual investors can choose Napoleons instead of ingots as the price of Napoleons (about 200 euros) is much lower than the price of 1-kilo ingots (about 30,000 euros). Regarding the proportion of gold to include, our results show that all proportions from 1% to 50% have SSD and TSD during the two above-mentioned periods. There is no FSD in all periods. In two sub-periods, from 1949 to 1971 (gold price stability) and from 1983 to 2004 (gold price decrease), there is only TSD.

Otherwise, our study shows that there is no advantage to including gold in bond and risk-free asset portfolios. In most cases, portfolios with gold were dominated by portfolios without gold. This means that investors' utility cannot be maximized by including gold in their portfolios. Gold is preferred only if investors include a very small percentage, from 1% to 2%.

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