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Bastien DRUT

INVESTISSEMENT SOCIALEMENT RESPONSABLE ET SELECTION DE PORTEFEUILLE

JURY :

Mme. Marie BRIERE, Chercheur associé à l'Université Libre de Bruxelles (ULB)

Mme. Valérie MIGNON (Co-directeur), Professeur à l'Université Paris Ouest – Nanterre La Défense

M. Kim OOSTERLINCK (Co-directeur), Professeur à l'Université Libre de Bruxelles (ULB)

M. Sébastien POUGET (Rapporteur), Professeur à l'Université de Toulouse

Mme. Hélène RAYMOND (Présidente), Professeur à l'Université Paris Ouest – Nanterre La Défense

M. Olivier SCAILLET (Rapporteur et Secrétaire), Professeur à l'Université de Genève et à l'ULB.

Mme Ariane SZAFARZ (Co-directeur), Professeur à l'Université Libre de Bruxelles (ULB)

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Avant propos

Cette thèse a été réalisée dans le cadre d'un contrat C.I.F.R.E. (Convention Industrielle de Formation par la REcherche) en partenariat avec la société de gestion C.A.A.M. (Crédit Agricole Asset Management) devenue Amundi suite à la fusion début 2010 avec la société de gestion S.G.A.M. (Société Générale Asset Management). L'établissement d'une convention de cotutelle entre l'Université Libre de Bruxelles (ULB) et l'Université Paris Ouest Nanterre La Défense m'a valu le privilège d'être encadré par les professeurs Valérie Mignon, Kim Oosterlinck et Ariane Szafarz.

Contents

Introduction générale

« La vie de l'homme d'affaires, c'est une vie de contrainte, et la richesse n'est évidemment pas le bien que nous cherchons : c'est seulement une chose utile, un moyen en vue d'une autre chose »
Aristote dans *Ethique à Nicomaque*

« Socially Responsible Investing can be a tool for dialogue between corporations and society »
Amy Domini, fondatrice de Domini Social Investments

« The social responsibility of business is to increase its profits »
Milton Friedman

Dans la théorie financière classique, les investisseurs sélectionnent leur portefeuille uniquement sur la base de paramètres financiers, c'est-à-dire de leur propre aversion au risque et des caractéristiques financières des titres disponibles. L'avènement de l'Investissement Socialement Responsable (ISR) offre un nouveau et vaste champ de recherche en sélection de portefeuille puisque, dans ce cadre, les investisseurs prennent également en considération des éléments extra-financiers dans leur gestion de portefeuille. Ils pondèrent les titres en prenant en compte des critères à caractère éthique, environnemental, social et/ou de gouvernance. L'ISR pose ainsi aux praticiens et aux théoriciens la stimulante question de savoir comment concilier indicateurs financiers et extra-financiers et des conséquences associées. De cette question en découlent plusieurs autres : comment intégrer le souhait d'investir de façon responsable dans la fonction d'utilité traditionnellement associée à un investissement ? Est-il possible de composer un portefeuille en accord avec ses valeurs sans sacrifier la performance financière ? Mieux, est-il possible d'obtenir de meilleurs rendements en investissant de façon responsable ? La présente thèse s'inscrit dans ce champ de recherche et apporte des éléments de réponse à ces questions. En particulier, celle-ci explore les conséquences théoriques et empiriques de l'introduction d'indicateurs socialement responsables dans la sélection de portefeuille.

Dans la suite de cette introduction, je me propose de dresser un état de l'art de la recherche en finance portant sur l'ISR. La première partie expose comment s'est structuré l'ISR et la place qu'il a prise sur les marchés financiers mondiaux. La partie suivante montre que la modélisation de la sélection de portefeuille dans le cadre de l'ISR dépend des objectifs des investisseurs et notamment du fait qu'ils soient prêts ou non à sacrifier la performance financière afin d'obtenir des portefeuilles plus en accord avec leurs valeurs. La troisième partie résume les principaux résultats des études empiriques menées sur l'ISR et souligne les difficultés que posent leur interprétation. Enfin, la dernière partie propose mes questions de recherche et annonce le plan général de ce manuscrit de thèse.

1. L'investissement socialement responsable

Le but de cette partie est préciser le fonctionnement et les pratiques de l'ISR au sein de l'industrie financière. Etant donné qu'investir de façon responsable n'a pas la même signification pour tous et que les acteurs de l'ISR sont très hétérogènes (Sandberg *et al.*, 2009), plusieurs types d'investissements responsables se sont succédés et/ou coexistent. Dans la toute première version de l'ISR, les investisseurs excluent des titres financiers d'entreprises ou d'Etats dont le comportement n'est pas en accord avec les valeurs morales et/ou éthiques de l'investisseur[1]. On parle de filtres négatifs dans ce cas. Les plus fréquents sont liés aux industries du tabac, de l'alcool, de l'armement, du jeu, du nucléaire et de la pornographie. Dans cette configuration d'exclusion de titres, la subjectivité de l'investisseur socialement responsable intervient dans la détermination de l'univers d'investissement : une fois certains titres exclus, l'investisseur détermine théoriquement son portefeuille selon une optimisation « moyenne-variance » de type Markowitz (1952, 1959). En pratique, les fonds d'investissement dits « à exclusion » ont très souvent été créés à l'initiative de groupes religieux et les critères motivant l'exclusion sont d'ordre moral ou éthique (Renneboog *et al.*, 2008a). L'un des exemples[2] les plus médiatisés est celui du désinvestissement des titres d'entreprises réalisant des affaires avec l'Afrique du Sud afin de protester contre les politiques discriminatoires du régime de l'apartheid (Ennis et Parkhill, 1986 ; Grossman et Sharpe, 1986 ; Wagner *et al.*, 1986). Cette vision de l'ISR a paru trop restrictive pour une large catégorie d'investisseurs sensibles aux externalités positives ou négatives produites par les entreprises ou gouvernements sans toutefois que celles-ci aient trait aux valeurs morales ou religieuses, typiquement les externalités environnementales.

En particulier, les entreprises peuvent, par le biais des projets qu'elles mettent en place, exercer une influence sur des biens publics ou sur le bien-être d'autres agents que ses actionnaires. La volonté d'investir préférentiellement sur les entités aux pratiques les plus socialement responsables, c'est-à-dire produisant les externalités les plus positives, a mené à la création d'une seconde génération de l'ISR, parfois appelée « best-in-class ». L'ambition directement associée à cette version de l'ISR est de contribuer au changement social et de

[1] Comme l'indiquent Renneboog *et al.* (2008a), les investissements éthiques trouvent leurs racines dans les traditions juives, chrétiennes et musulmanes. En particulier, le judaïsme propose de nombreux éléments de réflexion sur l'utilisation éthique de l'argent.

[2] Le fonds d'investissement Pax World Fund, créé en 1971, est généralement reconnu comme étant le premier fonds ISR « moderne ». Créé par des investisseurs opposés à la guerre du Vietnam, ses investissements évitaient le secteur de l'armement.

promouvoir les bonnes politiques d'entreprises et de gouvernements. Partant du constat que les externalités et les caractéristiques extra-financières à suivre et/ou prendre en compte diffèrent selon la nature de l'entité sous-jacente de l'investissement (le titre a-t-il été émis par une entreprise ou un Etat ? quel est le secteur d'activité de l'entreprise considérée ? l'Etat est-il développé ou émergent ? etc.), les investisseurs sélectionnent au sein d'une catégorie homogène de titres les entités aux meilleures pratiques. Ils les surpondèrent ensuite dans leurs portefeuilles sans exclure *a priori* les entités les moins responsables. Toutefois, il n'existe pas dans l'industrie financière de consensus sur le choix des indicateurs extra-financiers les plus pertinents, ni sur la façon de les intégrer dans le processus de gestion. Trois groupes de sous-critères sont généralement utilisés: les critères environnementaux, les critères sociétaux et les critères de gouvernance. Ces critères, généralement appelés « critères ESG », peuvent être pondérés par l'investisseur selon ses préférences (Landier et Nair, 2008). On parle de filtres positifs (Renneboog *et al.,* 2008a). Tout comme pour l'évaluation du risque financier des entreprises et des Etats, l'industrie financière a souvent recours à des agences de notation pour évaluer leurs performances extra-financières. Les indicateurs quantitatifs que constituent ces notations sont censés refléter la « valeur » extra-financière de l'entreprise ou de l'Etat (Arjaliès, 2010). Par ailleurs, tout comme les notations de crédit, les notations extra-financières produites par les agences de notation sont parfois remises en causes (Igalens et Gond, 2005 ; Chatterji *et al.*, 2009).[3]

Les versions postérieures des fonds ISR consistent en des combinaisons de filtres négatifs et positifs et intègrent parfois l'activisme actionnarial. Le principe de ce dernier est d'utiliser les droits de vote liés à la détention d'actions d'une société pour tenter d'influer sur sa

[3] Le parallèle avec la critique des agences de notations de crédit peut être prolongé. En effet, il est fréquemment reproché aux notations de crédit de mal prévoir les événements de crédit. De façon intéressante, Chatterji *et al.* (2009) montrent que les notations environnementales produites par l'agence américaine KLD expliquent très bien les performances environnementales passées des entreprises américaines mais peinent à prévoir les performances futures.

gouvernance d'entreprise, sa politique sociale et/ou environnementale. L'activisme actionnarial tranche, en effet, avec les précédentes implémentations de l'ISR en ce qu'il essaie d'aboutir directement à un changement social (Gollier et Pouget, 2009). L'exemple le plus connu est celui de CalPERS, le fonds de retraite des fonctionnaires californiens, dont les propositions sont très souvent adoptées par les actionnaires lors des assemblées générales (Smith, 1996 ; Barber, 2007).

A mesure que sont apparues les différentes versions de l'ISR, son ampleur sur les marchés financiers mondiaux a fortement crû ces dernières années. Les montants en jeu sont désormais considérables : plus de 3 000 milliards de dollars étaient investis dans des fonds socialement responsables aux Etats-Unis à la fin de l'année 2009 (Social Investment Forum, 2010) et 5 000 milliards d'euros en Europe pour la même année (Eurosif, 2010). De multiples initiatives pour promouvoir l'ISR ont été entreprises depuis une dizaine d'années. Des associations d'investisseurs se sont constituées pour faire émerger des lignes directrices communes permettant à l'ISR de former une masse critique lui conférant crédibilité et légitimité. Par ailleurs, dans plusieurs pays, les pouvoirs publics ont pris des dispositions pour encourager l'offre de fonds ISR par les sociétés de gestion (Arjaliès, 2010). A l'échelle internationale, la principale initiative de promotion de l'ISR consiste en l'association, sous l'égide de l'Organisation des Nations Unies (ONU), d'investisseurs s'engageant à respecter des principes pour l'Investissement Responsable (Principles for Responsible Investment, PRI) dans leurs processus d'investissement et mettant en place des groupes de travail communs en vue de l'amélioration des politiques d'entreprises et de gouvernements. En avril 2011, 850 groupes d'investissement de 45 pays les avaient signés (pour un montant agrégé sous gestion de 25 000 milliards de dollars). Eu égard à l'importance de ce mouvement et à la hauteur de ses ambitions vis-à-vis de la société, le besoin de nouvelles investigations théoriques et empiriques portant sur la sélection de portefeuille dans le cadre de l'ISR est donc patent. En particulier, il se pose la question de savoir comment intégrer le souhait d'investir de façon responsable dans la fonction d'utilité traditionnellement associée à un investissement ?

2. Comment intégrer l'ISR dans la sélection de portefeuille ?

La façon de prendre en compte des indicateurs socialement responsables dans la modélisation de la sélection de portefeuille dépend des objectifs de l'investisseur. Or de nombreux auteurs (Beal *et al.*, 2005; Landier et Nair, 2008; Nilsson, 2009; Sandberg *et al.*, 2009; Derwall *et al.*, 2011) s'accordent à dire qu'il existe une très forte hétérogénéité des objectifs chez les investisseurs « responsables ». Beal *et al.* (2005) identifient trois raisons pour lesquelles les investisseurs souhaitent investir de façon responsable : l'espoir de rendements financiers plus élevés, l'obtention de bénéfices non-financiers et la contribution au changement social. Dans le même ordre d'idée, Landier et Nair (2008) distinguent, eux aussi, trois types d'investisseurs responsables : ceux qui investissent responsable car ils croient que cela permet de maximiser le rendement financier, ceux qui désirent des portefeuilles non-investis dans des activités qui ne seraient pas en accord avec leurs valeurs et ceux qui souhaitent investir responsable sans que cela ne leur coute. Derwall *et al.* (2011) insistent également sur la segmentation au sein de la classe des investisseurs ISR. En particulier, ils opposent les investisseurs qui tolèrent une perte en termes de performances financières en échange d'une utilité non-financière aux investisseurs qui utilisent les indicateurs extra-financiers car ceux-ci comporteraient de l'information pertinente pour mieux anticiper les rendements des titres. Ces derniers ne retirent aucune utilité non-financière à investir de façon responsable et s'orientent vers l'ISR que parce que cela rapporterait plus. Dans la réalité, l'équilibre entre motivations extra-financières et motivations financières des investisseurs est sans doute un continuum (Bollen, 2007; Derwall *et al.*, 2011) : autrement dit, à la fois les rendements financiers et les bénéfices non-financiers seraient importants pour l'investisseur.

Il est donc clair que la question des performances financières des fonds ISR est centrale. Elle l'est évidemment pour les investisseurs qui s'intéressent à l'ISR afin de maximiser le rendement de leurs investissements. Mais elle l'est aussi pour la frange des investisseurs en ISR mus par des motivations extra-financières car ceux-ci souhaitent quantifier le coût à investir de façon responsable : certains d'entre eux refuseraient même d'investir dans des fonds ISR si cela leur imposait un coût trop important (Landier et Nair, 2008).

En conséquence, la modélisation de l'ISR pose un défi à la théorie financière classique. Dans le cadre de la sélection de portefeuille « moyenne-variance » développé par Markowitz (1952, 1959), l'investisseur est supposé maximiser le rendement attendu de son investissement pour une volatilité déterminée en fonction de son aversion pour le risque (financier) ou, de façon équivalente, minimiser la volatilité de son investissement pour un rendement attendu déterminé. Hormis le choix de l'univers d'investissement, le seul paramètre faisant intervenir les caractéristiques intrinsèques à l'investisseur est son aversion pour le risque financier. L'ISR complique l'optimisation « moyenne-variance » traditionnelle en ce qu'il introduit une autre dimension subjective de l'investisseur : sa définition de ce qui est socialement responsable et sa façon d'en tenir compte dans la sélection de portefeuille.

Du point de vue de la sélection de portefeuille, ne pas investir dans les actifs « irresponsables » ou surpondérer les actifs les plus « responsables » restreint l'univers d'investissement et devrait donc conduire à une perte en termes de diversification. En effet, dans l'hypothèse où les marchés sont efficients, les investisseurs anticipent la façon dont les performances extra-financières d'une entreprise ou d'un Etat modifient les rendements attendus : les portefeuilles « responsables » devraient obtenir des performances financières soit équivalentes soit moins bonnes que les portefeuilles efficients traditionnels. Il est possible d'aller un pas plus loin. Si la proportion d'investisseurs refusant de transiger avec les indicateurs socialement responsables est suffisamment importante, l'excès de demande pour les titres « responsables » et la baisse de la demande pour les titres « irresponsables » peut induire des modifications considérables de prix d'actifs (Heinkel *et al.*, 2001). Ainsi, Angel et Rivoli (1997) et Hong et Kasperczyk (2009) prévoient que les titres « socialement controversés », c'est-à-dire que certains investisseurs évitent d'avoir en portefeuille en raison de leurs convictions, ont des meilleurs rendements attendus car étant décotés. Ce surplus de rendement attendu s'accroit avec la proportion d'investisseurs agissant ainsi. Ces hypothèses sont largement vérifiées empiriquement (Kempf et Osthoff; 2007 ; Fabozzi *et al.*, 2008 ; Hong et Kasperczyk, 2009 ; Statman et Glushkov, 2009 ; entres autres) : après contrôle de nombreux facteurs, les actions des entreprises de secteurs controversés (tabac, alcool, jeu, armement, nucléaire, biotechnologies, pornographie) obtiennent des rendements plus élevés que les autres.

De nombreux gestionnaires de fonds affirment pourtant que les titres « responsables » peuvent obtenir de meilleurs rendements financiers que les autres, ce qui est généralement décrit par l'expression anglaise « doing well by doing good ». L'idée sous-jacente tiendrait à une erreur dans les anticipations de rendements : les indicateurs socialement responsables contiendraient de l'information valorisable financièrement et à laquelle n'ont pas accès les investisseurs non « responsables » (Derwall *et al.*, 2011). Dans le cas d'une entreprise, cette hypothèse n'est valide que si les revenus futurs de l'entreprise dépensent de ses performances extra-financières, par exemple sur les critères ESG, et que les prix des actions ne reflètent pas l'information valorisable associée. Ce surplus de rendements générés par des pratiques vertueuses correspondrait à des rendements dits « anormaux ». Dans cette configuration, la sélection de titres fondée au moins en partie sur des indicateurs socialement responsables pourrait permettre d'obtenir de meilleurs rendements financiers. Toutefois, la compréhension de cette éventuelle causalité reste à l'heure actuelle très limitée et constitue l'un des champs de recherche sur l'ISR les plus importants (Renneboog *et al.*, 2008a ; Derwall *et al.*, 2011).

En ce qui concerne la sélection de portefeuille dans le cadre de l'ISR, plusieurs éléments demeurent inexplorés. Il n'existe pas - à ma connaissance - de modélisation théorique de la seconde génération de l'ISR dans laquelle les investisseurs surpondèrent les titres des entités les plus responsables. Pour les praticiens, il serait par exemple intéressant de déterminer *a priori* à partir de quel degré d'exigence vis-à-vis des notations socialement responsables il y a un coût financier. D'ailleurs, cette exigence mène-t-elle dans toutes les situations à un coût pour l'investisseur ? Existe-t-il des configurations pour laquelle elle ne coûte rien ? Par ailleurs, le rôle de l'aversion au risque est, de façon surprenante, généralement omis dans les travaux portant sur l'ISR. Farmen et Van Der Wijst (2005) notent que ce paramètre joue un rôle dans l'ISR mais ne l'étudient pas en détail. Les investisseurs présentant de l'aversion pour le risque sont-ils théoriquement plus pénalisés que les autres par leur souhait d'investir « responsable » ? Ou tous les investisseurs doivent-ils consentir à un sacrifice financier équivalent quelle que soit leur aversion au risque ?

Enfin, étant donné que la question de l'efficience des portefeuilles est cruciale pour les investisseurs responsables, il est important de pouvoir disposer de tests d'efficience moyenne-variance le plus robuste possible. Certains investisseurs ne sont, par exemple, pas prêts à investir dans des portefeuilles socialement responsables qui ne seraient pas efficients d'un point de vue financier. La plupart d'entre eux sont prévus pour des univers d'investissement dans lesquels il existe un actif sans risque[4] or l'hypothèse de l'existence d'un actif sans risque peut largement être remise en cause. La crise actuelle de la dette publique en Europe montre que même les actifs supposés les plus sûrs, c'est-à-dire les obligations d'Etat des pays développés, sont soumis au risque de défaut. De plus, le gel des marchés monétaires et la faillite de la banque d'investissement Lehman Brothers en septembre 2008 ont mis en évidence les risques de liquidité et de contrepartie associés à ce type d'investissement (Acharya *et al.*, 2010 ; Bruche et Suarez, 2010 ; Krishnamurthy, 2010). Pour ces raisons, il semble plus réaliste de tester l'efficience moyenne-variance des portefeuilles en faisant l'hypothèse d'absence d'actif sans risque, ce qui revient à tester le « zero beta CAPM » de Black (1972). Or, très peu d'attention a été accordée à ces tests comparativement au cadre de l'existence d'un actif sans risque, notamment en ce qui concerne leur robustesse. Récemment, Levy et Roll (2010) ont ravivé ce pan de la littérature en proposant un nouveau test fondé sur les déviations minimales des paramètres permettant au portefeuille de marché de se situer sur la frontière efficiente : « celui-ci pourrait être efficient d'un point de vue moyenne-variance après tout ». Eu égard aux nombreux résultats (Gibbons, 1982; Gibbons *et al.*, 1989; MacKinlay et Richardson, 1991; entre autres) établissant que le portefeuille de marché n'est pas efficient et aux autres méthodologies disponibles (Basak *et al.*, 2002), une étude de la puissance des tests d'efficience moyenne-variance en l'absence d'actif sans risque apparaît nécessaire.

[4] De nombreux tests d'efficience moyenne-variance ont été proposés lorsqu'un actif sans risque est disponible dans l'univers d'investissement : Gibbons (1982), Jobson et Korkie (1982), Gibbons *et al.* (1989), MacKinlay and Richardson (1991). Parmi eux, le test de Gibbons *et al.* (1989) est devenu le test le plus utilisé dans la littérature empirique.

3. Les études empiriques menées sur l'ISR

Les nombreuses questions théoriques posées par l'ISR rendent nécessaires l'établissement d'investigations empiriques poussées, notamment en ce qui concerne les performances financières. Les études empiriques de rendements menées sur l'ISR sont de deux types : elles portent soit sur des fonds, soit sur des titres individuels. Alors qu'il existe des dizaines de travaux sur les premiers, les études sur les derniers sont beaucoup plus rares. La principale raison à cela est que les historiques d'indicateurs socialement responsables sont souvent de très faible taille et ne permettent pas d'effectuer une étude statistique satisfaisante. C'est notamment pour cette raison qu'il est encore très difficile de comprendre les liens entre performances extra-financières et performances financières des titres.

Le travail de Derwall *et al.* (2005) est pionnier dans cette veine de la littérature : les auteurs montrent que les actions des entreprises ayant les meilleures notations environnementales surperforment nettement celles des entreprises mal notées. Plusieurs autres travaux (Galema *et al.*, 2008; Kempf et Osthoff, 2007; Statman et Glushkov, 2009; Edmans, 2010) mettent en évidence l'existence d'une relation positive ou au pire non significative, entre les performances de l'action des entreprises et ses notations socialement responsables (environnement, relations avec les employés, diversité, droits de l'homme, gouvernance d'entreprise). En ce qui concerne les filtres négatifs, les résultats de la littérature sont unanimes (Kempf et Osthoff; 2007 ; Fabozzi *et al.*, 2008 ; Hong et Kasperczyk, 2009 ; Statman et Glushkov, 2009 ; entres autres) : ainsi que nous l'avons précédemment mentionné, les actions des entreprises de secteurs controversés (tabac, alcool, jeu, armement, nucléaire, biotechnologies, pornographie) obtiennent des rendements plus élevés que les autres. Enfin, Galema *et al.* (2009) adoptent un point de vue différent et se focalisent sur la perte en termes de diversification à exclure des titres non responsables de l'univers d'investissement : pour ce faire, ils mettent en œuvre la technique des « spanning tests » d'Huberman et Kandel (1987) qui permet de tester si la frontière efficiente construite à partir de N titres est significativement modifiée si on ajoute K titres à l'univers d'investissement.

Les études empiriques de performances des fonds ISR offrent des résultats parfois contradictoires. Ils dépendent notamment des pays et périodes considérés (Renneboog *et al.*, 2008b). De nombreuses études (Hamilton *et al.*, 1993; Goldreyer et Diltz, 1999; Statman, 2000; Bello, 2005 ; Renneboog *et al.*, 2008b) montrent que les performances des fonds ISR aux Etats-Unis ne sont pas statistiquement différentes de celles des fonds non-ISR de caractéristiques équivalentes. Bauer *et al.* (2005) montrent, pour leur part, que les fonds ISR aux Etats-Unis et en Allemagne ont connu une phase d'apprentissage : après avoir fortement sous-performé les fonds équivalents non-ISR au début des années 1990, ils ont obtenu des performances équivalentes à la fin des années 1990. En étudiant une base de données couvrant quasiment tous les fonds ISR du monde, Renneboog *et al.* (2008b) montrent que les fonds ISR sous-performent significativement des fonds équivalents non-ISR en France, en Irlande, en Suède et au Japon. A tout le moins, ces auteurs montrent que ces fonds sous-performent fortement leurs *benchmarks* en Europe, en Amérique du Nord et en Asie, ce qui accrédite selon eux l'hypothèse selon laquelle les investisseurs seraient prêts à supporter un coût financier pour investir de façon responsable. Un des inconvénients majeurs de ce type d'études est qu'elles assimilent des fonds ISR avec des objectifs et des processus très différents (fonds à exclusion et fonds du type « best-in-class »), ce qui limite quelque peu la portée de leurs conclusions. De façon intéressante, Goldreyer et Diltz (1999) montrent que les fonds ISR actions appliquant des filtres positifs obtiennent de meilleures performances que ceux appliquant des filtres négatifs. Malheureusement, l'amélioration méthodologique des études de performances de fonds ISR comme la comparaison de fonds aux caractéristiques plus similaires bute sur la rareté des données publiquement disponibles.

En termes de classe d'actifs, les études empiriques consacrées à l'ISR concernent quasi-exclusivement la classe des actions. Pourtant, 53% des montants investis dans les fonds ISR en Europe le sont en obligations contre 33% seulement pour les actions (Eurosif, 2010). La littérature empirique sur les fonds ISR investis en obligations est très limitée. Les études de Derwall et Koedijk (2009) et Bauer *et al.* (2009) font exception. Pour un panel de fonds américains sur la période 1997-2003, Derwall et Koedijk (2009) montrent que les fonds obligataires ISR n'obtiennent pas de rendements significativement différents des fonds obligataires équivalents. En étudiant un échantillon large d'obligations d'entreprises américaines sur la période 1995-2006, Bauer *et al.* (2009) montrent, quant à eux, que les entreprises les mieux évaluées pour la qualité de la relation avec les employés ont un risque de crédit plus faible. De façon surprenante, les études portant sur les fonds ou portefeuilles ISR constitués d'obligations d'Etat n'ont reçu que très peu d'attention dans la littérature. Erb *et al.* (1996) ont étudié les performances de différentes stratégies d'investissement en obligations d'Etat en fonction des indicateurs de risque-pays « International Country Risk Guide » (ICRG) : ils montrent qu'investir dans les obligations des pays dont la notation ICRG s'améliore apporte des performances significativement meilleures qu'investir dans les obligations des pays dont la notation se détériore. Connolly (2007) met, quant à lui, en évidence un lien statistique fort entre la notation de crédit des Etats et l'indicateur de corruption publié par l'organisation non-gouvernementale *Transparency International*. Ces résultats donnent certaines intuitions sur l'ISR en obligations d'Etat mais, globalement, de nombreuses pistes de recherche sont encore à explorer sur le sujet. En particulier, perd-on en termes de diversification lorsque l'on applique des filtres socialement responsables à un portefeuille d'obligations d'Etat ?

4. Questions de recherche et plan de thèse

Ma thèse tente d'apporter des éléments de discussion sur le thème de la sélection de portefeuille dans le cadre de l'ISR. Dans un premier chapitre, je m'intéresse à la perte en termes de diversification lorsque l'on cherche à améliorer la notation extra-financière moyenne d'un portefeuille d'obligations d'Etat. Je mets en évidence dans le chapitre 2 que le coût théorique à investir de façon responsable dépend de façon cruciale de l'aversion au risque de l'investisseur : je détaille dans quels cas les investisseurs averses au risque sont pénalisés ou non. Une application numérique illustre que surpondérer les actifs « responsables » dans un portefeuille pénalise tantôt plus les investisseurs présentant de l'aversion pour le risque que les investisseurs tolérant du risque et tantôt l'inverse. Enfin, le chapitre 3 étudie la robustesse des tests d'efficience moyenne-variance lorsqu'il n'existe pas d'actif sans risque. Cela permet d'appréhender de façon robuste la question du coût, en termes de diversification, de la prise en compte d'indicateurs socialement responsables dans la sélection de portefeuille. Dans la suite de cette introduction, je détaille le cadre d'analyse et les principaux éléments de conclusion des trois chapitres.

Le premier chapitre de cette thèse consiste en l'étude empirique d'un portefeuille ISR d'obligations d'Etat de pays développés. La littérature financière a, pour l'instant, accordé très peu d'attention à la mise en place de l'ISR sur le marché des obligations souveraines. Ceci est d'autant plus troublant qu'en ces temps de crise de la dette publique en Europe, la question de la gouvernance publique est sur le devant de la scène. Dans ce chapitre, j'étudie comment la frontière efficiente calculée à partir des rendements d'obligations d'Etat de vingt pays développés est modifiée par la prise en compte d'indicateurs socialement responsables dans le processus d'investissement. Les notations *Sustainable Country Ratings* de l'agence de notation extra-financière Vigeo y sont utilisées pour la première fois dans la littérature économique. Je montre qu'il est possible d'augmenter de façon substantielle la notation Vigeo moyenne du portefeuille sans perdre significativement en efficience dans le cadre moyenne-variance. Ce résultat diffère selon que l'on considère un indicateur de performances environnementales, sociales ou de gouvernance publique.

L'objectif du deuxième chapitre est de conceptualiser la modification de la sélection de portefeuille de type moyenne-variance induite par la considération d'indicateurs socialement responsables. En faisant l'hypothèse d'efficience des marchés, investir préférentiellement dans des entités socialement responsables (actions, obligations d'Etat ou d'entreprise) a pour conséquence de restreindre les possibilités d'investissement. Pour cette raison, j'explore les implications de la prise en compte d'un seuil minimal sur la notation socialement responsable moyenne du portefeuille dans le cadre moyenne-variance de Markowitz (1952, 1959). Les notations socialement responsables sont introduites dans l'optimisation moyenne-variance par le biais de contraintes linéaires. Dans ce cadre, je montre que le coût à investir de façon responsable diffère assez largement en fonction de l'aversion au risque de l'investisseur. Dans certaines configurations, les investisseurs présentant de l'aversion vis-à-vis du risque sont les plus pénalisés alors que c'est le contraire dans d'autres cas. Je montre que la relation entre les notations socialement responsables et les rendements attendus des actifs détermine si la frontière efficiente est plus pénalisée en bas ou en haut. En mettant en évidence précisément les situations dans lesquelles l'ISR est couteux, ces résultats aident à interpréter l'apparente contradiction trouvée dans la littérature sur le fait que l'ISR réduise ou non le pouvoir de diversification d'un portefeuille.

Enfin, étant donné le caractère central des performances financières des portefeuilles ISR, le dernier chapitre s'attache à la mesure de l'efficacité des tests d'efficience moyenne-variance d'un portefeuille donné dans l'hypothèse réaliste où il n'existe pas d'actif sans risque. Récemment, le débat lié à l'efficience du portefeuille de marché a été ravivé par Levy et Roll (2010) qui suggèrent qu' « après tout, le portefeuille de marché pourrait être efficient d'un point de vue moyenne-variance » alors qu'une abondante littérature s'accordait jusqu'ici à affirmer le contraire. Ce chapitre propose notamment un nouveau test d'efficience fondé sur la distance verticale du portefeuille à la frontière efficiente dans le plan moyenne-variance. Cette distance a été suggérée par plusieurs auteurs (Kandel et Stambaugh, 1995; Wang, 1998; Li *et al.*, 2003) pour mesurer l'inefficience d'un portefeuille mais il n'existe pas de test fondé sur elle. Des simulations de Monte Carlo montrent que notre test obtient de meilleures performances que les autres tests pour des échantillons larges puisque sa taille est plus petite pour une puissance comparable. Nous proposons une application numérique au marché d'actions américain qui montre que le portefeuille de marché n'est pas efficient d'un point de vue moyenne-variance, ce qui revient à rejeter le « zero-beta CAPM ».

General Introduction

"The life of money-making is one undertaken under compulsion, and wealth is evidently not the good we are seeking; for it is merely useful and for the sake of something else."
Aristotle, *Nicomachean Ethics*, Book I, Chapter 5

"Socially Responsible Investing can be a tool for dialogue between corporations and society."
Amy Domini, founder, Domini Social Investments

"The social responsibility of business is to increase its profits."
Milton Friedman

In modern financial theory, investors choose investments for their portfolios strictly on the basis of financial parameters, i.e. their own aversion to risk and the financial characteristics of the securities available in their economic sphere. The advent of socially responsible investing (SRI) provides a vast and new field for research into portfolio selection because, as we shall see, investors also take extra-financial factors into consideration in their decision-making process. They determine the assets' weights by considering ethical, environmental, social and/or governance criteria. SRI asks stimulating questions to theoreticians and practitioners about how to conciliate financial and extra-financial indicators. How to integrate the wish of investing responsibly in the utility function usually associated with an investment? Is this possible to compose a portfolio in accordance with one's values without financial sacrifice? It this possible to obtain higher financial returns by investing responsibly? This PhD thesis aims at proposing some answers to these questions. In particular, it explores the theoretical and empirical consequences of including social responsibility indicators in a conventional portfolio selection process.

In the remainder of this general introduction, I propose to give a short overview of the state of the art about research on SRI. The first section exposes how the SRI industry is structured and the importance it gets on the global financial markets. The next section shows that portfolio selection modelling in the framework on SRI depend on the investors' objectives and on the fact that they are ready or not to sacrifice financial returns. The third section summarizes the main results of empirical studies on SRI and underlines the difficulties related to their interpretation. The last section proposes my research questions and announces the general plan of this PhD.

1. The socially responsible investment

The objective of this section is to precise the organization and practices of SRI within the financial industry. As investing responsibly does not mean the same for everyone and as SRI players are very heterogeneous (Sandberg *et al.*, 2009), several types of responsible investments developed and coexist. In its most basic form, SRI means that investors exclude securities issued by any company or government that does not comply with their own moral and/or ethical values[1]. This is known as using negative screens. The most widely used filters screen out the tobacco, alcohol, arms, gaming, nuclear and pornography industries. When ruling out certain stocks, the socially responsible investor's subjectivity comes into play in determining the investment universe. Once stocks have been excluded, the investor turns to theory to determine the composition of the portfolio, using a Markowitz-inspired mean-

[1] As Renneboog *et al.* (2008a) have indicated, ethical investing has its origins in Jewish, Christian and Muslim traditions. Judaism in particular has many thoughts on the ethical use of money.

variance optimisation (1952, 1959). In practice, so-called ethical exclusion funds are very often set up on the initiative of religious groups, with moral or ethical criteria for exclusion (Renneboog *et al.*, 2008a). One of the best publicised examples[2] involves divestment from firms doing business in South Africa to protest the discriminatory policies of the apartheid regime (Ennis and Parkhill, 1986; Grossman and Sharpe, 1986; Wagner *et al.*, 1986). This view of SRI was considered too restrictive by a broad category of investors sensitive to positive and negative externalities that are produced by firms or governments but are not necessarily related to moral or religious values. These typically concern environmental factors.

In particular, firms may implement projects to exercise an influence on public property or on the wellbeing of agents other than their own shareholders. The desire to invest preferentially in entities with the most socially responsible practices has led to the creation of a second generation of SRI practices, sometimes called best-in-class. The direct ambition of this version of SRI is to contribute to social change and to promote the best company and government practices. The process starts with the observation that the externalities and non-financial characteristics to be followed and/or taken into account vary with the nature of the underlying investment (was a security issued by a company or a government?; what is the business sector of the company under consideration?; is the country a developed or emerging economy?). Investors select from a homogeneous category of securities those that represent the entities with the best practices. They then overweight these securities in their portfolios, without automatically excluding the least responsible entities. However, there is no consensus in the financial industry as to which non-financial (or sustainability) indicators are the most relevant or how they should be incorporated into the investment process. Three groups of sub-criteria are often used: environmental, social and governance (ESG) factors. Investors may

[2] Pax World Fund, an investment fund established in 1971, is widely recognised as the first “modern” SRI fund. Founded by investors opposed to the Vietnam war, its investment choices avoid the armaments sector.

weight these ESG criteria as they see fit. This is known as using positive filters. As is the case when assessing companies' and governments' financial risks, the financial industry frequently relies on credit rating agencies to evaluate non-financial performance (Arjaliès, 2010). The quantitative indicators that make up these ratings are supposed to reflect the non-financial "value" of the company or government. Besides, like credit ratings, social ratings produced by rating agencies are sometimes criticized (Igalens and Gond, 2005; Chatterji *et al.*, 2009).[3]

Later versions of SRI funds consist of combinations of negative and positive filters and sometimes integrate shareholder activism. The principle of shareholder activism is to use the voting rights attached to a company's shares to try to influence its corporate governance or its social and/or environmental policies. Shareholder activism contrasts with former versions of SRI as it directly tries to lead to a social change (Gollier and Pouget, 2009). The best-known example is that of CalPERS, the California state employees' pension fund, whose shareholder proposals are very frequently adopted (Smith, 1996; Barber, 2007).

The reach of SRI into global financial markets has broadened considerably in recent years. At end-2009, investments in socially responsible funds amounted to $3.07 trillion in the USA (Social Investment Forum, 2010) and €5 trillion in Europe (Eurosif, 2010). Many initiatives to promote SRI have been launched. Investors' associations emerged to define large guidelines for the SRI movement. In many countries, public authorities took dispositions to encourage the supply of SRI funds by asset managers (Arjaliès, 2010). The most significant initiative on the international scale is the creation of the Principles for Responsible Investment (PRI), which investors commit to comply with in their investment processes. By April 2011, 850 investment firms in 45 countries representing $25 trillion in assets under management had

[3] Credit ratings are often criticized because they would not predict credit events properly. Interestingly, Chatterji *et al.* (2009) show that the environmental ratings produced by the US agency KLD explain well the past environmental performances of companies but badly predict future performances.

signed the PRI. Given the amounts involved, there is an obvious need for new theoretical and empirical investigations into portfolio selection for SRI purposes.

2. How to integrate SRI in portfolio selection

The best method for applying social responsibility indicators to modelling portfolio selection depends on the investor's objectives. Many authors (Beal *et al.*, 2005; Landier and Nair, 2008; Nilsson, 2009; Sanderg *et al.*, 2009; Derwall *et al.*, 2011) agree that "responsible" investors have very disparate objectives. Beal *et al.* (2005) identify three reasons why investors want to invest in a responsible manner: earning higher returns, receiving non-financial benefits and contributing to social change. Along the same lines, Landier and Nair (2008) distinguish three types of responsible investors: those who invest responsibly because they believe they will be able to maximise financial return, those who do not want their portfolios invested in activities that clash with their values, and those who wish to invest responsibly at no cost. Derwall *et al.* (2011) also describe segmentation of the SRI investor class. They contrast investors who tolerate losses in financial performance in exchange for non-financial utility with investors who choose to invest responsibly to boost returns. In realitu, the balance between responsible and financial motivations is most likely a continuum (Bollen, 2007; Derwall *et al.*, 2011). In other words, both financial returns and non-financial benefits are important to the investor.

It is clear that the issue of the financial performances of SRI funds is key. Of course, it is key for investors interested in SRI because they believe it is a way to maximize the returns of their investment. But is it also key for the group of responsible investors driven by extrafinancial concerns because they want to quantify the cost of investing responsibly: some even refuse to invest in SRI funds if they would incur a financial cost.

As a result, SRI modelling presents a challenge to standard financial theory. With the mean-variance portfolio selection principle developed by Markowitz (1952, 1959), the investor is assumed to be maximising the expected return on his investment for a predetermined volatility level based on his (financial) risk aversion, or equivalently, minimising the volatility of his investment for a predetermined expected return. Apart from the choice of the investment universe, the only parameter involving the investor's intrinsic nature is risk aversion. SRI complicates traditional mean-variance optimisation by introducing a subjective, investor-specific dimension: his personal definition of what is or is not socially responsible, as well as his view of how to take these notions into consideration in portfolio selection.

From the point of view of portfolio selection, not investing in "irresponsible" assets or overweighting the most "responsible" assets restricts the investment universe and should thus lead to a loss in terms of diversification. Assuming that markets are efficient, "responsible" portfolios should achieve financial performance that is either equivalent to or not as good as that of conventional portfolios. It is possible to take this reasoning one step further. If the proportion of uncompromising investors using responsible filters is large enough, excess demand for "responsible" securities and reduced demand for "irresponsible" ones may lead to significant changes in asset prices (Heinkel *et al.*, 2001). Thus, Angel and Rivoli (1997) and Hong and Kasperczyk (2009) predict that "socially controversial" securities, i.e. those that some investors avoid holding in their portfolios because of their convictions, should have better expected returns because they trade at a discount. This expected additional return grows in line with the proportion of investors who act in this way. These assumptions are well corroborated empirically (Kempf and Osthoff, 2007; Fabozzi *et al.*, 2008; Hong and Kasperczyk, 2009; Statman and Glushkov, 2009; and others): after controlling for various factors, shares of companies in controversial sectors such as tobacco, alcohol, gaming, arms, nuclear power, biotechnology and pornography achieve higher returns than other stocks.

However, many fund managers affirm that "responsible" assets can earn better financial returns than others, what is usually described by the expression "doing well by doing good". The underlying idea reflects an error in return expectations. Social responsibility indicators contain information that has financial value, to which non-"responsible" investors do not have access (Derwall *et al.*, 2011). In the case of a company, this hypothesis may only hold if the future cash flows depend on extra-financial performances, for instance ESG criteria, and if stock prices does not reflect this information. As a result, selecting securities based on social responsibility indicators, at least in part, may deliver better financial returns. However, this possible causal link is not well understood and is one of the most significant areas for SRI research (Renneboog *et al.*, 2008a; Derwall *et al.*, 2011).

Several aspects of SRI portfolio selection are still unexplored. I know of no theoretical models of second-generation SRI in which investors overweight the securities of the most responsible entities. For practitioners, it would be interesting to determine the theoretical level at which a socially responsible rating requirement triggers a financial cost. Moreover, does this requirement incur a cost for the investor in every situation? Moreover, and surprisingly, the role of risk aversion is generally omitted from the literature on SRI. Farmen and Van Der Wijst (2005) note that this parameter plays a role in SRI but they do not examine it in detail. Are risk-averse investors theoretically at a comparative disadvantage because of their desire to invest "responsibly?". Or are all investors equal regardless of their level of risk aversion?

Finally, the question of portfolio efficiency is crucial for a certain proportion of responsible investors who are unwilling to invest in socially responsible portfolios that are not efficient from a financial standpoint. In this regard, it is important to have mean-variance efficiency tests that are as robust as possible. But most of the tests are designed for investment universes in which a risk-free asset exists,[4] when in practice the risk-free asset assumption can be seriously questioned. Europe's ongoing government debt crisis shows that even the assets considered the safest, namely developed country government bonds, are subject to default risk. Moreover, the seizing-up of money markets and the collapse of Lehman Brothers in September 2008 highlighted the counterparty and liquidity risks associated with this type of investment (Acharya *et al.*, 2010; Bruche and Suarez, 2010; Krishnamurthy, 2010). For these reasons, it seems more realistic to test portfolios' mean-variance efficiency under the assumption that there is no risk-free asset, thereby testing Black's Zero-Beta Capital Asset Pricing Model (1972). In fact, very little attention has been paid to these tests in comparison with those whose framework assumes the existence of a risk-free asset, particularly as regards their robustness. Recently, Levy and Roll (2010) revived this branch of the literature when they proposed a new test based on the minimal deviations in the parameters that would put the market portfolio on the efficient frontier: "The market portfolio may be mean/variance efficient after all." Considering the many findings showing that the market portfolio is not efficient (Gibbons, 1982; Gibbons *et al.*, 1989; MacKinlay and Richardson, 1991; and others), as well as the other available methodologies (Basak *et al.*, 2002), it seems necessary to study of the power of mean-variance efficiency tests in the absence of a risk-free asset.

[4] Many mean-variance efficiency tests have been proposed when a risk-free asset is available in the investment universe: Gibbons (1982), Jobson and Korkie (1982), Gibbons *et al.* (1989), MacKinlay and Richardson (1991). Of these, the test proposed by Gibbons *et al.* (1989) has become the most widely used in the empirical literature.

3. The empirical studies on SRI

The numerous theoretical questions arising from the advent of SRI make deep empirical investigations necessary, notably concerning financial returns. Empirical studies of SRI returns focus either on funds or on individual securities. Although scores of studies have been done on funds, those on individual securities are few and far between. The main reason is that data series for social responsibility indicators are often very modest in size and do not permit adequate statistical analysis. This is why it is still so difficult to understand the links between securities' financial and non-financial performance.

Derwall *et al.* (2005) broke new ground in this area of the literature, showing that shares of companies with the best environmental ratings clearly outperform those of poorly rated companies. Several other works (Galema *et al.*, 2008; Kempf and Osthoff, 2007; Statman and Glushkov, 2009; Edmans, 2010) show a positive relationship – or at worst no significant relationship – between companies' share price performance and their socially responsible ratings (environment, labour relations, diversity, human rights, corporate governance). Regarding negative filters, the literature is unanimous (Kempf and Osthoff, 2007; Fabozzi *et al.*, 2008; Hong and Kasperczyk, 2009; Statman and Glushkov, 2009; and others): returns on shares of companies in controversial sectors (tobacco, alcohol, gaming, arms, nuclear power, biotechnology, pornography) are higher than those on other stocks. Lastly, Galema *et al.* (2009) adopt a different point of view and focus on the loss in terms of diversification caused by the exclusion irresponsible stocks from the investment universe: to do so, they use the spanning test methodology of Huberman and Kandel (1987) that allows to test if the efficient frontier built with N assets is significantly modified if K other assets are considered.

The evidence from studies of SRI fund performance is at times contradictory. Findings depend on the countries and time periods under consideration (Renneboog *et al.,* 2008b). Many studies (Hamilton *et al.*, 1993; Goldreyer and Diltz, 1999; Statman, 2000; Bello, 2005; Renneboog *et al.*, 2008b) show that the performance of US SRI funds does not differ statistically from that of non-SRI funds with equivalent characteristics. Bauer *et al.* (2005) show that US and German SRI funds have gone through a learning phase. After sharply underperforming equivalent non-SRI funds in the early 1990s, they achieved comparable performance in the late 1990s. A study by Renneboog *et al.* (2008b) of a database covering almost all SRI funds worldwide shows that they significantly underperform equivalent non-SRI funds in France, Ireland, Sweden and Japan. The authors show that, at the very least, SRI funds severely underperform their benchmarks in Europe, North America and Asia, and they cite this finding to support the argument that investors would be willing to bear a financial cost to invest responsibly. A major drawback to this type of study is that it lumps together SRI funds with very different objectives and processes (exclusion funds and best-in-class funds), and this seriously limits the scope of their conclusions. In an interesting study, Goldreyer and Diltz (1999) show that SRI equity funds that apply positive filters obtain better performance than those using negative filters.

In terms of asset classes, empirical SRI research focuses almost exclusively on equity. However, 53% of the amount invested in European SRI funds is in bonds compared with only 33% in shares (Eurosif, 2010). The empirical literature on bond-invested SRI funds is scant. The Derwall and Koedijk (2009) study is an exception: for a sample of US funds during the 1997-2003 period, the authors show that SRI bond funds do not obtain significantly different returns from equivalent bond funds. However, studies of SRI funds and portfolios made up of government bonds have received very little attention in the literature. Erb *et al.* (1996) studied the performance of various investment strategies using government bonds in relation to the country risk indicators of the International Country Risk Guide (ICRG). They show that investing in bonds of countries with improving ICRG ratings produces significantly better performance than investing in bonds of countries with deteriorating ratings. Connolly (2007) demonstrates a strong statistical link between governments' credit ratings and the corruption indicator published by the non-governmental organisation Transparency International. These findings provide some insights into SRI in government bonds, but globally, many avenues of research have yet to be explored on this topic. In particular, is there a loss of diversification when social responsibility filters are applied to a government bond portfolio?

4. Research questions and general plan of the PhD thesis

My thesis attempts to provide input for the discussion of portfolio selection for SRI purposes. In the first section, I examine whether seeking to improve a government bond portfolio's average sustainability rating results in a loss of diversification. In Chapter 2, I show that the theoretical cost of investing responsibly depends crucially on the investor's level of risk aversion: I detail cases in which risk-averse investors are or are not penalised. A digital application illustrates that overweighting "responsible" assets in a portfolio sometimes hurts risk-averse investors more than risk-tolerant investors and at other times the opposite. Finally, Chapter 3 proposes a new mean-variance efficiency test in the absence of a risk-free asset, to facilitate more robust estimation of whether there is a loss of diversification when social responsibility indicators are taken into account in portfolio selection. Later in this introduction, I detail the analytical framework and the main conclusions of these three chapters.

The first chapter of this thesis consists of an empirical study of an SRI portfolio of developed-country government bonds. The financial literature has thus far paid very little attention to implementing SRI on the sovereign bond market. This is especially worrying because in these times of government debt crisis in Europe, the question of public governance is in the limelight. In this chapter, I examine how the efficient frontier calculated from returns on the government bonds of 20 developed countries is modified by taking social responsibility indicators into account in the investment process. Here, for the first time in the economic literature, I use the Sustainable Country Ratings produced by Vigeo, a sustainability rating agency. I show that it is possible to substantially increase the portfolio's average Vigeo rating without a significant loss of mean-variance efficiency. This finding differs depending on the choice of an indicator of environmental, social or governance performance.

The objective of the second chapter is to conceptualise the modification of mean-variance portfolio selection when social responsibility indicators are taken into consideration. The efficient market hypothesis implies that investing preferentially in socially responsible entities (equities, government and corporate bonds) limits investment possibilities. For this reason, I explore the implications of setting a minimum threshold for the portfolio's average social responsibility rating within the mean-variance framework developed by Markowitz (1952, 1959). Social responsibility ratings are introduced into the mean-variance optimisation through linear constraints. Within this framework, I show that the cost of investing responsibly varies quite widely depending on the investor's risk aversion. In certain configurations, risk-averse investors suffer the most, while the opposite is true in other cases. I demonstrate that the relationship between social responsibility ratings and expected asset returns determines whether the impact on the efficient frontier is heavier at the lower or upper bounds. Because these findings are based on precisely the situations in which SRI involves costs, they help us understand the apparent contradiction in the literature on whether SRI reduces a portfolio's diversification power.

Finally, given the central importance of SRI portfolios' financial performance, the final chapter looks at measuring the performance of mean-variance efficiency tests for a given portfolio under the realistic assumption that there is no risk-free asset. Recently, the debate over the efficiency of the market portfolio has been revived by Levy and Roll (2010), who suggest, "The market portfolio may be mean/variance efficient after all," despite the abundant literature thus far united in affirming the opposite. In particular, this chapter proposes a new efficiency test based on the portfolio's vertical distance from the efficient frontier in the mean-variance framework. Several authors (Kandel and Stambaugh, 1995; Wang, 1998; Li *et al.*, 2003) have suggested using this distance to measure a portfolio's inefficiency, but no test based on it exists. Monte Carlo simulations show that our test obtains better performance than other tests for large samples, because it achieves comparable power at smaller size. The digital application that we propose for the US equity market shows that the market portfolio is not mean-variance efficient. This amounts to rejection of the Zero-Beta Capital Asset Pricing Model.

Chapter 1

Sovereign Bonds and Socially Responsible Investment [1]

1.1. Introduction

Little attention has been paid to the link between sovereign bond returns and the performance of states in terms of environmental, social and governance (ESG) issues. This is striking, considering the considerable share of the sovereign bond market in the global capital markets and the boom of the Socially Responsible Investment (SRI)[2] segment. This is all the more striking since governments have the power to improve regulations related to ESG criteria. However, as many asset managers have signed up to the Principles for Responsible Investment (PRI),[3] there is a crucial need to investigate the link between the financial performance of sovereign bonds and extra-financial SRI factors. The objective of this chapter is to assess the possibility of increasing the socially responsible value of a sovereign bond portfolio without a significant loss of diversification in the mean–variance plan.

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[1] This chapter is based on Drut (2010a). I thank Ariane Szafarz, Marie Brière, Ombretta Signori, Valérie Mignon, Kim Oosterlinck, Luc Renneboog, Kokou Topeglo and all the participants of the 2nd PRI Academic Conference for their helpful comments. I specially thank the extra-financial rating agency Vigeo for supplying its Sustainability Country Ratings and Vigeo's employees for their availability.

[2] SRI is defined by the European Social Investment Forum (2008) as "a generic term covering ethical investments, responsible investments, sustainable investments, and any other investment process that combines investors' financial objectives with their concerns about environmental, social and governance (ESG) issues". In practice, SRI has taken various forms, including negative screening, positive screening, and shareholder activism. See Renneboog *et al.*, (2008,a) for a concise description of the successive generations of SRI.

[3] PRI is a joint initiative of the United Nations Environment Programme Finance Initiative (UNEPFI) and the United Nations Global Compact (2005). According to the PRI, investors "will incorporate ESG issues into investment analysis and decision-making process", "support development of ESG-related tools, metrics and analyses", and "encourage academic and other research on this theme".

A lively and ongoing debate is taking place on the financial performances of SRI. Do SRI investments differ significantly from conventional investments? Do investors pay an additional price for SRI? In practice, there are two main ways to investigate this question: at the fund level and at the asset level. Bauer *et al.* (2005) find that ethical funds do not underperform conventional funds, while Renneboog *et al.* (2008b) show that SRI funds strongly underperform their domestic benchmarks. If these two studies agree on the fact that screening activities do not add value, results about the potential cost of SRI are mixed, leaving the basic question unresolved. In the particular case of fixed-income funds, Derwall and Koedijk (2009) show that SRI funds performance are not significantly different from conventional funds. Another vein in the literature studies SRI performance at the asset level: for instance, Derwall et al. (2005) link stock returns to environmental performance based on scores produced by Innovest Strategic Value Advisors,[4] an extra-financial rating agency. They show that companies with good environmental performances have significantly higher returns. Kempf and Osthoff (2007) and Statman and Glushkov (2009) extend this analysis to other dimensions of SRI, using ratings from KLD Research and Analytics, Inc.[5] They find that socially responsible portfolios obtain significantly higher returns than conventional ones. However, to the best of our knowledge, this type of analysis has not yet been applied to sovereign bond portfolios.

Few papers explore the link between sovereign bond returns and qualitative factors. Erb *et al.* (1996) exhibit a link between sovereign bond returns and country risk measured

[4] Innovest Strategic Value Advisors is an extra-financial rating agency. Among other things, it evaluates companies' environmental performances along 60 variables and gives them a score between 1 and 10.
[5] KLD Research and Analytics, Inc. is an extra-financial rating agency. It rates companies on different themes: corporate governance, community, diversity, employee relations, environment, human rights, products.

according to the International Country Risk Guide (ICRG)[6]. Portfolios invested in countries with upgraded ICRG ratings perform significantly better than portfolios of countries with downgraded ICRG ratings. Unfortunately, the study by Erb *et al.* (1996) suffers from a lack of data for several countries, due to the heterogeneous starting dates of the ICRG ratings, making it impossible to draw firm conclusions. Connolly (2007) puts forward a link between sovereign credit ratings and the corruption index measured by Transparency International's Corruption Perceptions Index[7]. While these two studies focus on governance characteristics, Scholtens (2009), assesses the environmental performances of sovereign bond funds in The Netherlands and shows that they differ according to the environmental indicator. However, despite the production of country ratings according to ESG factors for several years, no academic research has yet assessed the financial performances of responsible sovereign bond investments. Our paper aims to fill this gap. To do so, we consider the Sustainability Country Ratings (SCR) produced by Vigeo[8], which are indices meant to represent the countries' socially responsible performance; and we investigate the impact on a government bond portfolio diversification of taking socially responsible indicators into account in a portfolio process.

The question of the diversification benefits in the government bond market is well covered in the empirical literature. Levy and Lerman (1988) find, for instance, very high correlations between developed countries' government bond returns, with the notable exception of Japan. Similarly, Solnik *et al.* (1996) notice that the correlation of the major international sovereign bond indices increased over time while Cappiello *et al.* (2006) explain

[6] The ICRG rating is published by the PRS Group. It rates more than 140 countries and comprises 22 variables in three subcategories of risk: political, financial and economic.
[7] Transparency International is an international non-governmental organization addressing corruption. Each year, it publishes the Corruption Perceptions Index that uses different surveys to evaluate perceptions of the degree of corruption in 180 countries.
[8] Vigeo is an extra-financial agency that evaluates the ESG performances of companies and countries.

the rise of within-region correlation as a result of stronger homogeneity of economic conditions. However, Hunter and Simon (2004) show that the diversification benefits to US investors from investing in international government bonds are significant on a currency-hedged basis, even during periods of market weakness. [9]

In this chapter, we bridge two areas of portfolio management research: one concerning SRI, the other concerning sovereign bond diversification within a group of developed countries. We first compute the efficient frontier of portfolios including sovereign bonds from twenty developed countries[10] over the period 1995-2008. We then add a linear constraint imposing the portfolio average Sustainability Country Rating (SCR) to be above a minimum threshold. [11] We make these minimum thresholds grow and we observe the induced deformation of the efficient frontier. In theory, the stronger the constraint, the weaker the potential diversification becomes. However, in practice, the loss of mean-variance efficiency might be insignificant. To test whether SRI leads to significant losses we use the test proposed by Basak *et al.* (2002). The results show that sovereign bond portfolios with a high socially responsible component are reachable without any significant loss of diversification. This is good news for investors in the socially responsible bond market.

Our contribution is twofold. First, this chapter opens the way to analyzing sovereign bond markets in the SRI framework. Second, it uses an original dataset (the Vigeo SCR) that to our knowledge, has not been used before in a financial perspective.

[9] Though, Hanson *et al.* (2009) provide new evidence contradicting these observations, both papers share the spanning test methodology proposed by De Roon and Nijman (2001) and De Roon *et al.* (2001).
[10] The same sample as Erb *et al.* (1996), that is to say: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.
[11] The particular problem of the mean-variance optimization subject to linear constraints has been studied by Black (1972) and Best and Grauer (1990).

The remainder of the chapter is structured as follows. Section 2 presents the data and describes the SCR construction. In Section 3, we present the methodology used to determine the impact of successive SCR constraints on the bond efficient frontier. The results are exposed in Section 4. Section 5 concludes.

1.2.Data

The data on sovereign bond monthly returns come from Citigroup [12] World Government Bond Index (WGBI) "All maturities", [13] downloaded from Datastream, from December 31st 1994 to December 31st 2008. We use total returns in US dollars hedged for exchange rate risk.

The SCR data are drawn at the end of 2008. The rating system is based on universally recognized social responsibility criteria. Vigeo selected criteria is based on a number of international codes and norms including: the Millennium Development Goals[14], Agenda 21[15], the International Labour Organization (ILO) conventions, the United Nations Charters and Treaties, and the OECD Guiding Principles.

For transparency reasons, Vigeo gathers only official data from international institutions and non-governmental organizations: the World Bank, the United Nations Development Program, the United Nations Environment Program, the United Nations Office on Drugs and Crime, the United Nations Children's Emergency Fund, the Food and Agriculture Organization, the United Nations Conference on Trade and Development, the

[12] Formerly from Salomon Brothers
[13] We use the "All Maturities" indexes rather than comparable maturity indexes because there was no common maturity with sufficiently long series of observations.
[14] These eight goals were established in 2000 by 189 countries as targets to be achieved by 2015.
[15] Agenda 21 on sustainable development was adopted by 179 countries in 1992 at the UN Earth Summit in Rio de Janeiro.

United Nations Department for Disarmament Affairs, the International Labour Institute, the Organisation for Economic Co-operation and Development, the Office of the High Commissioner for Human Rights, Coface, Amnesty International, Transparency International, Freedom House and Reporters Without Borders.

Three separate ratings are available as well as a composite index. The specific indexes are the Environmental Responsibility Rating (ERR), Social Responsibility and Solidarity Rating (SRSR), and the Institutional Responsibility Rating (IRR). They correspond to the three classical SRI dimensions (see Table 1 for a comprehensive list). For each rating, Vigeo has selected several criteria representing either commitments or quantitative realisations. For each criterion, countries are rated on a scale ranging from 0 to 100 (the best grade).

Table 1 Themes taken into account in the Vigeo Sustainability Country Ratings

Environmental Responsability	
Participation in International environmental conventions	Air Biodiversity Water Land Information systems
Air emissions	Climate change Ozone layer protection Local and regional air quality
Water	Measure of water withdrawal
Biodiversity	Percentage of threatened species Percentage of protected areas
Land use	Proportion of land covered by forest Evolution of the propotion of forest
Environmental pressures	Nuclear waste Energy consumption measures
Institutional responsability	
Respect, protection and promotion of civil rights	Respect, protection and promotion of human rights Respect, protection and promotion of labour rights
Democratic institutions	Political freedom and stability measure Control of corruption measure Independance of justice measure Market regulation measure Press freedom measure
Society Responsability and Solidarity	
Social protection	Inequality measure Total unemployment Youth unemployment
Education	Public education expenditure Primary school education enrolment Secondary school education enrolment
Health	Public health expenditure Mortality (Infant mortality, life expectancy) HIV/Aids prevalence rate Tuberculosis prevalence and death rates
Gender equality	Gender equality Gender enpowerment index
Development aid	Development aid measures
Safety policy	Participation in international conventions

For the commitment criteria, i.e. the signature and ratification of treaties and conventions, the grade is: 0 if the country did not sign, 50 if the country signed but did not ratify, and 100 if the country signed and ratified. For the quantitative criteria, a score is computed following the decile method: the 10 percent of worst-performing countries obtain a score of 10, and so on. Vigeo ranks not only levels but also trends computed as variation rates between the first and the last available values. More precisely, if a country's trend lies in the top 20 percent, then it benefits from a premium of ten points for the criterion at stake; if the country exhibits a negative trend, it gets a ten-point penalty.

The three specific ratings (ERR, SRSR, IRR) are weighted averages of scores. The SCR global index is an equally-weighted average of these three ratings. The advantage of using these Vigeo ratings comes from the wide spectrum of criteria taken into account. The main drawback is that, contrary to credit ratings, no historical data are available, which makes it impossible to run a dynamic analysis. Another potential problem is that the decile rankings used in the Vigeo ratings in our study could result in equivalent ratings on a given criterion for countries with very different performances.

1.3. Methodology

The purpose of our study is to determine to what extent constraints on country ratings lead to a significant loss of diversification in sovereign bond portfolios. Consider a financial market including *n* sovereign bonds, each from a different country ($i = 1, \ldots, n$). A portfolio *p* of securities is defined by the vector of portfolio weights $\omega_p = \begin{bmatrix}\omega_{p1} & \omega_{p2} & \ldots & \omega_{pn}\end{bmatrix}'$, where $\omega_{pi} \geq 0$, $\omega' \iota = 1$ and $\iota = \begin{bmatrix}1 & \ldots & 1\end{bmatrix}'$. Denote by μ the vector of expected returns and Σ the return covariance matrix of the sovereign bonds. Denote also by $\phi = \begin{bmatrix}\phi_1 & \phi_2 & \ldots & \phi_n\end{bmatrix}'$ the vector of country ratings. Similarly to Barracchini (2007) and Scholtens (2009), we define the portfolio rating ϕ_p as the weighted average rating of the corresponding countries:

$$\phi_p = \omega_p' . \phi$$

The same computation applies for all indexes in use (specific ratings EER, SRSR, IRR, or the global index: SCR). The portfolio's ratings are thus directly linked to its shares in well-rated countries.

First, we compute the true efficient frontier without any constraint on the portfolio rating, by applying the standard mean-variance optimization:

$$\begin{aligned} &\min_{\{\omega\}} \quad \frac{1}{2}\omega'\Sigma\omega \\ &subject\ \ to \quad \mu_p = \omega'\mu \\ &\qquad\qquad\quad\ \omega'\iota = 1 \\ &\qquad\qquad\quad\ \omega \geq 0 \end{aligned}$$

Then, we compute efficient frontiers with a constraint requiring the portfolio rating to be above a minimum threshold ϕ_0 :

$$\begin{aligned} &\min_{\{\omega\}} \quad \frac{1}{2}\omega'\Sigma\omega \\ &subject\ \ to \quad \mu_p = \omega'\mu \\ &\qquad\qquad\quad\ \omega'\iota = 1 \\ &\qquad\qquad\quad\ \omega \geq 0 \\ &\qquad\qquad\quad\ \phi_p = \omega'\phi \geq \phi_0 \end{aligned}$$

Opting for a higher SRI constraint restricts the set of possible combinations of sovereign bonds. This implies a move of the efficient frontier to the south-east of the mean-variance space. In order to measure the significance of the efficient frontier move, we apply the Ehling and Ramos (2006) procedure that uses the test proposed by Basak, Jagannathan and Sun (2002), referred to as the BJS test.

The BJS test is meant to test the mean-variance efficiency of a given benchmark portfolio. It is based on an efficiency measure λ defined as the difference between the variance of the efficient portfolio with the same expected return as the benchmark and the variance of the benchmark. Under the null, the benchmark is mean-variance efficient and $\lambda = 0$. BJS (2002) derive the asymptotic distribution of the sample measure of efficiency λ_T :

$$\sqrt{T}(\lambda_T - \lambda) \rightarrow N(0, \sigma^2)$$

where σ^2 is the variance of the efficiency measure and T is the sample size.

To compare two efficient frontiers, Ehling and Ramos (2006) use one of them as the reference efficient frontier and take two points of the other one as benchmark portfolios: the minimum variance portfolio and the tangency portfolio. A limitation of this methodology is that it does not capture the expected utility loss to the investor, which is a combination of the expected return and volatility. Given that the mean-variance efficiency statistics of these portfolios have no reason to be equal, Ehling and Ramos (2006) consider that the second efficient frontier is mean-variance inefficient compared to the first if one of the two benchmark portfolios is significantly inefficient according to the BJS test. We follow the same procedure here.

The WGBI index returns hedged for foreign exchange (FX) variations are used to compute the sovereign bond returns. At each date, the reference efficient frontier is built from portfolios that are fully invested in the twenty WGBI indexes, excluding short sales. Then, we compute the efficient frontier with a constraint "portfolio rating above a given threshold". We successively consider increasing thresholds, starting from the lowest rating.[16] For each of these "constrained" efficient frontiers, we run the BJS test for the two portfolios suggested by Ehling and Ramos (2006). In this way, we sequentially obtain the rating thresholds leading to the rejection of the null hypothesis of mean-variance efficiency at the respective probability levels of 10%, 5%, and 1%.

1.4. Empirical results

1.4.1. Descriptive statistics of the WGBI indexes

[16] The lowest threshold corresponds to the reference efficient frontier.

Table 2 reports the descriptive statistics of the WGBI indexes in US dollars hedged for FX variations for the period January 1995-December 2008 for the twenty study countries.

Table 2 Descriptive statistics of the WGBI indexes in US dollars hedged for FX variations, period January 1995-December 2008

	Ann. Mean	Ann. Std. Dev.	Max.	Min.	Skewness	Kurtosis
AUS	6.67%	4.38%	4.84%	-2.11%	0.50	3.39
AUT	7.09%	3.47%	4.61%	-2.05%	-0.03	3.74
BEL	7.53%	3.48%	3.50%	-1.76%	-0.16	2.92
CAN	8.16%	4.35%	4.45%	-2.15%	0.43	3.59
CHE	7.46%	3.48%	3.19%	-1.68%	-0.11	2.72
DEU	7.20%	3.35%	3.83%	-1.60%	-0.14	3.00
DNK	7.45%	3.44%	4.33%	-1.46%	0.07	3.42
ESP	7.70%	3.63%	4.04%	-1.66%	0.14	3.23
FIN	7.68%	3.37%	3.62%	-1.69%	-0.05	3.08
FRA	7.47%	3.59%	4.28%	-1.75%	-0.01	3.05
GBR	6.64%	4.77%	5.10%	-2.56%	0.11	3.20
IRL	7.32%	4.27%	4.97%	-2.03%	0.21	3.46
ITA	7.29%	3.72%	3.72%	-1.78%	0.07	2.83
JPN	7.39%	3.50%	4.80%	-4.65%	-0.18	8.97
NLD	7.42%	3.51%	4.40%	-2.00%	-0.02	3.48
NOR	6.06%	3.61%	3.84%	-3.03%	0.03	4.01
NZL	5.07%	3.84%	4.54%	-2.84%	0.55	4.46
PRT	7.48%	3.36%	3.97%	-1.86%	-0.05	3.28
SWE	8.11%	3.91%	3.81%	-2.27%	0.03	3.10
USA	7.21%	4.65%	5.41%	-4.38%	-0.15	4.48

AUS stands for Australia, AUT Austria, BEL Belgium, CAN Canada, CHE Switzerland, DEU Germany, DNK Denmark, ESP Spain, FIN Finland, FRA France, GBR United Kingdom, IRL Ireland, ITA Italy, JPN Japan, NLD Netherlands, NOR Norway, NZL New Zealand, PRT Portugal, SWE Sweden and USA United States.

Table 2 shows that the WGBI indexes offer annualized returns from 5.07%/year to 8.16%/year and volatilities from 3.35%/year to 4.77%/year for the period January 1995 - December 2008. The distribution of the returns is close to that of a normal distribution: skewness is close to 0 (except for the Australian and New Zealand indexes with skewness superior to 0.5) and kurtosis is close to 3 (except for Japan with kurtosis of 8.97). In addition, the descriptive statistics of the returns are very close for the Eurozone[17] countries, due to common monetary policy. For these countries, the annualized volatility of the WGBI indexes

[17] Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal and Spain belong to the Eurozone since the 1st of January 1999.

is very low, around 3.5%/year. The annualized volatility of the US and UK WGBI indexes is much higher than those of the other indexes. This is related to maximal monthly gains that are the highest for these two countries and should be interpreted as a particularly strong flight-to-quality phenomenon.

Table 3 reports the correlation matrix of the monthly returns. All correlation pairs are positive. Correlations are higher between geographically or culturally close countries. We roughly distinguish two homogeneous zones, a European zone and a dollar zone[18], and we find the well-known result that Japan is uncorrelated with other countries. For example, the correlations are very high within the ten countries of the Eurozone. Even within this set of similar assets, good diversification possibilities emerge. For example, the Japanese index return exhibits low correlations with all other indexes (the highest correlation of the Japanese index is 0.36 with Australia). Additionally, with the exception of the Australian index, the New Zealand index is quite weakly correlated with the others (correlation of 0.67 at most). In Europe, Norway and Switzerland also offer diversification possibilities: their correlations with the other WGBI indexes do not exceed 0.73.

Table 3 Correlation matrix of the monthly returns of the WGBI indexes in US dollars hedged for FX variations, period January 1995-December 2008

[18] That is to say: Australia, Canada, New Zealand and United States.

	AUS	AUT	BEL	CAN	CHE	DEU	DNK	ESP	FIN	FRA	GBR	IRL	ITA	JPN	NLD	NOR	NZL	PRT	SWE	USA
AUS	1.00	0.65	0.66	0.75	0.53	0.66	0.66	0.61	0.66	0.63	0.65	0.62	0.58	0.36	0.65	0.59	0.73	0.63	0.65	0.68
AUT		1.00	0.97	0.62	0.74	0.97	0.90	0.88	0.91	0.96	0.77	0.91	0.85	0.28	0.97	0.72	0.59	0.91	0.79	0.74
BEL			1.00	0.64	0.72	0.98	0.91	0.90	0.93	0.97	0.79	0.92	0.87	0.31	0.98	0.71	0.58	0.91	0.82	0.74
CAN				1.00	0.47	0.63	0.65	0.60	0.65	0.63	0.65	0.60	0.57	0.29	0.63	0.55	0.64	0.60	0.58	0.78
CHE					1.00	0.73	0.71	0.66	0.70	0.71	0.58	0.68	0.60	0.24	0.72	0.56	0.52	0.67	0.62	0.56
DEU						1.00	0.90	0.88	0.91	0.97	0.81	0.89	0.83	0.30	0.99	0.71	0.59	0.89	0.80	0.76
DNK							1.00	0.86	0.90	0.91	0.80	0.87	0.84	0.22	0.91	0.73	0.56	0.86	0.86	0.72
ESP								1.00	0.87	0.90	0.76	0.91	0.94	0.13	0.88	0.68	0.49	0.97	0.83	0.68
FIN									1.00	0.90	0.75	0.89	0.82	0.28	0.93	0.72	0.54	0.87	0.83	0.69
FRA										1.00	0.80	0.91	0.87	0.22	0.97	0.69	0.56	0.91	0.81	0.75
GBR											1.00	0.77	0.73	0.19	0.81	0.62	0.57	0.74	0.71	0.71
IRL												1.00	0.90	0.17	0.92	0.71	0.51	0.90	0.80	0.70
ITA													1.00	0.12	0.84	0.65	0.48	0.92	0.78	0.66
JPN														1.00	0.30	0.22	0.32	0.16	0.19	0.28
NLD															1.00	0.71	0.59	0.89	0.80	0.75
NOR																1.00	0.49	0.68	0.69	0.52
NZL																	1.00	0.53	0.51	0.67
PRT																		1.00	0.81	0.69
SWE																			1.00	0.60
USA																				1.00

1.4.2. Descriptive statistics of the Sustainability Country Ratings

For the twenty countries under study, the Vigeo and Standard and Poor's ratings available at the end of December 2008 appear in the Table 4.

Table 4 Vigeo and Standard and Poor's ratings at the end of December 2008

	Environmental Responsibility Rating (ERR)	Social Responsibility and Solidarity Rating (SRSR)	Institutional Responsibility Rating (IRR)	Sustainability Country Rating (SCR)	Standard & Poor's Long-term Credit Rating
AUS	57.74	72.93	91.67	74.11	AAA
AUT	67.14	77.60	97.40	80.71	AAA
BEL	52.44	85.54	89.39	75.79	AA+
CAN	48.91	78.95	83.92	70.60	AAA
CHE	74.24	79.48	91.58	81.77	AAA
DEU	61.71	76.65	94.56	77.64	AAA
DNK	60.94	84.86	97.80	81.20	AAA
ESP	52.84	77.91	92.95	74.57	AAA
FIN	65.18	84.68	97.67	82.51	AAA
FRA	60.29	80.27	91.58	77.38	AAA
GBR	64.94	81.98	94.98	80.63	AAA
IRL	51.25	82.84	92.89	75.66	AAA
ITA	54.14	77.09	85.76	72.33	A+
JPN	52.69	72.20	77.34	67.41	AA
NLD	56.80	87.71	97.18	80.56	AAA
NOR	68.30	92.89	97.64	86.27	AAA
NZL	54.20	80.46	86.00	73.55	AA+
PRT	51.67	68.54	93.60	71.27	AA-
SWE	71.05	91.18	98.45	86.89	AAA
USA	47.75	67.89	62.83	59.46	AAA
Average	58.71	80.08	90.76	76.52	
Std. Dev.	7.71	6.72	8.58	6.55	

AUS stands for Australia, AUT Austria, BEL Belgium, CAN Canada, CHE Switzerland, DEU Germany, DNK Denmark, ESP Spain, FIN Finland, FRA France, GBR United Kingdom, IRL Ireland, ITA Italy, JPN Japan, NLD Netherlands, NOR Norway, NZL New Zealand, PRT Portugal, SWE Sweden and USA United States.

Globally, all twenty countries have high ratings for the SRSR and IRR but obtain poor ratings for ERR. The dispersion of the ratings score is quite similar among the three SCR components, except IRR for which Japan and United States are well below the other countries. This dispersion shows that even if the sample countries are developed and homogeneous from a wealth point of view, there is discrimination between good and bad performers regarding ESG criteria. The Spearman’s rank correlation in Table 5 indicates that the three SCR components are certainly not perfectly correlated (the correlation ranking goes from 43.3% between ERR and SRSR to 68.9% between ERR and IRR). For these countries, the Vigeo ratings appear much more scattered than the Standard and Poor’s credit ratings; mostly because 15 countries out of 20 were rated AAA at the end of 2008. This is striking that the best and the worst Vigeo-rated countries (respectively Sweden and the United States) are both rated AAA by Standard and Poor's at the end of the year 2008.

Table 5 Spearman's rank correlation of the Vigeo ratings

	SCR	ERR	IRR	SRSR
SCR	100.0%	88.3%	84.6%	72.9%
ERR		100.0%	68.9%	43.3%
IRR			100.0%	58.1%
SRSR				100.0%

SCR stands for Sustainability Country Rating, ERR for Environmental Responsibility Rating, IRR for Institutional Responsibility Rating and SRSR for Social Responsibility and Solidarity Rating.

The analysis of the SCR confirms certain popular views: the Scandinavian countries (Denmark, Finland, Norway, Sweden) obtain the best scores for each sub-rating, with Norway and Sweden far above the other countries for the global rating (these countries are the only ones with a rating superior to the mean of the rating plus one standard deviation). The SCR also puts Japan and the United States at the bottom of the ranking. In particular, the United States is the worst-rated for each sub-rating. This position is due to the fact that the US is not a signatory to several international conventions, is a high energy-consuming economy and has weak development aid. We also notice that several South European countries (Italy, Portugal, Spain) have poor SRI scores, especially for ERR.

Some of the ratings go against popular views. Canada is often cited as an example of a sustainable country but is ranked only 18th with the SCR. Actually, Canada is rated low for the same reasons as the United States: it is also a non-signatory to several international conventions, is a high energy-consuming economy and has weak development aid. Another surprise is the poor ERR rating of The Netherlands, often praised as a green country. This could be explained by its particularly high level of carbon dioxide emissions per capita, its high consumption of ozone-depleting chlorofluorocarbons (CFC)[19] or its intensive use of pesticides, fertilizers and water in agriculture.

It is possible to distinguish several groups of countries in the Vigeo rankings displayed in Table 4: Scandinavian countries are at the top followed by Northern and Western European countries; and Southern European and Anglo-Saxon countries are at the bottom. This is obviously because the Vigeo responsible ratings and the vast majority of criteria upon which they are built relate to economic factors such as the legal environment, macroeconomic conditions and the quality of the public governance. Paldam (2002) shows for instance that the most important factor to explain the level of corruption in cross-country regressions is the GDP per capita. Moreover, some criteria used by Vigeo consist of direct measurement of the part of the government budget allocated to a given topic: i.e. development aid, education expenditures, health expenditures, etc. Therefore, it is logical that countries whose governments' objectives and priorities are similar, obtain comparable Vigeo ratings.

Because of the dispersion of the SCR, the question of how a constraint on the ratings affects diversification power is obviously relevant.

1.4.3. BJS test on SRI constraints portfolios

We first compute the static efficient frontier given by the historical returns of the twenty WGBI indexes currency-hedged without restriction on the portfolio rating. Then, we compute the efficient frontiers given by portfolios of WGBI indexes with a constraint of the type of "portfolio ratings superior to a threshold". For each threshold, we run the BJS (2002)

[19] The CFC is an organic compound that has destructive effects on the ozone layer.

test by considering the unconstrained efficient frontier as the reference and two points of the constrained efficient frontier (minimum variance and tangency portfolios) as benchmarks. To compute the tangency portfolio of the unconstrained frontier, we use the average on the sample study of the US 1 month interbank rate as risk free. The null hypothesis is the following:

H0: *"The portfolio constrained on the SCR is mean-variance efficient with reference to the unconstrained efficient frontier"*

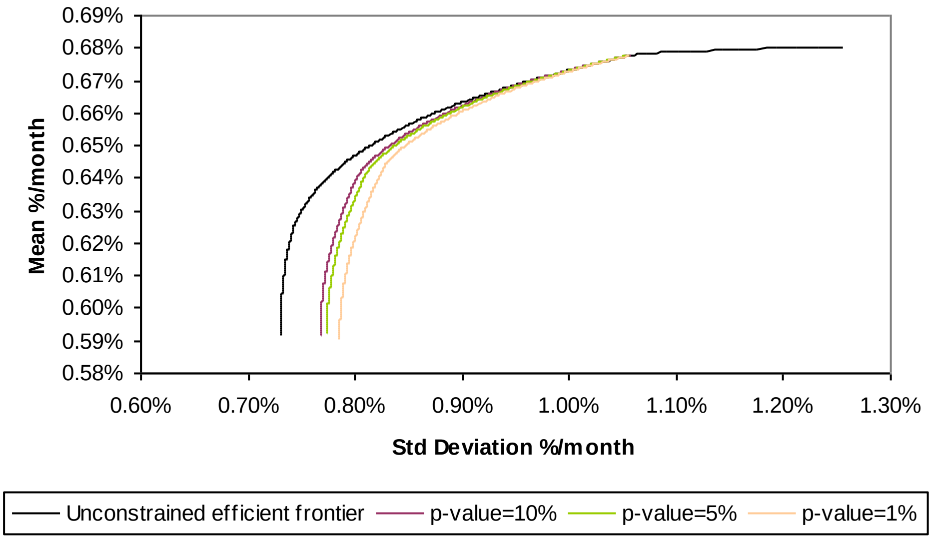
The rejection of H0 means that the constrained portfolio is not mean-variance efficient and that the constraint on the rating implies a significant loss of diversification. If H0 is not significantly rejected, it means that the mean-variance efficiency is not rejected and that socially responsible portfolios can be built without a significant diversification cost. In Table 6, we report the thresholds on portfolio ratings for which the mean-variance efficiency of the portfolios is rejected with a probability level of 10%, 5% and 1%.

Table 6 Thresholds of the portfolio rating corresponding to the rejection of H0 at the probabilities 10%, 5% and 1%

	Portfolio rating		
Minimum variance portfolio			
	Null hypothesis rejection probability		
	10%	*5%*	*1%*
Sustainable Country Rating (SCR)	79.56	80.01	80.73
Environmental Responsability Rating (ERR)	66.51	67.08	68.01
Social Responsability and Solidarity Rating (SRSR)	83.35	83.92	84.82
Institutional Responsability Rating (IRR)	90.84	91.23	91.95
Tangency portfolio			
	Null hypothesis rejection probability		
	10%	*5%*	*1%*
Sustainable Country Rating (SCR)	79.47	79.86	80.55
Environmental Responsability Rating (ERR)	67.08	67.65	68.58
Social Responsability and Solidarity Rating (SRSR)	82.72	83.23	84.10
Institutional Responsability Rating (IRR)	90.99	91.38	92.10

For each Vigeo rating, the thresholds of the portfolio rating corresponding to the rejection of H0 differ slightly between the minimum variance and the tangency portfolios: similarly to Ehling and Ramos (2006), we keep the less mean-variance efficient portfolio according to the BJS (2002) test. For the SCR, we plot in Figure 1 the constrained efficient frontiers corresponding to these rejections of mean-variance efficiency against the unconstrained efficient frontier.

Figure 1 Efficient frontiers defined by the WGBI indexes hedged for FX in US dollars with restrictions on the Vigeo Sustainability Ratings, period January 1995-December 2008



For each rating type, the thresholds of the portfolio rating corresponding to the rejection at 10%, 5% and 1% of mean-variance efficiency are very close. The efficiency measures all have a negative sign, which is expected by construction: by imposing a linear constraint on the weights of the WGBI indexes, the efficient frontier moves to the south-east in accordance with modern portfolio theory.

For each rating, we report the Vigeo ratings and the threshold on the portfolio rating corresponding to the rejection of the mean-variance efficiency at the 5% significance level (Figures 2 to 5). The portfolio rating thresholds corresponding to the rejection of the null hypothesis of mean-variance efficiency are all above the mean of the ratings of the twenty countries. Concerning the SCR, i.e. our global proxy of countries' socially responsible behaviour, only portfolios with a rating superior to 79.86 (which corresponds to the mean of the SCR of the study's countries plus 0.51 standard deviation) significantly displace the efficient frontier with a probability of 5%. This means that one can significantly improve the average rating of the portfolio without significant loss of diversification power. It is thus possible to create socially responsible portfolios of sovereign bonds without a significant diversification cost.

Figure 2 Sustainability Country Ratings and threshold on the SRI portfolio rating for the rejection of the BJS (2002) test at 5%

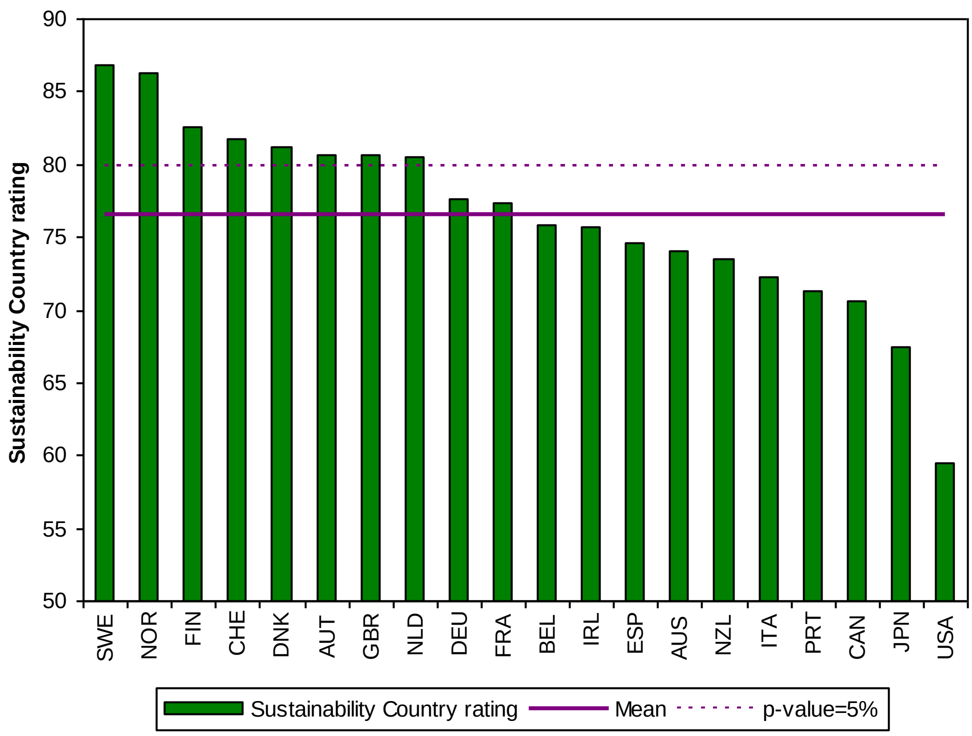


Figure 3 Environmental Responsibility Ratings and threshold on the SRI portfolio rating for the rejection of the BJS (2002) test at 5%

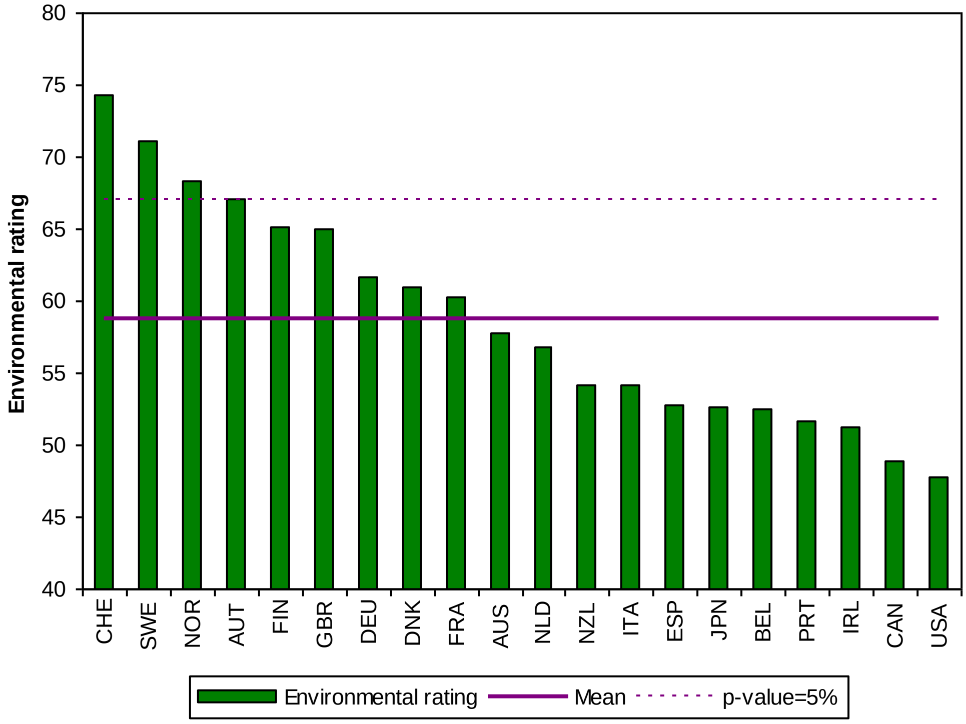


Figure 4 Institutional Responsibility Ratings and threshold on the SRI portfolio rating for the rejection of the BJS (2002) test at 5%

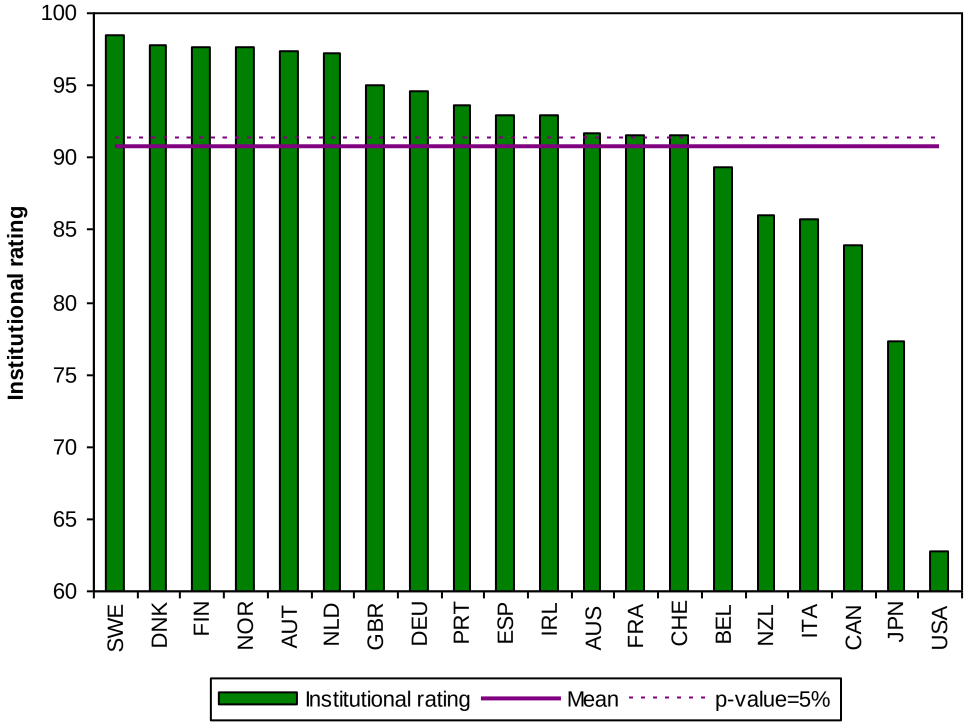
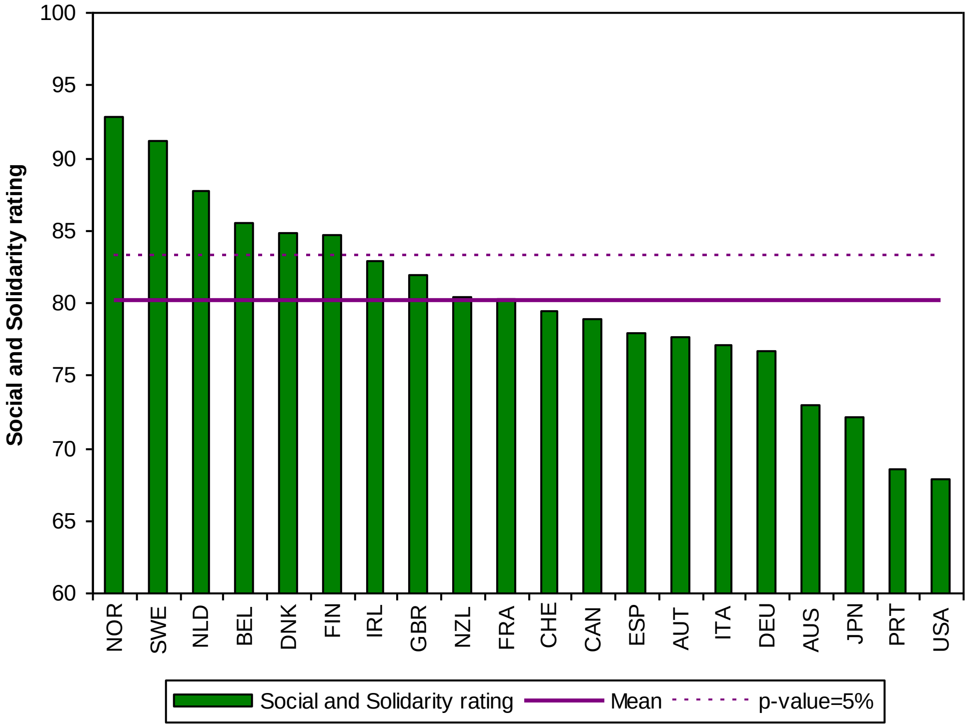


Figure 5 Social Responsibility and Solidarity Ratings and threshold on the SRI portfolio rating for the rejection of the BJS (2002) test at 5%



The possibility of improving the portfolio rating differs depending on the rating types: while it is possible to substantially increase the portfolio rating without significantly moving away from the efficient frontier for the SCR, ERR and SRSR, this is not the case for IRR. Indeed, for IRR, the portfolio rating corresponding to a rejection at a probability of 5% of the mean-variance efficiency is very close to the mean of the ratings of the sample countries. Actually, the ability to improve the average rating of the portfolio without losing diversification power depends heavily on the ratings of the countries whose sovereign bonds are the least correlated with others, that is to say Japan or New Zealand for our sample.

Table 7 Weights of the WGBI indexes in the minimum variance and tangency portfolios corresponding to the rejection of the BJS (2002) test at a probability level of 10%, 5% and 1%

	Minimum variance portfolio				**Tangency portfolio**			
	Unconstrained Frontier	Constrained Frontiers			Unconstrained Frontier	Constrained Frontiers		
		Null hypothesis rejection probability				Null hypothesis rejection probability		
		10%	5%	1%		10%	5%	1%
AUS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
AUT	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
BEL	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CAN	0.00%	0.00%	0.00%	0.00%	5.62%	0.00%	0.00%	0.00%
CHE	15.28%	25.14%	25.46%	25.72%	18.21%	25.49%	25.63%	25.88%
DEU	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
DNK	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ESP	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
FIN	0.00%	5.96%	5.09%	3.82%	0.00%	12.91%	12.23%	11.02%
FRA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
GBR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
IRL	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ITA	1.14%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
JPN	39.36%	28.29%	26.50%	22.98%	41.04%	28.24%	26.33%	22.95%
NLD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
NOR	12.03%	29.03%	30.75%	32.17%	0.00%	7.84%	8.61%	9.97%
NZL	6.89%	0.68%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PRT	25.30%	0.00%	0.00%	0.00%	27.66%	0.00%	0.00%	0.00%
SWE	0.00%	10.90%	12.20%	15.31%	7.47%	25.52%	27.20%	30.18%
USA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

For the global SCR, we report in Table 7 the composition of the minimum variance and tangency portfolios corresponding to the rejection of mean-variance efficiency at the 10%, 5% and 1% probability level and those of the unconstrained frontier. Both limited portfolios and unconstrained portfolios exclude many countries including the United States. Concerning the portfolios of the unconstrained frontier, investment is concentrated in countries (Canada, Japan, New Zealand, Norway, Portugal, Sweden, and Switzerland) whose WGBI indexes are low-correlated. There are few differences in the composition of the minimum variance and tangency portfolios. With regard to the constrained portfolios, the proportion of highly rated countries is closely linked to the constraint on the portfolio's SCR: the stronger the constraint, the higher the proportion of well-rated countries (mainly Sweden and Switzerland) and the lower the proportion of badly rated countries. Some countries included in portfolios of the unconstrained frontier are absent from the constrained portfolios (Italy, Portugal, Canada) and, on the contrary, some countries absent from the unconstrained frontier are included in the constrained portfolios (Finland in the minimum variance and the tangency portfolios and Sweden in the tangency portfolio). For Eurozone countries, it can be noticed that Portugal has a positive weight in the unconstrained portfolios, the other countries being absent, while only Finland appears in the constrained portfolios. The impact of the constraint on SCR is to concentrate the investment on Finland which is the best rated country of the Eurozone. This illustrates the importance of taking into account the link between the level of socially responsible indicators and sovereign bond correlations when building a socially responsible portfolio.

Table 8 Descriptive Statistics of the minimum variance and tangency portfolios corresponding to the rejection of the BJS (2002) test at a probability level of 10%, 5% and 1%, period January 1995-December 2008

	Minimum variance portfolio				**Tangency portfolio**			
	Unconstrained Frontier	Constrained Frontiers			Unconstrained Frontier	Constrained Frontiers		
		Null hypothesis rejection probability				Null hypothesis rejection probability		
		10%	5%	1%		10%	5%	1%
Ann. Mean	7.10%	7.10%	7.10%	7.10%	7.52%	7.52%	7.52%	7.52%
Ann. Std. Dev.	2.53%	2.66%	2.69%	2.73%	2.58%	2.72%	2.74%	2.79%
Max.	2.60%	2.56%	2.53%	2.48%	2.76%	2.76%	2.73%	2.68%
Min.	-1.86%	-1.85%	-1.85%	-1.85%	-1.85%	-1.88%	-1.87%	-1.87%
Skewness	-0.13	-0.11	-0.11	-0.11	-0.17	-0.12	-0.12	-0.12
Kurtosis	3.57	3.01	2.95	2.87	3.44	3.08	3.03	2.96
Sharpe Ratio	0.33	0.31	0.31	0.31	0.37	0.35	0.35	0.34
Vigeo SCR	73.33	79.56	80.01	80.73	72.73	79.47	79.86	80.55

In addition, descriptive statistics of portfolios' returns are available in Table 8. While the average SCR of the constrained portfolios are well improved compared to the unconstrained portfolios, their Sharpe ratios are relatively undamaged. For example, the

Sharpe ratio of the tangency portfolio of the true efficient frontier is 0.37 with an average SCR equal to 72.73 while that corresponding to the rejection of mean-variance efficiency at a probability level of 1% is 0.34 with an average SCR equal to 80.55. As we compare portfolios with equal mean returns, we observe the impact on other moments of the constraint on the average SCR: while volatility increases with the strength of the constraint (from 2.58% per year to 2.79% per year with the previous example), skewness and kurtosis decrease (respectively from -0.17 to -0.12 and from 3.44 to 2.96), making the extreme risks lower.

In the case of IRR, the difficulty of sensibly improving the portfolio rating with no undue loss of diversification power could be explained by the particularly poor performance of Japan (more than one standard deviation below the average of the countries of the sample) and the weak performance of other countries whose sovereign bonds are not closely correlated with the others, e.g. New Zealand and Canada.

As far as ERR is concerned, the possibility of substantially increasing the average SRI rating of the sovereign bond portfolio compared to the average rating of the sample countries without significantly losing diversification benefits likely comes from the not-so-bad ratings of Japan (15^{th} country) and New Zealand (12^{th}). It may also come from the particularly good performance of Switzerland (more than one standard deviation above the average rating of the countries of the sample), whose sovereign bond returns are moderately correlated with the others.

As regards SRSR and SCR, the results are intermediate with the very high ratings of Norway and Sweden (more than one standard deviation above the mean rating of the study's countries in both cases) and the very low ratings of Japan. The rejection of H0 at the 5%

probability level occurs for portfolio ratings respectively equal to 83.23 (corresponding to the mean plus 0.47 standard deviation) and 79.86 (corresponding to the mean plus 0.51 standard deviation).

1.5. Conclusion

In the current context of financial turmoil, the sovereign bond market is in the spotlight, notably because of the huge increase of public debt. The difficulties that the Greek government faced to refinance its debt at the beginning of the year 2010 illustrate the importance to consider governance indicators in the sovereign bonds portfolio management. Additionally, the considerable size of the sovereign bond market and the growing interest for SRI are strong arguments in favour of developing financial research that joins the two themes. Indeed, it is very likely that investors searching for responsible investments in the stock market would act likewise in the sovereign bond market. However, countries and companies are obviously not judged on the same criteria. For this reason, the first challenge of our study was to find appropriate country ratings that make it possible to define SRI in sovereign bonds. We have chosen the Vigeo Sustainable Country Ratings because they take into account a large set of criteria referring to environmental, social and governance issues. Moreover, we find them to be a good indicator of countries' socially responsible performance. And they are highly reliable because they use only data from international organisations such as the World Bank and various United Nations bodies.

Restricting the set of possible investments reduces the diversification possibilities and as a result displaces the efficient frontier to the south-east. Thus, in principle, requiring higher global socially responsible performances reduces the possibility of diversification. However, our results show that portfolio ratings may be improved at a very low cost, that is, without significantly displacing the efficient frontier. The consequence is that asset managers can create sovereign bond portfolios with a higher than average socially responsible rating without significantly losing diversification possibilities.

This positive result differs across the three sub-ratings of the Sustainability Country Ratings. In sum, requiring better average ratings costs more in terms of diversification for the Institutional Responsibility rating than for the Environmental Responsibility and Social Responsibility and Solidarity ratings. This shows that the investors' decisions to favour some ESG criteria rather than others may have dramatic consequences for the composition and diversification of his/her portfolio. This point is particularly important in an industry with bespoke products.

This work is in line with existing literature focusing on the potential cost associated with SRI (Adler and Kritzman, 2008; Renneboog *et al.*, 2008,b) but it brings the discussion into the sovereign bond market. As we worked only on developed countries, one interesting direction for further research would be to focus on emerging and developing countries. Indeed, the process of building sovereign bond portfolios is very different for emerging markets. We expect that the socially responsible indicators for emerging countries would be much more scattered than for developed countries and also that ESG criteria play a very different role. Another topic would be to study how to build a socially responsible portfolio containing sovereign bonds and other asset classes, for example corporate bonds, and the financial consequences of this mix. Finally, because of the relativity of individual ethics, another possible area of research is the way in which investors weight different criteria in investment selection and the implications of those weightings.

Chapter 2

SRI in the mean-variance portfolio selection framework

The first chapter indicates that a deviation from mean-variance optimality may arise due to a SR constraint. Another interesting insight is that its impact differs depending on whether the portfolio is located on the efficient frontier (at the bottom or at the top).

2.1. The empirical observation of the investor's risk aversion importance in SRI[1]

2.1.1. Introduction

With the spread of Socially Responsible Investment (SRI), a growing share of investors take into account non-financial criteria in their portfolio allocation. In practice, SRI[2] objectives appear as investors' motivations next to mean-variance optimization, thus adding complexity to asset allocation. Beal *et al.* (2005) identify three reasons for investing ethically: the hope of superior financial returns, non-wealth returns, and contribution to social change. Landier and Nair (2008) – henceforth LN - introduce an original colour code: "*red investors' sole goal is to maximize returns*", "*yellow investors want their portfolios to be exempt from*

[1] This chapter is based on Drut (2009).
[2] SRI is defined by the European Social Investment Forum (2008) as "*a generic term covering ethical investments, responsible investments, sustainable investments, and any other investment process that combines investors' financial objectives with their concerns about environmental, social and governance (ESG) issues*".

wrongly earned money", "*blue investors typically want to know how much it will cost to them to invest responsibly*". The latter consider SRI only if the financial cost is small.

An intensive stream of research[3] is devoted to the following question: is it possible to "do well by doing good"? That is to say: do socially responsible entities, companies and governments achieve superior financial returns?[4] Unfortunately, the link between socially responsible and financial performances is often difficult to identify mainly because of the lack of reliable and historic measures of SRI performances (LN, 2009). Nevertheless, it is feasible to evaluate the expected cost of a portfolio taking into account socially responsible indicators (Drut, 2009, Galema *et al.*, 2009). Surprisingly, the investor's level of risk aversion, a major parameter in portfolio management, is generally left out of the story. This note aims at filling this gap.

Contrasting with existing methodologies, this paper estimates the "SRI cost", that is the cost of investing responsibly. Estimating this cost matters because if it is low, then LN blue investors may decide to invest in SRI funds. Basically, there is no reason to expect SRI cost to be the same for every risk aversion level. To document this assertion, we take the example of sovereign bond portfolios and estimate "SRI cost" faced by investors with different risk aversion levels but all concerned by environmental issues (e.g., public policies against climate change). The Environmental Performance Index (EPI) provided by the Universities of Yale and Columbia is used to measure the countries' SRI performance.

The main results are that the "SRI cost" decreases with the investor's level of risk aversion for developed market bonds but increases with the investor's risk aversion in

[3] See Derwall et *al.* (2005) and Statman and Glushkov (2008) among others.
[4] If this statement holds, then all three Landier and Nair (2009) categories of investors should opt for SRI.

emerging bond markets: the cost of being a nice guy is lower if you are cautious for developed markets while this is the contrary for emerging markets.

This sub-chapter paper is organized as follows. Section 2 presents the sovereign bond data and the EPI index. Section 3 exposes the estimation methodology. Sector 4 reports the empirical results. Section 5 concludes.

2.1.2. Data

We consider sovereign bond indices obtained from Datastream for the period from January 1995 to June 2009. More precisely, we use World Government Bond Index (WGBI) indices of Citigroup in All Maturities[5] for the developed markets and Emerging Markets Bonds Index Global (EMBI Global) of JP Morgan for emerging markets[6]. The indices are considered in US dollars and unhedged for FX variation. Descriptive statistics are given in Tables 1 to 4.

Table 1 *WGBI indices monthly returns in US dollars*

	Ann. Mean	Ann. Std. Dev.	Skewness	Kurtosis	Maximum	Minimum
AUS	8.58%	12.12%	-0.41	4.64	10.28%	-14.64%
AUT	7.24%	11.04%	0.22	4.03	10.83%	-9.73%
BEL	7.75%	10.95%	0.29	4.00	11.18%	-9.26%
CAN	9.19%	9.04%	-0.44	5.67	7.86%	-11.88%
CHE	6.55%	12.05%	0.85	4.54	15.40%	-7.86%
DEU	7.28%	10.89%	0.36	3.94	11.54%	-8.80%
DNK	8.04%	10.91%	0.30	5.51	14.17%	-10.39%
ESP	8.73%	10.80%	0.05	4.10	10.92%	-10.20%
FIN	8.06%	10.84%	0.26	3.61	10.70%	-8.58%
FRA	7.94%	10.86%	0.30	4.10	11.81%	-9.18%
GBR	8.05%	9.15%	-0.10	3.56	7.73%	-9.08%
IRL	8.10%	11.30%	-0.29	5.40	9.39%	-13.80%
ITA	9.14%	10.87%	0.06	3.79	10.37%	-10.01%
JPN	4.08%	12.23%	0.89	7.36	16.62%	-11.22%
NLD	7.49%	10.98%	0.29	4.03	11.07%	-9.22%
NOR	7.48%	11.06%	-0.01	4.01	9.89%	-11.31%
NZL	8.24%	12.93%	-0.21	4.49	11.32%	-13.81%
PRT	8.55%	10.84%	0.09	4.05	10.98%	-9.89%
SWE	7.62%	11.43%	0.18	3.20	9.73%	-8.77%
USA	6.65%	4.76%	-0.18	4.27	5.41%	-4.38%

Note : AUS stands for Australia, AUT Austria, BEL Belgium, CAN Canada, CHE Switzerland, DEU Germany, DNK Denmark, ESP Spain, FIN Finland, FRA France, GBR United Kingdom, IRL Ireland, ITA Italy, JPN Japan, NLD Netherlands, NOR Norway, NZL New Zealand, PRT Portugal, SWE Sweden and USA United States.

[5] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.
[6] Argentina, Brazil, Bulgaria, China, Ecuador, Mexico, Panama, Peru, Philippines, Poland, Russia, South Africa, Venezuela.

Table 2 *WGBI correlation matrix*

	AUS	AUT	BEL	CAN	CHE	DEU	DNK	ESP	FIN	FRA	GBR	IRL	ITA	JPN	NLD	NOR	NZL	PRT	SWE	USA
AUS	100.0%	60.0%	60.0%	68.4%	45.1%	57.7%	62.4%	62.4%	60.7%	59.1%	46.8%	64.3%	63.5%	18.3%	59.0%	57.2%	80.3%	61.9%	65.4%	25.1%
AUT	60.0%	100.0%	99.6%	44.4%	89.9%	99.6%	98.6%	95.1%	96.5%	99.0%	69.5%	93.3%	86.7%	40.7%	99.7%	75.5%	67.7%	98.1%	79.9%	44.8%
BEL	60.0%	99.6%	100.0%	44.6%	90.0%	99.6%	98.8%	95.6%	97.1%	99.1%	69.8%	93.4%	87.1%	40.6%	99.8%	75.1%	67.6%	98.3%	80.3%	45.1%
CAN	68.4%	44.4%	44.6%	100.0%	28.7%	42.5%	46.7%	47.6%	48.0%	43.0%	38.8%	50.4%	46.8%	7.1%	43.9%	51.9%	55.5%	45.9%	51.8%	34.1%
CHE	45.1%	89.9%	90.0%	28.7%	100.0%	91.1%	90.0%	83.7%	86.9%	89.2%	57.6%	78.4%	73.0%	49.4%	90.0%	64.4%	57.1%	87.3%	67.1%	38.3%
DEU	57.7%	99.6%	99.6%	42.5%	91.1%	100.0%	98.7%	94.8%	96.7%	98.9%	68.7%	92.2%	85.6%	41.4%	99.8%	74.2%	66.1%	97.6%	78.9%	45.0%
DNK	62.4%	98.6%	98.8%	46.7%	90.0%	98.7%	100.0%	96.3%	96.9%	98.5%	68.1%	93.5%	88.2%	39.2%	98.8%	74.3%	69.2%	97.8%	81.5%	45.6%
ESP	62.4%	95.1%	95.6%	47.6%	83.7%	94.8%	96.3%	100.0%	95.5%	95.9%	69.0%	94.6%	94.3%	32.3%	95.1%	72.2%	66.9%	98.0%	84.8%	46.7%
FIN	60.7%	96.5%	97.1%	48.0%	86.9%	96.7%	96.9%	95.5%	100.0%	95.8%	68.9%	92.3%	86.8%	38.1%	97.0%	74.9%	66.6%	96.1%	82.8%	43.6%
FRA	59.1%	99.0%	99.1%	43.0%	89.2%	98.9%	98.5%	95.9%	95.8%	100.0%	70.0%	93.7%	88.5%	38.7%	99.0%	73.8%	66.1%	98.5%	79.8%	46.3%
GBR	46.8%	69.5%	69.8%	38.8%	57.6%	68.7%	68.1%	69.0%	68.9%	70.0%	100.0%	74.2%	68.6%	21.6%	69.4%	57.5%	52.3%	69.0%	63.7%	40.7%
IRL	64.3%	93.3%	93.4%	50.4%	78.4%	92.2%	93.5%	94.6%	92.3%	93.7%	74.2%	100.0%	92.1%	30.0%	93.1%	70.7%	66.9%	94.1%	81.9%	49.5%
ITA	63.5%	86.7%	87.1%	46.8%	73.0%	85.6%	88.2%	94.3%	86.8%	88.5%	68.6%	92.1%	100.0%	23.7%	86.2%	68.5%	64.7%	91.4%	82.4%	44.5%
JPN	18.3%	40.7%	40.6%	7.1%	49.4%	41.4%	39.2%	32.3%	38.1%	38.7%	21.6%	30.0%	23.7%	100.0%	40.6%	26.4%	28.5%	35.3%	25.9%	24.2%
NLD	59.0%	99.7%	99.8%	43.9%	90.0%	99.8%	98.8%	95.1%	97.0%	99.0%	69.4%	93.1%	86.2%	40.6%	100.0%	74.8%	67.0%	97.9%	79.7%	45.5%
NOR	57.2%	75.5%	75.1%	51.9%	64.4%	74.2%	74.3%	72.2%	74.9%	73.8%	57.5%	70.7%	68.5%	26.4%	74.8%	100.0%	56.0%	74.8%	76.5%	22.1%
NZL	80.3%	67.7%	67.6%	55.5%	57.1%	66.1%	69.2%	66.9%	66.6%	66.1%	52.3%	66.9%	64.7%	28.5%	67.0%	56.0%	100.0%	68.2%	64.7%	26.5%
PRT	61.9%	98.1%	98.3%	45.9%	87.3%	97.6%	97.8%	98.0%	96.1%	98.5%	69.0%	94.1%	91.4%	35.3%	97.9%	74.8%	68.2%	100.0%	82.6%	43.9%
SWE	65.4%	79.9%	80.3%	51.8%	67.1%	78.9%	81.5%	84.8%	82.8%	79.8%	63.7%	81.9%	82.4%	25.9%	79.7%	76.5%	64.7%	82.6%	100.0%	34.8%
USA	25.1%	44.8%	45.1%	34.1%	38.3%	45.0%	45.6%	46.7%	43.6%	46.3%	40.7%	49.5%	44.5%	24.2%	45.5%	22.1%	26.5%	43.9%	34.8%	100.0%

Table 3 *EMBI Global indices monthly returns in US dollars*

	Ann. Mean	Ann. Std. Dev.	Skewness	Kurtosis	Maximum	Minimum
ARG	4.36%	29.15%	-1.14	9.55	33.80%	-43.91%
BGR	15.26%	19.60%	-1.12	16.60	25.77%	-36.38%
BRA	16.35%	20.93%	-0.54	8.87	26.76%	-27.39%
CHN	8.34%	6.75%	0.81	16.45	13.05%	-9.45%
ECU	15.43%	33.14%	-1.71	10.89	24.45%	-55.78%
MEX	11.94%	10.80%	-0.66	7.58	12.39%	-14.75%
PAN	16.24%	16.63%	0.06	7.32	21.80%	-16.81%
PER	16.43%	18.29%	-1.23	7.41	14.09%	-25.39%
PHL	11.57%	10.84%	-1.63	14.03	11.90%	-19.58%
POL	11.03%	10.09%	0.72	12.48	17.18%	-11.87%
RUS	23.54%	32.09%	-2.50	25.89	35.19%	-71.62%
VEN	15.65%	21.46%	-1.11	15.34	31.57%	-37.96%
ZAF	10.19%	10.01%	-1.88	17.19	12.03%	-17.78%

Note : ARG stands for Argentina, BGR Bulgaria, BRA Brazil, CHN China, ECU Ecuador, MEX Mexico, PAN Panama, PER Peru, PHL Philipinnes, POL Poland, RUS Russia, VEN Venezuela, ZAF South Africa.

Table 4 *EMBI Global correlation matrix*

	ARG	BRA	BGR	CHN	ECU	MEX	PAN	PER	PHL	POL	RUS	VEN	ZAF
ARG	100.0%	43.5%	40.0%	39.4%	46.7%	49.7%	50.5%	43.9%	42.9%	42.2%	27.6%	53.1%	50.1%
BRA	43.5%	100.0%	57.9%	25.7%	56.2%	69.1%	63.9%	72.6%	56.8%	48.2%	50.4%	54.8%	50.7%
BGR	40.0%	57.9%	100.0%	46.9%	55.0%	67.2%	65.3%	68.3%	63.8%	67.5%	56.1%	65.1%	66.5%
CHN	39.4%	25.7%	46.9%	100.0%	31.0%	50.2%	40.5%	38.2%	37.8%	64.4%	24.7%	46.9%	71.5%
ECU	46.7%	56.2%	55.0%	31.0%	100.0%	53.1%	53.6%	59.6%	54.3%	52.1%	52.1%	58.2%	51.6%
MEX	49.7%	69.1%	67.2%	50.2%	53.1%	100.0%	75.3%	68.2%	68.2%	75.7%	55.3%	59.1%	67.9%
PAN	50.5%	63.9%	65.3%	40.5%	53.6%	75.3%	100.0%	63.9%	57.6%	66.7%	45.8%	59.5%	60.3%
PER	43.9%	72.6%	68.3%	38.2%	59.6%	68.2%	63.9%	100.0%	69.7%	58.2%	51.8%	58.7%	62.9%
PHL	42.9%	56.8%	63.8%	37.8%	54.3%	68.2%	57.6%	69.7%	100.0%	60.3%	58.9%	53.0%	63.7%
POL	42.2%	48.2%	67.5%	64.4%	52.1%	75.7%	66.7%	58.2%	60.3%	100.0%	40.6%	52.6%	65.9%
RUS	27.6%	50.4%	56.1%	24.7%	52.1%	55.3%	45.8%	51.8%	58.9%	40.6%	100.0%	47.1%	52.8%
VEN	53.1%	54.8%	65.1%	46.9%	58.2%	59.1%	59.5%	58.7%	53.0%	52.6%	47.1%	100.0%	68.3%
ZAF	50.1%	50.7%	66.5%	71.5%	51.6%	67.9%	60.3%	62.9%	63.7%	65.9%	52.8%	68.3%	100.0%

The Environmental Performance Index[7] (EPI) is computed jointly by the Universities of Yale and Columbia, in collaboration with the World Economic Forum and the Joint Research Centre of the European Commission. EPI is a typical SRI indicator, in particular for the environmental (E) aspect of the traditional ESG (Environmental, Society and Governance concerns) criteria. We use here EPI values for year 2008 (see Table 5).

Table 5 2008 EPI scores for the sample countries

Switzerland	95.51	**Japan**	84.54	**Poland**	80.49
Sweden	93.12	**Ecuador**	84.36	**Venezuela**	80.05
Norway	93.12	**Italy**	84.22	**Australia**	79.83
Finland	91.44	**Denmark**	83.99	**Mexico**	79.80
Austria	89.43	**Russia**	83.85	**Netherlands**	78.73
New Zealand	88.90	**Spain**	83.14	**Bulgaria**	78.47
France	87.75	**Panama**	83.06	**Belgium**	78.41
Canada	86.64	**Ireland**	82.74	**Peru**	78.08
Germany	86.31	**Brazil**	82.65	**Philippines**	77.94
United Kingdom	86.31	**Argentina**	81.78	**South Africa**	68.98
Portugal	85.75	**United States**	81.03	**China**	65.08

Switzerland and the Scandinavian Countries obtain the best EPI scores, China and South Africa the worse. On average, developed markets obtain better scores than emerging markets,

[7] EPI focuses on two overarching environmental objectives: reduction of environmental stresses to human health, and promotion of the ecosystem vitality and sound natural resource management. These two objectives are gauged using 25 performance indicators tracked in six well-established policy categories, which are then combined to create a final score. The values of EPI are downloaded from the EPI website: http://epi.yale.edu

but some developed markets (Belgium, the Netherlands, Australia and the US) exhibit relatively low scores.

2.1.3. Methodology

Consider a market of n securities and a portfolio p of securities defined by the vector of portfolio weights $\omega_p = [\omega_{p1} \quad \omega_{p2} \quad \dots \quad \omega_{pn}]'$, where $\omega' \iota = 1$ and $\iota = [1 \quad \dots \quad 1]'$. Following the notation of Lo (2008), the vector of expected returns of the securities is denoted by μ and Σ is the return covariance matrix of the securities while $\phi = [\phi_1 \quad \phi_2 \quad \dots \quad \phi_n]'$ is the vector of EPI scores of the countries. Then a natural definition of the EPI score ϕ_p of the portfolio *p is:*

$$\phi_p = \sum_{i=1}^{n} \omega_{pi} \phi_i$$

As proposed by Drut (2010a), the socially responsible criterion is introduced in the standard mean-variance optimization by means of an additional linear constraint[8] requiring the EPI score of the portfolio to be above a given threshold ϕ_0:

$$\begin{aligned} &\min_{\{\omega\}} \quad \frac{1}{2} \omega' \Sigma \omega \\ &\textit{subject to} \quad \mu_p = \omega' \mu \\ &\qquad\qquad\quad \omega' \iota = 1 \\ &\qquad\qquad\quad \phi_p = \omega' \phi \geq \phi_0 \end{aligned}$$

For an investor ready to bear a volatility $V = \omega' \Sigma \omega$ and requiring an EPI score ϕ_p above a threshold ϕ_0, the "SRI cost" $C(V, \phi_0)$ is defined as the difference between the expected return on the efficient EPI-unconstrained portfolio corresponding to the volatility V

[8] From a theoretical point of view, this problem is similar to the general mean-variance approach subject to linear constraints addressed by Best and Grauer (1990), Best and Grauer (1991), Lo *et al.* (2003), Alexander and Baptista (2006), for example.

and its EPI-constrained counterpart. We estimate the "SRI cost" $C(V,\phi_0)$ for several volatilities and levels of constraints on the EPI portfolio score ϕ_p.

2.1.4. Application to sovereign bonds

In this section, we show that the "SRI cost" decreases with the investor's risk aversion for developed market bonds but increases with the investor's risk aversion for emerging market bonds. Table 6 reports the "SRI cost" at different levels of average EPI on the portfolio for both developed and emerging markets.

Table 6 Annualized returns reduction due to SRI constraint for developed and emerging markets

			Level of constraint on the portfolio EPI				Annualized return without EPI constraint
			65	75	85	95	
Developed Markets	**Annualized Volatility**	5.0%	0.00%	0.04%	0.15%	0.33%	9.40%
		7.5%	0.16%	0.28%	0.43%	0.61%	12.46%
		10.0%	0.36%	0.50%	0.66%	0.84%	14.99%
		12.5%	0.57%	0.72%	0.88%	1.06%	17.39%
			65	75	85	95	
Emerging Markets	**Annualized Volatility**	15.0%	0.00%	0.00%	0.33%	3.08%	19.57%
		17.5%	0.00%	0.00%	0.11%	1.55%	21.72%
		20.0%	0.00%	0.00%	0.02%	0.88%	23.83%
		22.5%	0.00%	0.00%	0.00%	0.50%	25.92%

Note: 0.88% corresponds to $C(V = 12.5\%, \phi_0 = 85)$ and indicates that an investor accepting an annualized volatility of 12.5%/year and requiring a portfolio EPI above 85 incurs an expected annualized return loss of 0.88% compared to the case without EPI constraint.

Holding annualised volatility constant, the higher the portfolio average EPI, the more important the "SRI" cost in both the developed and the emerging markets contexts. In other words, and consistent with modern portfolio theory, returns are lower for a given level of risk when the portfolio average EPI constraint is stronger.

However, the "SRI cost" increases with the level of risk for a given EPI constraint for developed markets while a contrary pattern is observed for emerging markets. Figures 1 and 2 demonstrate how the the efficient frontier is modified by the EPI constraint. The effect of the EPI constraint appears at the top of the efficient frontier for developed markets and at bottom for emerging markets. In the case of emerging markets, EPI constraints induce important changes to the level of minimum variance.

Figure 1 Efficient frontiers for developed markets

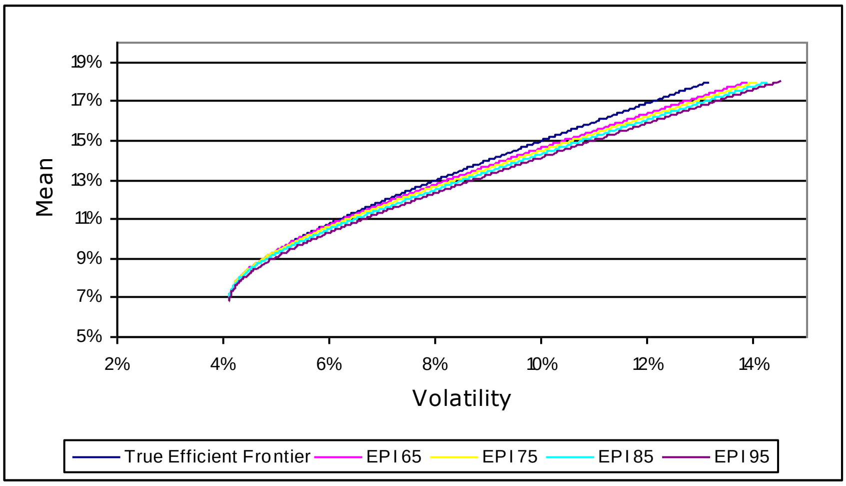
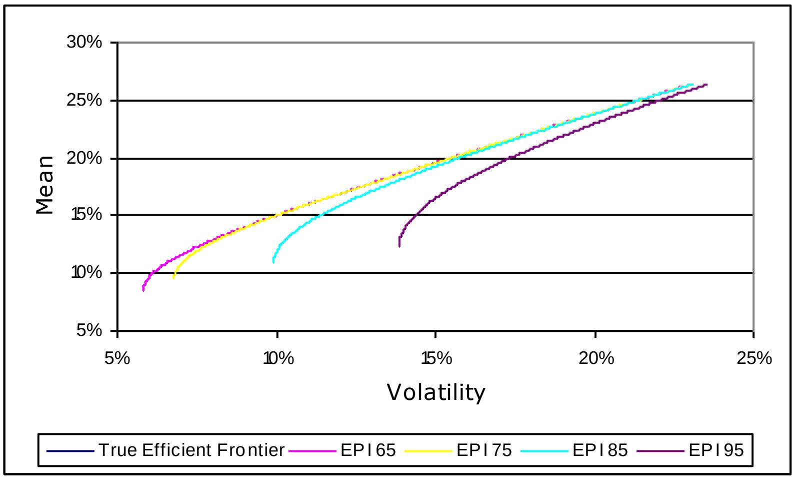


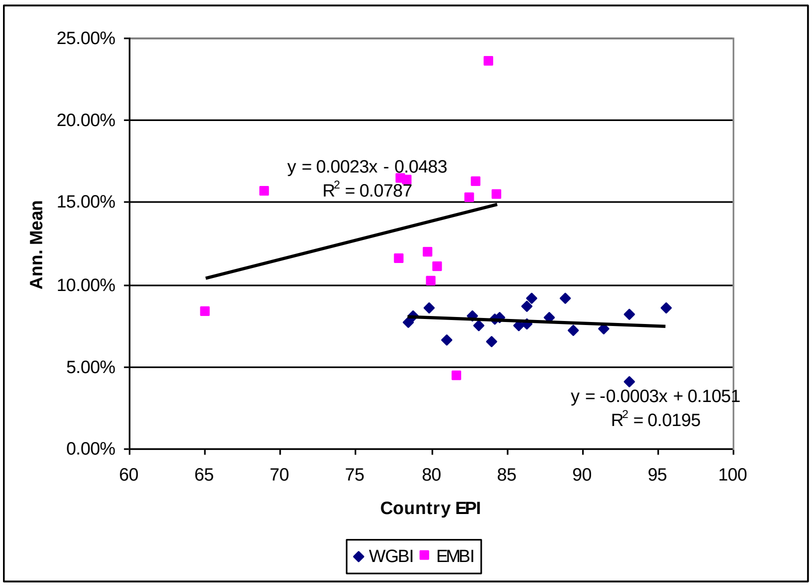
Figure 2 Efficient frontiers for emerging markets



This difference between developed and emerging markets finds can be explained by the link between EPI scores and sovereign bonds' characteristics (see Figures 3 and 4 below).

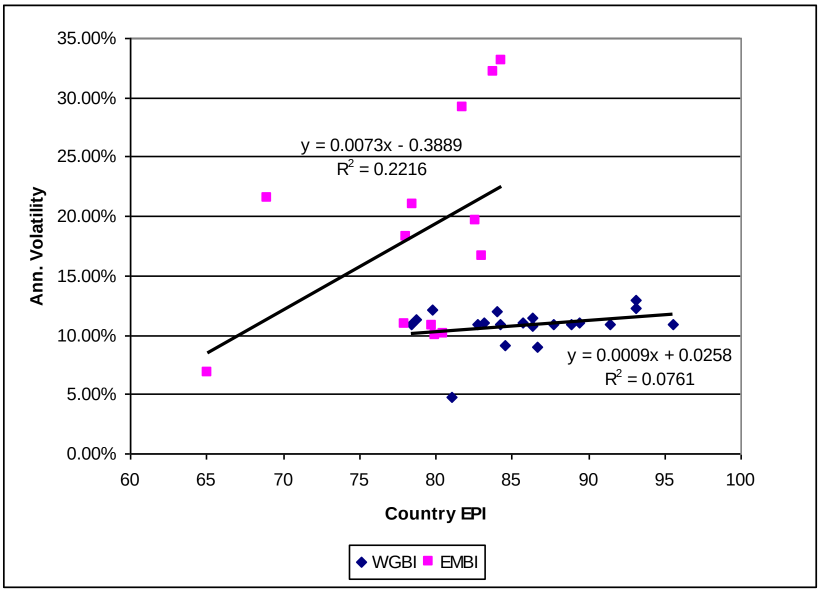
Links between EPI scores and returns are weak while links between EPI scores and annualized volatilities are positive and more significant (this link being stronger for the EMBI Global indices). Examining the pattern for emerging markets, one can get the intuition that is it difficult to build portfolios with high average EPI and low volatility as the highest rated countries have, at the same time, higher returns and higher volatilities. An example is provided by China, which has both the lowest EPI score and the lowest volatility.[9] In the case of developed markets, the difficulty in building portfolios with high average EPI and high returns may be the result of the negative but insignificant link between annualized returns and EPI scores. Moreover, markets with the highest annualized returns (Italy, Canada, Spain, Australia) are not the greenest according to the EPI.

Figure 3 *Relationship between indices' annualized returns and EPI scores*



[9] One reason is that the renminbi was pegged to the US dollar for the majority of the sample period.

Figure 4 *Relationship between indices' annualized volatilities and EPI scores*



It is also noteworthy that the "SRI cost" is zero in some cases: for example, an investor in emerging market bonds accepting a 22.5% per year annualized volatility achieve a portfolio EPI score up to 85 with no SRI cost (see Table 6). For emerging markets, there is a threshold on the EPI weighted-average below which the SRI cost is zero at each given level of risk. This threshold increases or decreases with the level of volatility. The SRI cost in developed markets increases with volatility and the strength of the SRI constraint.

2.1.5. Conclusion

The purpose of this sub-chapter was to investigate the impact of risk aversion on "SRI cost" by building green sovereign bond portfolios. Three conclusions can be drawn. First, the cost of being a nice guy depends on how cautious you are and SRI fund managers should first gauge investors' risk aversion before addressing the question of the cost of investing responsibly?. Second, the fact that "SRI cost" increases or decreases with risk aversion is data-driven and depends on the link between socially responsible and financial performances.

Third, when considering SRI as an additional linear constraint, there is no expected "SRI cost" in some circumstances.

2.2. *Theoretical investigation of the investor's risk aversion importance in SRI* [10]

2.2.1. Introduction

In Markowitz's (1952) setting, portfolio selection is driven solely by financial parameters and the investor's risk aversion. The exclusion of non-financial criteria may however be viewed as too restrictive since such criteria play a key role, as illustrated by the rising share of Socially Responsible Investment (SRI).[11] Indeed, according to the Social Investment Forum (2007), 11% of the assets under management in the United States in 2007 were invested in SRI, and this share was 17.6% in Europe as reported by the European Sustainable Investment Forum (2008). Moreover, by May 2009, 538 asset owners and investment managers, representing $18 trillion of assets under management, had signed the Principles for Responsible Investment (PRI)[12]. Within the SRI industry, initiatives are burgeoning and patterns are evolving rapidly. The aim of this chapter is to investigate the impact of such SRI concerns on mean-variance portfolio selection.

In practice, SRI takes various forms. Negative screening consists in excluding assets on ethical grounds (often related to religious beliefs), while positive screening selects the best-SR rated assets (typically, by combining environmental, social, and governance ratings). Renneboog *et al.* (2008a) describe "negative screening" as the first generation of SRI, and

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[10] This chapter is based on Drut (2010b). I thank Rob Bauer, Marie Brière, Eric de Bodt, James Hawley, Céline Louche, Benjamin Lorent, Valérie Mignon, Kim Oosterlinck, Hugues Pirotte, Jean-Charles Rochet, Richard Roll, Ombretta Signori, Ariane Szafarz and all the participants to the Oikos/PRI Young Scholars Finance Academy 2010 and to the 7th Journée ULB-Sorbonne for their helpful comments.

[11] SRI is defined by the European Sustainable Investment Forum (2008) as "a generic term covering ethical investments, responsible investments, sustainable investments, and any other investment process that combines investors' financial objectives with their concerns about environmental, social and governance (ESG) issues".

[12] The PRI is an investor initiative in partnership with the UNEP Finance Initiative and the UN Global Compact. The six principles for responsible investment advocate deep consideration for ESG criteria in the investment process (see PRI, 2009).

"positive screening" as the second generation. The third generation combines both screenings, while the fourth adds shareholder activism.

SRI financial performances are a fundamental issue. Indeed, a big debate takes place in the asset management industry and in the literature on the possible value creation generated by responsible practices of companies or governments. Does SRI perform as well as conventional investments? In other words, is doing "good" also doing well? A large body of empirical literature is devoted to the comparison between SR and non-SR funds. According to Bauer *et al.* (2005), there is little evidence that the performances of SR funds differ significantly from their non-SR counterparts. Conversely, Renneboog *et al.* (2008b) find that SRI funds significantly underperformed their benchmarks in many countries (US, UK, many continental countries, Asia-Pacific countries) in the period 1991-2003. Moreover, Geczy *et al.* (2006) find that restricting the investment universe to SRI funds can seriously harm diversification. On the whole, those statements seem hard to reconcile, and the debate on the relative performances of SRI is still open.

At the portfolio selection level, the particular motivations of responsible investors have to be considered. While, in the financial theory, the objective of traditional investors is purely based on financial characteristics (Markowitz, 1952; Levy and Markowitz, 1979; Kroll *et al.*, 1984; to quote few), that of responsible investors combines extra-financial and financial characteristics (Heinkel *et al.*, 2001; Bollen, 2007; Benson, 2008; Dorfleitner, 2010; Drut, 2010a). When the latter apply negative screening, they restrict the investment universe. Within Markowitz's (1952) mean-variance theoretical framework, this implies that the SR efficient frontier and the capital market line will be dominated by their non-SR counterparts. Farmen and Van Der Wijst (2005) notice that, in this case, the cost of investing responsibly is function of the risk aversion. In respect of positive screening, i.e. preferential investment in well-rated SRI assets without prior exclusion, each investor chooses her own SR commitment (Beal *et al.,* 2005; Landier and Nair, 2008). This translates into a trade-off between financial efficiency and portfolio ethicalness (Beal *et al.,* 2005). Likewise, Dorfleitner *et al.* (2010) propose a theory of mean-variance optimization including stochastic social returns within the investor's utility function. However, to our knowledge, easily implementable mean-variance portfolio selection for second-generation SRI is still missing from the literature. Moreover, despite its crucial importance, the impact of risk aversion on the cost of SRI has not been investigated so far. This sub-chapter paper aims at filling those two gaps by offering a fully operational mean-variance framework for SR portfolio management, a framework that can be used for all asset classes (stocks, bonds, commodities, mutual funds, etc.).

This sub-chapter measures the trade-off between financial efficiency and SR claims in the traditional mean-variance portfolio selection. We compare the optimal portfolios of SR-insensitive investors and their SR-sensitive counterparts in order to assess the cost associated with SRI. In particular, we make explicit the consequences of any given SR threshold on portfolios' optimality. Our contribution is twofold. First, we extend the Markowitz's (1952) model[13] by imposing an SR threshold. This leads to four possible SR-efficient frontiers: a) the SR-frontier is the same as the non-SR frontier (i.e. no cost), b) only the left portion is penalized (i.e. a cost for high-risk-aversion investors only), c) only the right portion is penalized (i.e. a cost for low-risk aversion investors only), and d) the full frontier is penalized (i.e. a cost for all investors). Second, we highlight the key role of risk aversion in SRI. To illustrate this, we complement our theoretical approach by an empirical application to emerging bond portfolios. We take the example of a portfolio selection considering a

[13] See Steinbach (2001) for a literature review on the extensions of the Markowitz's (1952) model.

threshold on the average environmental rating and we show that in this case, risk-averse investors are more penalized than investors with low risk aversion.

The rest of the sub-chapter is organized as follows. Section 2 proposes the theoretical framework for the SR mean-variance optimization in the presence of risky assets only. Section 3 adds a risk-free asset. Section 4 applies the SRI methodology to emerging sovereign bond portfolios. Section 5 concludes.

2.2.2. SRI portfolio selection (risky assets)

In this section, we explore the impact of considering responsible ratings in the mean-variance portfolio selection. To this end, we first assess the social responsibility of the optimal portfolios resulting from the traditional optimization of Markowitz (1952) and we seek whether there is a simple relationship between the SR ratings and the expected returns. Then we consider the case of an SR-sensitive investor who wants her portfolio to respect high SR standards, and we explore the consequences of such a constraint for optimal portfolios.

Consider a financial market with n risky securities[14] $(i = 1, \dots, n)$. Let us denote by $R = [R_1, \quad \dots, \quad R_n]'$ the vector of stochastic returns with $\mu = [\mu_1, \quad \dots, \quad \mu_n]'$ the vector of expected returns and by $\Sigma = (\sigma_{ij})$ the $n \times n$ positive-definite covariance matrix of the returns. A portfolio p is characterized by its composition, that is its associated vector $\omega_p = [\omega_{p1} \quad \omega_{p2} \quad \dots \quad \omega_{pn}]'$, where ω_{pi} is the weight of the i^{th} asset in portfolio p, $\iota = [1 \quad \dots \quad 1]'$ and $\omega_p ' \iota = 1$.

[14] Notations of Lo (2008) are used here.

In the traditional mean-variance portfolio selection (Markowitz, 1952), the investor maximizes her portfolio's expected return $\mu_p = \omega_p{}'\mu$ for a given volatility or variance $\sigma_p^2 = \omega_p{}'\Sigma\omega_p$. Let $\lambda > 0$ be the parameter accounting for the investor's level of risk aversion, which can also be interpreted as the risk calibration chosen by a funds manager. The problem of the SR-insensitive investor is then written as follows.[15]

Problem 1

$$\begin{aligned} &\max_{\{\omega\}} \quad \omega'\mu - \frac{\lambda}{2}\omega'\Sigma\omega \\ &subject\ \ to \quad \omega'\iota = 1 \end{aligned} \tag{1}$$

It is well-known (Roll, 1977) that the solutions to Problem 1 form a hyperbola in the mean-variance plane (μ_p, σ_p^2) that will be referred to here as the SR-insensitive efficient frontier. In particular, the minimum-variance portfolio $(\mu_{MV}, \sigma_{MV}^2)$ is:

$$\mu_{MV} = \frac{\iota'\Sigma^{-1}\mu}{\iota'\Sigma^{-1}\iota} \tag{2}$$

$$\text{and}\, \sigma_{MV}^2 = \frac{1}{\iota'\Sigma^{-1}\iota} \tag{3}$$

Let us now add an SR rating to the story. Typically, this is an extra-financial rating relating to environmental, social, or governance issues used by SRI funds managers to make their portfolio selection. It can also combine several ratings (Landier and Nair, 2008). Let ϕ_i be the SR rating associated with the i^{th} security and $\phi = [\phi_1 \quad \phi_2 \quad \ldots \quad \phi_n]'$. We assume that the rating is additive. Consequently, the rating ϕ_p of portfolio *p* is given by:

$$\phi_p = \omega_p{}'\phi = \sum_{i=1}^{n} \omega_{pi}\phi_i \tag{4}$$

[15] For sake of simplicity, short sales are allowed here.

This linearity hypothesis (see Barracchini, 2007; Drut, 2010; Scholtens, 2009) is often used by practitioners and extra-financial agencies to SR-rate portfolios or financial indices.[16]

We make here the assumption that the SR ratings are time-independent from expected returns and volatilities, i.e. the fact to be well or badly SR-rated today does not influence the security return tomorrow. However, cross-section dependence may occur, i.e. the best SR-rated securities may have the highest expected returns or the contrary. In the perspective of portfolio selection, this cross-section link needs to be assessed. We do it by means of the parameter δ :

$$\delta = \frac{(\mu - \mu_{MV}\, \iota)' \Sigma^{-1} \phi}{(\mu - \mu_{MV}\, \iota)' \Sigma^{-1} (\mu - \mu_{MV}\, \iota)} \tag{5}$$

It corresponds to the theoretical coefficient of the expected return μ in the General Least Squares (GLS) regression of the social ratings vector ϕ on the matrix $(\iota\ \mu)$. This is very close to the coefficient of the cross-sectional mean-beta regression of Roll and Ross (1994) and Kandel and Stambaugh (1995). It can be either positive or negative because, for instance, the assets with the highest expected returns can be the best or the worst SR-rated.

Now that SR ratings have been introduced, we aim at determining those of optimal portfolios. Indeed, even when investors are SR-insensitive (thus facing Problem 1), their optimal portfolios can be SR-rated. Proposition 1 expresses those ratings ϕ_p associated with SR-insensitive efficient portfolios.

[16] See for instance the Carbon Efficient Index of Standard & Poor’s with the carbon footprint data from Trucost PLC.

Proposition 1

(i) Along the SR-insensitive frontier, the SR rating ϕ_p is a linear function of the expected return μ_p :

$$\phi_p = \phi_{MV} + \delta\,(\mu_p - \mu_{MV}) \qquad (6)$$

where $\phi_{MV} = \frac{\iota'\Sigma^{-1}\phi}{\iota'\Sigma^{-1}\iota}$ is the SR rating of the minimum-variance portfolio.

(ii) If $\delta > 0$, the SR rating ϕ_p of the optimal portfolios increases with respect to the expected return and its minimum is ϕ_{MV} and obtained for the minimum-variance portfolio.

(iii) If $\delta < 0$, the SR rating ϕ_p of the optimal portfolios decreases with respect to the expected return and its maximum is ϕ_{MV} and obtained for the minimum-variance portfolio.

Proof: see Appendix 1.

Proposition 1 gives the SR rating ϕ_p of any portfolio lying on the SR-insensitive frontier. The SR rating ϕ_p can be written as a linear function of the expected return μ_p as in eq. (6) because both are linear functions of the risk appetite parameter $\frac{1}{\lambda}$. The direction of the link between the portfolio SR rating ϕ_p and the expected return μ_p is determined by the sign of parameter δ which measures the cross-section dependence between the SR ratings and the returns (see eq. (5)). In fact, parameter δ quantifies the trade-off between risk aversion and SR rating. If $\delta > 0$, resp. $\delta < 0$, the riskier the optimal portfolio, the better, resp. the worse, its SR rating. In other words, if $\delta > 0$, resp. $\delta < 0$, the best SR-rated portfolios are at the top, resp. at the bottom, of the SR-insensitive frontier.

Consider now the case of an SR-sensitive investor. For instance, she requires a stock portfolio that is well-rated for environment. Henceforth, the SR rating ϕ_p is introduced in the mean-variance optimization by means of an additional linear constraint imposing a given threshold ϕ_0 on ϕ_p. For positive screening, the threshold value is left to the investor's discretion (Beal *et al.*, 2005, Landier and Nair, 2008). The SR-sensitive optimization is summarized by Problem 2. Note that this mathematical formulation is very close to the mean-variance-liquidity optimization derived by Lo *et al.* (2003).

Problem 2

$$\begin{aligned} &\max_{\{\omega\}} \quad \omega'\mu - \frac{\lambda}{2}\omega'\Sigma\omega \\ &\textit{subject to} \quad \omega'\iota = 1 \\ &\qquad\qquad\quad \phi_p = \omega'\phi \geq \phi_0 \end{aligned} \tag{7}$$

As no asset is a priori excluded, Problem 2[17] is different from negative screening[18] (see Farmen and Van Der Wijst, 2005), and close to positive screening. We derive the analytical solutions to Problem 2 by using Best and Grauer's (1990) methodology. Proposition 2 summarizes the results.

[17] A badly SR-rated asset might indeed be present in an efficient portfolio, for instance because its expected return is very high.

[18] For negative screening, ϕ_i is binary.

Proposition 2

The SR-sensitive efficient frontier (Problem 2) depends on the sign of δ and on the threshold value ϕ_0, in the way given by Table 1:

Table 1 SR-sensitive efficient frontier

	$\delta > 0$	$\delta < 0$
$\phi_{MV} > \phi_0$	The SR-sensitive frontier is identical to the SR-insensitive frontier (see Figure 1)	For $\lambda < \lambda_0$, the SR-sensitive frontier is a hyperbola lying below the SR-insensitive frontier. For $\lambda > \lambda_0$, the SR-sensitive frontier is identical to the SR-insensitive frontier. (see Figure 3)
$\phi_{MV} < \phi_0$	For $\lambda < \lambda_0$, the SR-sensitive frontier is identical to the SR-insensitive frontier. For $\lambda > \lambda_0$, the SR-sensitive frontier is another hyperbola lying below the SR-insensitive frontier (see Figure 2)	The SR frontier differs totally from the SR-insensitive frontier. (see Figure 4)

With $\lambda_0 = \dfrac{\phi'\Sigma^{-1}(\mu - \mu_{MV}\,\iota)}{\phi_{MV} - \phi_0}$ the risk aversion parameter for which the disjunction between the SR-insensitive frontier and SR-sensitive frontier occurs. The associated portfolio has an expected return E_0

$$E_0 = \mu_{MV} + \frac{\phi_0 - \phi_{MV}}{\delta} \tag{8}$$

and an expected variance V_0:

$$V_0 = \sigma_0^2 = \sigma_{MV}^2 + \left(\frac{\phi_0 - \phi_{MV}}{\delta}\right)^2 \frac{1}{(\mu - \mu_{MV}\,\iota)'\Sigma^{-1}(\mu - \mu_{MV}\,\iota)} \tag{9}$$

Proof: see Appendix 2.

Proposition 2 details the configurations in which a SRI cost occurs and if so, for which type of investors. The impact of the SR constraint depends both on parameter δ (cross-section dependence between the returns and the SR ratings), and on the strength of the constraint ϕ_0. As showed in Proposition 1, if $\delta > 0$, resp. $\delta < 0$, the best SR-rated portfolios are at the top, resp. at the bottom, of the SR-insensitive frontier. As a consequence, the SR constraint impacts first the efficient frontier at the bottom, resp. at the top. Thus, for a given SR constraint, the investor's risk aversion has an impact on the expected SRI cost. In addition, the higher the investor's SR sensitivity, i.e. the higher the threshold ϕ_0, the larger the portion of the efficient frontier being displaced.

The four possible cases in Proposition 2 are illustrated in Figures 1 to 4. First, consider the case where $\delta > 0$, i.e the SR rating increases with respect to the expected return along the SR-insensitive frontier. If the SR constraint is weak, i.e. if the SR rating threshold is below that of the minimum-variance portfolio ($\phi_{MV} > \phi_0$), all the optimal portfolios have a higher SR rating than the threshold. It follows that the SR-sensitive and the SR-insensitive frontiers are identical (see Figure 1). And the SRI cost is zero, corresponding to the most favourable case. On the opposite, if the SR constraint is strong, i.e. if the SR rating threshold is above that of the minimum-variance portfolio ($\phi_{MV} < \phi_0$), the SR-sensitive and the SR-insensitive frontiers are the same above the corner portfolio (E_0, σ_0^2) and differ elsewhere (see Figure 2). In this case, the SR constraint penalizes portfolios with a low risk exposure but has no cost for investors with low risk aversion.

Figure 1 SR-sensitive frontier versus SR-insensitive frontier with $\delta > 0$ and $\phi_{MV} > \phi_0$

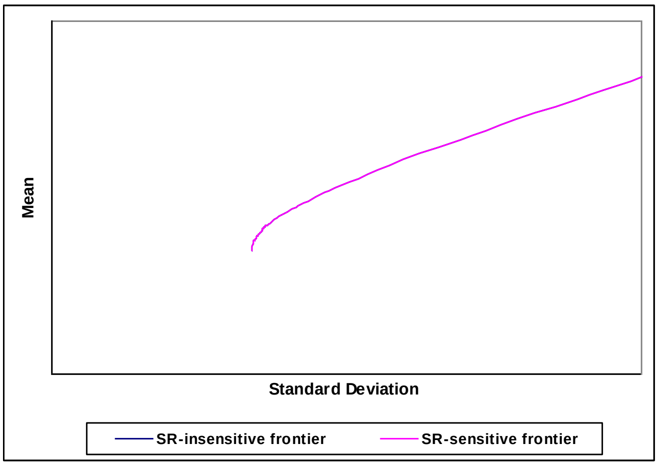
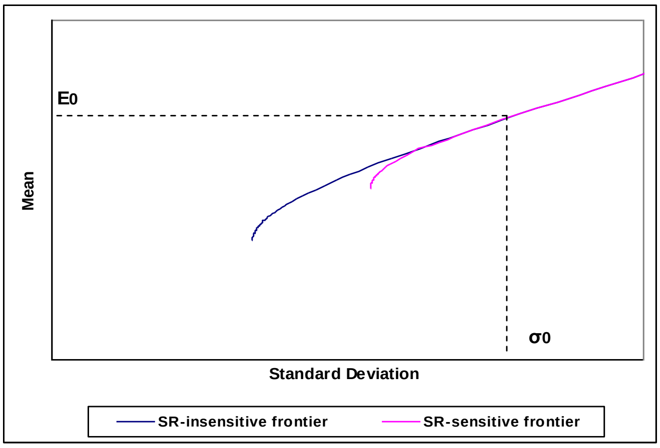


Figure 2 SR-sensitive frontier versus SR-insensitive frontier with $\delta > 0$ and $\phi_{MV} < \phi_0$



Consider now the case where $\delta < 0$, i.e. the SR rating decreases from the maximum SR rating ϕ_{MV} with respect to the expected return along the SR-insensitive frontier. Two possibilities occur: either the threshold ϕ_0 is below the maximum SR rating ϕ_{MV} and the best SR-rated portfolios are not affected by the SR constraint; or the threshold is above the maximum SR rating ϕ_{MV} and the SR constraint is binding for every investor. The first situation ($\phi_{MV} > \phi_0$) is analogous to that of Figure 2: the SR-sensitive frontier is identical to the SR-insensitive frontier below the corner portfolio (E_0, σ_0^2) and is dominated above (see Figure 3). In practical terms, only investors with a high risk exposure are penalized by their SR sensitivity while it does not cost anything for risk averse investors. However, if the SR constraint is strong ($\phi_{MV} < \phi_0$), the SR-sensitive and the SR-insensitive frontiers are totally different (see Figure 4). Globally, this is the worst case and there is an SRI cost for all investors.

Figure 3 SR-sensitive frontier versus SR-insensitive frontier with $\delta < 0$ and $\phi_{MV} > \phi_0$

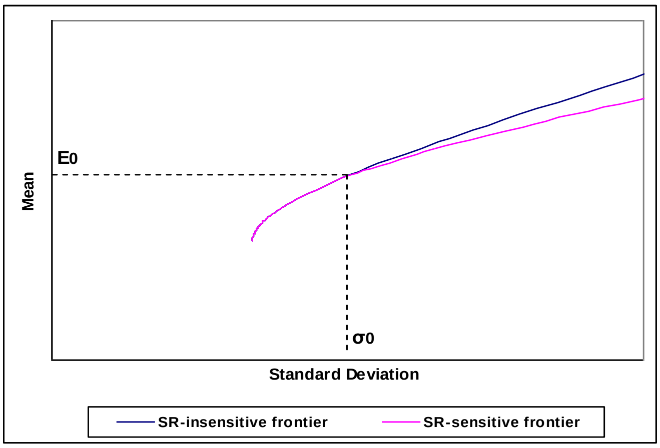
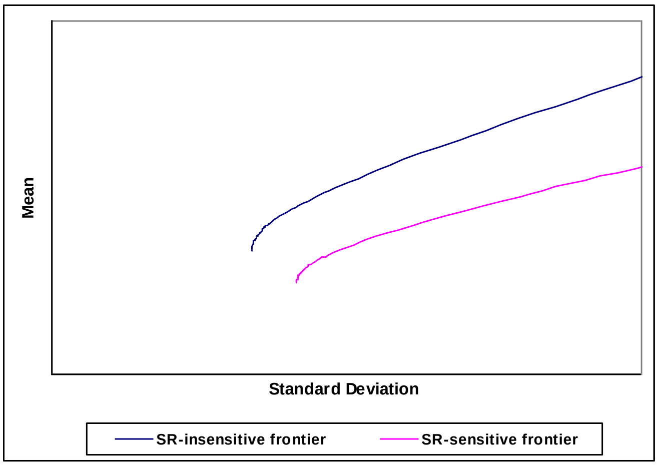


Figure 4 SR-sensitive frontier versus SR-insensitive frontier with $\delta < 0$ and $\phi_{MV} < \phi_0$



To sum up, the investor's risk aversion matters in the cost of responsible investing.[19] Four cases are possible: a) no cost for anybody (Figure 1), b) a cost for high risk aversion

[19] This section highlights the impact of a constraint on the portfolio rating in the mean-variance optimization. However, the cost of investing responsibly, if non-zero, may be non-significant (see Drut, 2010a). The significance of the mean-variance efficiency loss may be assessed using the test of Basak *et al.* (2002) or any spanning test (see de Roon and Nijman (2001) for a literature review).

investors only (Figure 2), c) a cost for low risk aversion investors only (Figure 3), and d) a cost for all the investors (Figure 4).

In practice, SRI funds managers may rapidly detect if they face SRI-caused diversification loss by estimating first the sample mean vector and covariance matrix of the returns and then by running a cross-sectional GLS regression of the SR ratings on the expected returns. Thus, Table 1 indicates which particular case SRI funds managers face.

2.2.3. Portfolio selection with a riskless asset

In this section, we assume the existence of a risk-free asset. Its social responsibility has to be considered in order to SR-rate portfolios. We first assess the SR ratings of the SR-insensitive efficient portfolios in this framework and then study whether an SR-sensitive investor is penalized

Denote by r the return of the risk-free asset and by ω_r the fraction of wealth invested in this risk-free asset. Problem 3 refers to the standard mean-variance portfolio selection in the presence of a risk-free asset, that has been extensively studied by Lintner (1965), Sharpe (1964) and Merton (1972).

Problem 3

$$\begin{aligned} &\max_{\{\omega\}} \quad \omega'\mu + \omega_r r - \frac{\lambda}{2}\omega'\Sigma\omega \\ &subject\ to \quad \omega'\iota + \omega_r = 1 \end{aligned} \tag{10}$$

In the mean-standard deviation plane, the efficient frontier is referred as the Capital Market Line (CML). In problem 3, the investor ignores responsible ratings. We therefore refer this line as "SR-insensitive CML".

As in Section 2, we consider now that companies and governments are SR-rated. Henceforth, we denote by ϕ^* the SR rating of the risk-free asset and define the portfolio rating as $\phi_p = \omega'\phi + \omega_r\phi^*$. We measure here the cross-sectional dependence between the returns and the SR ratings by the parameter δ^*:

$$\delta^* = \frac{(\mu - r\iota)'\Sigma^{-1}(\phi - \phi^*\iota)}{(\mu - r\iota)'\Sigma^{-1}(\mu - r\iota)} \tag{11}$$

It can be interpreted as the coefficient of the cross-sectional GLS regression of the social ratings $\phi - \phi^*\iota$ in excess of that of the risk-free asset, and the returns in excess of that of the risk-free asset $R - r\,\iota$. Similarly to the parameter δ, the parameter δ^* can take both signs depending on the fact that the best SR rated securities have the highest financial returns or not.

In the following, we seek to determine the portfolio SR ratings ϕ_p of the optimal portfolios on the "SR-insensitive CML", when investors have no SR claims at all.

Proposition 3

(i) Along the SR-insensitive capital market line, the responsible rating ϕ_p is a linear function of the expected return μ_p :

$$\phi_p = \phi^* + \delta^* (\mu_p - r) \quad (12)$$

(ii) If $\delta^* > 0$, the SR rating of the optimal portfolios ϕ_p increases with respect to the expected return and its minimum is ϕ^* and obtained for the minimum-variance portfolio.

(iii) If $\delta^* < 0$, the SR rating of the optimal portfolios ϕ_p decreases with respect to the expected return and its maximum is ϕ^* and obtained for the minimum-variance portfolio.

Proof: see Appendix 3.

Proposition 3 attributes a SR rating ϕ_p to any portfolio of the SR-insensitive CML. It is striking that this relationship expressed by eq. (12) has the same form as eq. (6) in the case without a risk-free asset. Note that the portfolio of an infinitely risk averse investor would be fully invested in the risk-free asset and would have its SR rating ϕ^*. Here also, the direction of this link between the expected return μ_p and the portfolio SR rating ϕ_p is determined by the sign of the cross-section parameter δ^* of eq. (11). Thus, if $\delta^* > 0$, resp. $\delta^* < 0$, the best SR-rated portfolios are at the top, resp. at the bottom, of the SR-insensitive CML.

Similarly to Section 2, we now consider the case of SR-sensitive investors wishing their portfolios to respect high SR standards and so, requiring the portfolio rating $\phi_p = \omega'\phi + \omega_r \phi^*$ to be above a threshold ϕ_0. This corresponds to Problem 4.

Problem 4

The investor faces the following program:

$$\begin{aligned} &\max_{\{\omega\}} \quad \omega'\mu + \omega_r r - \frac{\lambda}{2}\omega'\Sigma\omega \\ &subject\ to \quad \omega'\iota + \omega_r = 1 \\ &\qquad\qquad \phi_p = \omega'\phi + \omega_r\phi^* \geq \phi_0 \end{aligned} \tag{13}$$

In Problem 4, the constraints in the mean-variance optimization are also linear. Thus, as we did for Problem 2, we rely on the Best and Grauer's (1990) methodology. Proposition 4 summarizes the results.

Proposition 4

The SR-sensitive Capital Market Line depends on the sign of the cross-sectional correlation δ^* and on the threshold value ϕ_0, as described in Table 2.

Table 2 The SR-sensitive Capital Market Line

	$\delta^* > 0$	$\delta^* < 0$
$\phi^* > \phi_0$	The SR-sensitive capital market line is the same as the SR-insensitive capital market line. (see Figure 5)	For $\lambda < \lambda_0^*$, the SR-sensitive capital market line is a hyperbola lying below the SR-insensitive capital market line. For $\lambda > \lambda_0^*$, the SR-sensitive capital market line is identical to the SR-insensitive capital market line. (see Figure 7)
$\phi^* < \phi_0$	For $\lambda < \lambda_0^*$, the SR-sensitive capital market line is identical to the SR-insensitive capital market line. For $\lambda > \lambda_0^*$, the SR-sensitive capital market line is a hyperbola lying below the SR-insensitive capital market line. (see Figure 6)	The SR-sensitive capital market line differs totally from the SR-insensitive capital market line and becomes a hyperbola. (see Figure 8)

With $\lambda_0^* = \frac{(\mu - r\iota)'\Sigma^{-1}(\phi - \phi^*\iota)}{(\phi_0 - \phi^*)}$ the risk aversion parameter for which the disjunction between the SR-sensitive and SR-insensitive CMLs occur. The associated portfolio has an expected return E_0^* :

$$E_0^* = r + \frac{\phi_0 - \phi^*}{\delta^*} \tag{14}$$

And an expected variance V_0^* :

$$V_0^* = \sigma_0^{2*} = \left(\frac{\phi_0 - \phi^*}{\delta^*}\right)^2 \frac{1}{(\mu - r\iota)'\sum^{-1}(\mu - r\iota)} \tag{15}$$

Proof: see Appendix 4.

Proposition 4 delineates the conditions under which SRI is costly in presence of a risk-free asset. Its conclusion is roughly the same than in Proposition 2, i.e. the impact of the SR constraint depends both on the parameter δ^* of cross-section correlation between the SR ratings and the returns, and on the strength of the SR constraint ϕ_0. As showed in Proposition 3, if $\delta^* > 0$ (resp. $\delta^* < 0$), the best SR-rated portfolios are at the top (resp. at the bottom) of the SR-insensitive CML and the SR constraint affects first the CML at the bottom (resp. at the top). However, contrary to the case without a risk-free asset, the modified part of the CML has a different mathematical form: for this segment, the CML becomes a hyperbola in the mean-standard deviation plane.

Figures 5 to 8 illustrate the four possible cases described by Proposition 4. First, consider the case where the cross-section correlation δ^* between the SR ratings and the expected returns is positive. In this case, the SR rating increases with respect to the expected return along the SR-insensitive CML with a minimum equal to the risk-free asset's SR rating ϕ^*. If the investor does not claim a portfolio better SR-rated than the risk-free asset ($\phi^* > \phi_0$), she incurs no financial penalty whatever her risk aversion (see Figure 5). However, when investors want a SR-better portfolio than the risk-free ($\phi^* < \phi_0$), a disjunction appears between the SR-sensitive and the SR-insensitive CMLs. They are identical above the corner portfolio (E_0^*, σ_0^{2*}) and but the SR-sensitive CML is dominated below (see Figure 6). In other words, risk averse investors are penalized, not the others.

Figure 5 SR-sensitive Capital Market Line versus SR-insensitive Capital Market Line with $\delta^* > 0$ and $\phi^* > \phi_0$

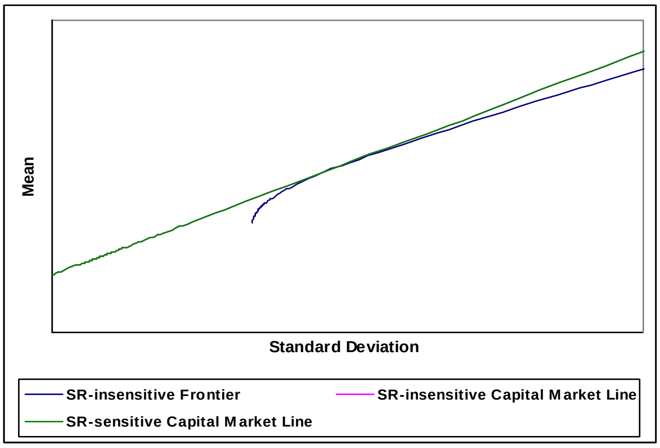
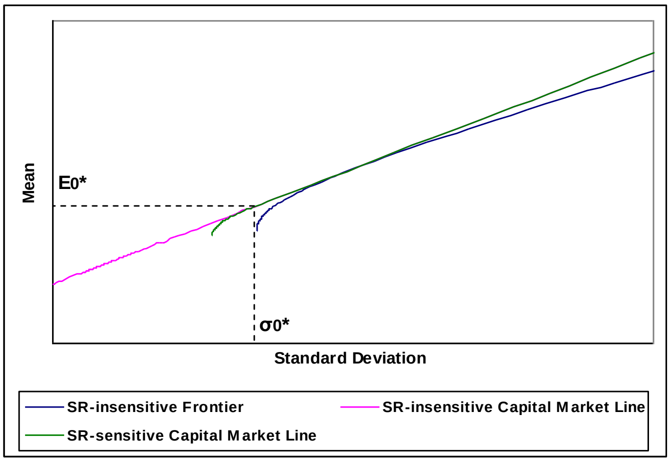


Figure 6 SR-sensitive Capital Market Line versus SR-insensitive Capital Market Line with $\delta^* > 0$ and $\phi^* < \phi_0$



Consider now the case where the cross-section correlation parameter $\delta*$ between the SR ratings and the expected returns is negative ($\delta* < 0$). This case is very similar to the case where $\delta < 0$ in Section 2. If the SR rating threshold is below the minimum SR rating of the SR-insensitive CML ($\phi* > \phi_0$), the SR-sensitive CML is identical to the SR-insensitive one below the corner portfolio (E_0^*, σ_0^{2*}) and is dominated above (see Figure 7). Alternatively ($\phi* < \phi_0$), the whole SR-sensitive CML is dominated and becomes entirely a hyperbola (see Figure 8), meaning a SRI cost for all the investors.

Figure 7 SR-sensitive Capital Market Line versus SR-insensitive Capital Market Line with

$\delta* < 0$ and $\phi* > \phi_0$

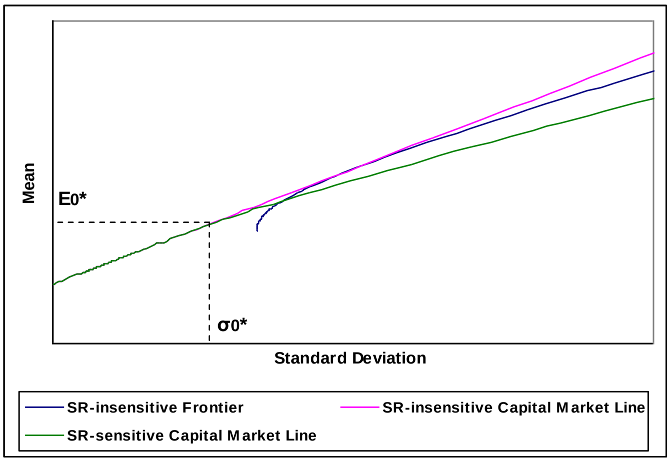
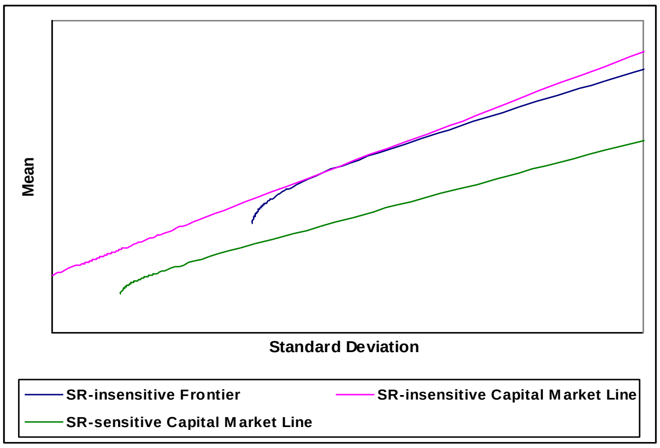


Figure 8 SR-sensitive Capital Market Line versus SR-insensitive Capital Market Line with

$\delta* < 0$ and $\phi* < \phi_0$



To sum up, we make explicit the possible configurations that SRI funds managers can face in presence of a risk-free asset. Like in Section 2, a two-step procedure allows to determine quickly if they are subject to a penalty: 1) estimate the mean and the covariance of the returns 2) run a cross-sectional GLS regression of the excess SR ratings $\phi - \phi^*$ on the excess expected returns $\mu - r\iota$.

2.2.4. Application to an emerging bond portfolio

In this section, we propose a numerical application to get the flavour of our theoretical findings. We consider the case of a responsible US investor on the emerging bond market wishing to favour in average in her portfolio countries with the best environmental performances.

We consider the EMBI+ indices from JP Morgan as proxy for emerging bond returns. These indices track total returns for actively traded external debt instruments in emerging markets.[20] They are expressed in US dollars and taken at a monthly frequency from January 1994 to October 2009. They are extracted from Datastream.[21]

In the same way as Scholtens (2009), we use the Environmental Performance Index (EPI) as responsible ratings to assess the countries' environmental performances. The EPI[22] is provided jointly by the universities of Yale and Columbia in collaboration with the World Economic Forum and the Joint Research Centre of the European Commission. EPI focuses on two overarching environmental objectives: reducing environmental stress to human health and promoting ecosystem vitality and sound management of natural resources. These objectives

[20] Argentina, Brazil, Bulgaria, Ecuador, Mexico, Panama, Peru, Philippines, Russia, Venezuela.
[21] Descriptive statistics are available in Appendix 5. As for many other financial variables, they are negatively skewed and leptokurtic.
[22] The EPI index is computed every two years since 2006.

are gauged using 25 performance indicators tracked in six well-established policy categories, which are then combined to create a final score (see Appendix 6). EPI scores attributed in 2008 are reported in Table 3.

Table 3 Environmental Performance Index 2008

ARGENTINA	81.78
BRAZIL	82.65
BULGARIA	78.47
ECUADOR	84.36
MEXICO	79.80
PANAMA	83.06
PERU	78.08
PHILIPPINES	77.94
RUSSIA	83.85
VENEZUELA	80.05
Mean	81.00
Standard Deviation	2.44
UNITED STATES	81.03

Sources: Universities of Yale and Columbia.

Here, the portfolio EPI is defined in the same way as in eq. (2). We start by estimating the portfolio EPI along the SR-insensitive frontier, which corresponds to estimating the relationship (3) of Proposition 1. We obtain the following estimates for the parameters ϕ_{MV} and δ :

$$\hat{\phi}_{MV} = 78.26 \qquad \hat{\delta} = 0.30 \tag{16}$$

As $\hat{\delta} > 0$, the portfolio EPI increases with the expected return on the SR-insensitive efficient frontier: a 1%/year increase in expected returns corresponds to an increase of 0.30 in the EPI portfolio. The minimal EPI portfolio $\hat{\phi}_{MV}$ on the SR-insensitive frontier is obtained for the minimum-variance portfolio and is equal to 78.26.

As an illustration of Problem 2, we seek to determine the impact of SR claims on the efficient frontier and impose a set of constraints $\phi_p > \phi_0$ on the portfolio EPI. Figure 9 exhibits the SR-sensitive frontiers for several thresholds ϕ_0. The corner portfolios for which there is a disjunction between the SR-sensitive and SR-insensitive frontiers are displayed in Table 4.

Figure 9 SR-sensitive frontiers versus SR-insensitive frontier for the EMBI+ indices, January 1994 to October 2009

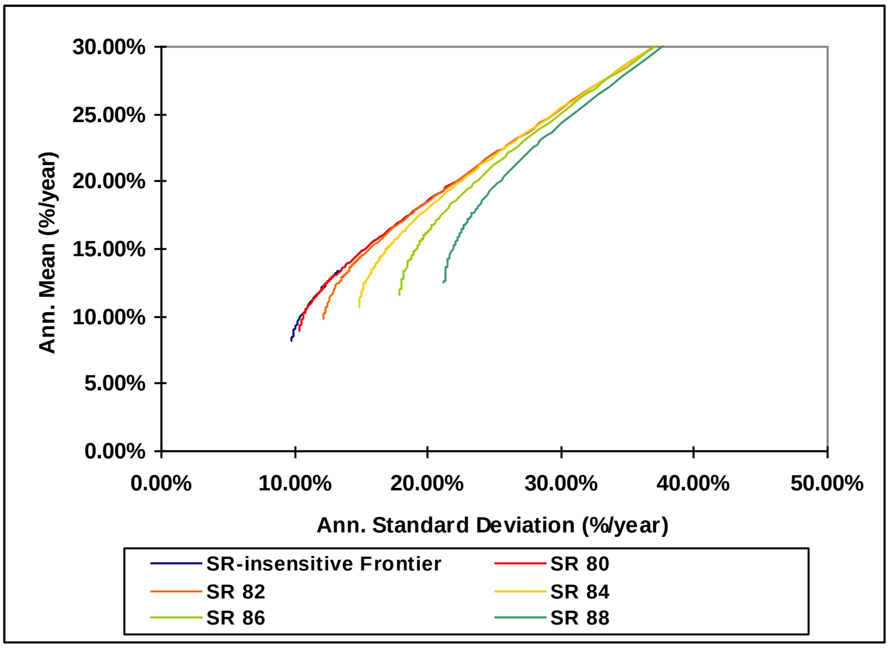


Table 4 Corner portfolios for which the SR constraint is binding

ϕ_0	λ_0	Expected return E_0 (%/year)	Expected volatility σ_0 (%/year)
82	3.14	20.13	22.22
84	2.05	26.84	32.17
86	1.52	33.55	42.48
88	1.21	40.26	52.93

As expected from Proposition 2, for $\phi_0 < \hat{\phi}_{MV} = 78.26$, the SR-sensitive frontier is the same as the SR-insensitive frontier. For $\phi_0 > \hat{\phi}_{MV} = 78.26$, the SR-sensitive frontier differs from the SR-insensitive frontier at the bottom and is the same at the top. For instance, with a threshold equal to 84 on the portfolio EPI, the SR-sensitive and the SR-insensitive frontiers are the same for expected returns above 26.84%/year and differ for expected returns below 26.84%/year. In the case of emerging bonds, improving the portfolio EPI costs more for investors with high risk aversion.

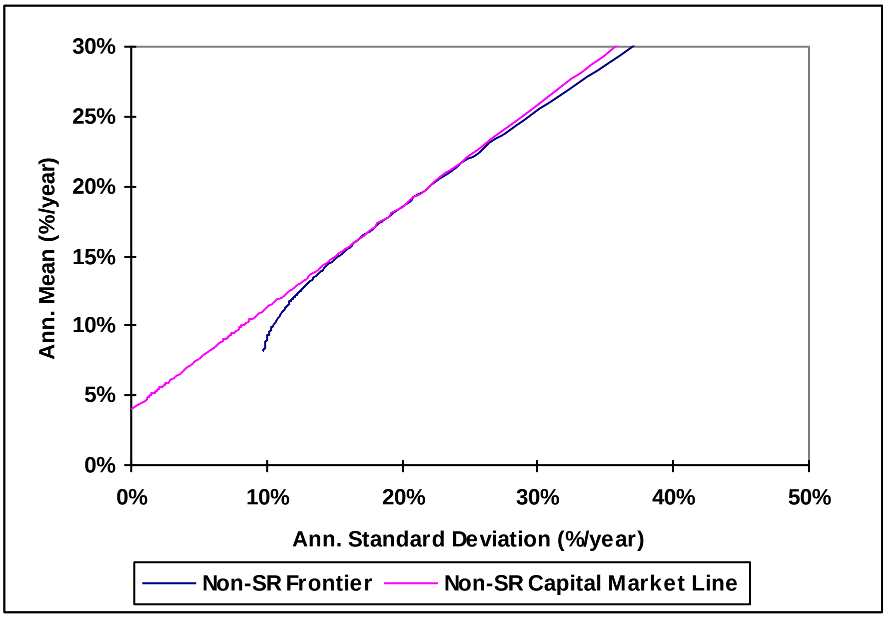
In order to illustrate Problems 3 and 4, we rely on the US 1-month interbank rate as a risk-free asset.[23] Its responsible rating corresponds to the EPI of the United States $\phi^* = 81.03$. Then, we estimate the parameter δ^*:

$$\hat{\delta}^* = 0.02 \tag{17}$$

As $\hat{\delta}^* > 0$, the portfolio EPI increases with the expected return of the SR-insensitive CML. More precisely, for a 1%/year increase in expected returns, the EPI portfolio is 0.02 higher. The minimal EPI portfolio on the SR-insensitive CML is obtained for the risk-free asset and thus, is equal to the EPI of the United States $\phi^* = 81.03$. The SR-insensitive CML is shown in Figure 10.

[23] This variable is extracted from Datastream.

Figure10 SR-insensitive CML for the EMBI+ indices, January 1994 to October 2009



From now on, we consider SR investors wishing to adopt high environmental standards and impose a set of constraints $\phi_p > \phi_0$ in the same way as in Problem 4. Figure 11 exhibits the SR-sensitive CMLs for several thresholds ϕ_0, and Table 5 displays the corner portfolios.

Figure 11 SR-sensitive CMLs versus SR-insensitive CML for the EMBI+ indices, January 1994 to October 2009

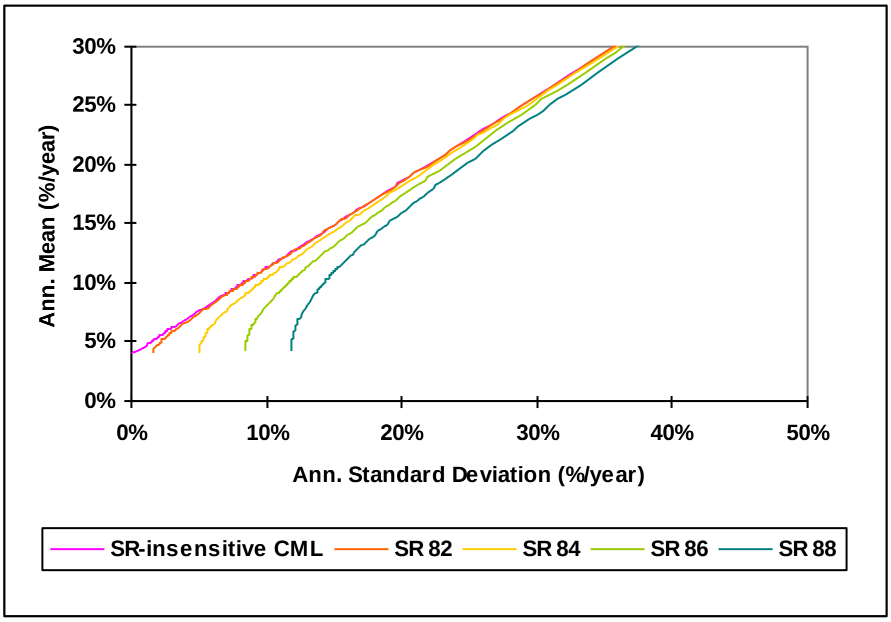


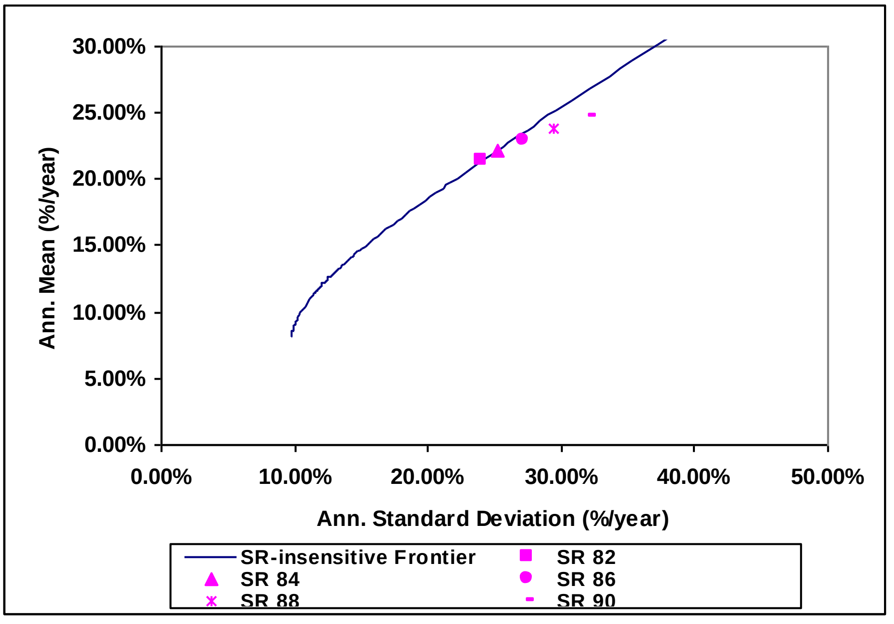
Table 5 Corner portfolios for which the SR constraint is binding

ϕ_0	λ_0	Expected return E_0 (%/year)	Expected volatility σ_0^* (%/year)
82	1.16	50.01	63.06
84	0.38	144.97	193.08
86	0.23	239.93	323.11
88	0.16	334.89	453.13

As expected, for $\phi_0 < \phi^* = 81.03$, the SR-sensitive and SR-insensitive CMLs are identical. For $\phi_0 > \phi^* = 81.03$, the SR-sensitive CML differs from the SR-insensitive one at the bottom and is the same at the top. Here also, the SRI cost appears for investors with high risk aversion. We notice that the corner portfolios have particularly high expected returns and volatilities (see Table 5): this can be explained by the particularly low sensitivity $\hat{\delta}^*$. For example, if we consider a threshold $\phi_0 = 82$, the corner portfolio has an expected return of 50.01%/year and an expected volatility of 63.06%/year, meaning that for expected returns below 50.01%/year, the SR-sensitive and SR-insensitive CMLs are disconnected. However, we observe in Figure 11 that the SR-insensitive and SR-sensitive CMLs are very close for expected returns slightly above 20%/year.

This numerical application highlights that the cost implied by high environmental requirements in an emerging bond portfolio differs according to the investor's risk aversion. In this particular case, it costs more to be green for risk averse investors. Let us now focus on a typical investor. Sharpe (2007) suggests that the "representative investor" has a risk aversion parameter $\lambda = \frac{2}{0.7}$ in the traditional mean-variance optimization of eq. (1). We seek to determine the consequences of SR thresholds for this “representative investor” by computing the optimal portfolios for different thresholds on the portfolio EPI. Figure 12 displays these portfolios (the means and variances of the optimal portfolios are given in Appendix 7).

Figure 12 Displaced optimal portfolios for the “representative investor”



For the “representative investor”, the constraint on the portfolio EPI has no cost while the threshold is below 82.37, which is slightly above the average EPI rating of the sample’s countries. When the threshold is above 82.37, an SRI cost appears and the optimal portfolio is no longer on the SR-insensitive frontier. This SRI cost rises with the strength of the constraint. In this case, the “representative investor” is directly concerned by the disjunction between SR-sensitive and SR-insensitive frontiers for reasonable SR thresholds.

2.2.5. Conclusion

The rapid growth of the SRI funds' market share has given birth to a burgeoning academic literature. Some empirical studies show that there is little difference between the financial returns of SRI funds and conventional funds and some other show an underperformance of the former against the latter. To shed light on this debate, this sub-chapter aimed at modelling SRI in the traditional mean-variance portfolio selection framework (Markowitz, 1952).

In our study, SRI is introduced in the mean-variance optimization as a constraint on the average socially responsible rating of the underlying entities. We show that a threshold on the SR rating may impact the efficient frontier in four different ways, depending on the strength of the responsible constraint, i.e. how much the investor wants to respect high SR standards, and on the cross-sectional link between the expected returns and the SR ratings. The SR-sensitive efficient frontier can be: a) identical to the SR-insensitive efficient frontier (i.e. no cost for anybody), b) penalized at the bottom only (i.e. a cost for high risk-aversion investors only), c) penalized at the top only (i.e. a cost for low risk-aversion investors only), d) totally dominated by the SR-insensitive efficient frontier (i.e. a cost for every investor). The results are the same in the presence of a risk-free asset. Our work highlights the fact that the investor's risk aversion or the funds' risk exposure clearly play a role in the potential cost of investing responsibly, this cost being zero in some cases. This finding is important for practical purposes since it could help portfolio managers of SRI funds to detect a priori in which cases diversification loss would occur.

Due to their general characteristics, our results may be useful in other applications in the asset management industry, notably for portfolio selection with asset liquidity constraints. One possible extension of our analysis is to relax the assumption of independence between expected returns and responsible ratings. Further research could therefore focus on modelling the impact of an SRI constraint in the mean-variance optimization when expected returns and volatilities depend on responsible ratings.

Chapter 3

The mean-variance efficiency tests when there is no riskless asset[1]

3.1 Introduction

Testing the mean-variance (MV) efficiency of the market portfolio, or equivalently testing the validity of the Capital Asset Pricing Model (CAPM) of Sharpe (1964) and Lintner (1965), is a major task for financial econometricians. The debate on this issue dates back to the breakthrough theoretical contributions of Roll (1977) and Ross (1977) questioning the efficiency of the market portfolio. In the wake of these contributions, numerous empirical studies (Gibbons, 1982; Gibbons *et al.*, 1989; MacKinlay and Richardson, 1991; among others) found that the market portfolio may indeed lie far away from the efficient frontier. Ironically, this debate was recently fuelled by Levy and Roll (2010), who published an article in the *Review of Financial Studies* entitled "*The market portfolio may be mean-variance efficient after all*". Based on a new test, we take a fresh look at this issue with the ambition to arbitrate between the contradictory arguments of Roll (1977) and Levy and Roll (2010).

More generally, all portfolio managers are—or should be—faced with the issue of checking whether a given portfolio is optimal within a predefined investment universe. For this purpose, MV efficiency, as defined by Markowitz (1952, 1959), remains the key optimality concept.

[1] This chapter is based on Brière *et al.* (2011). We are grateful to Dick Roll for stimulating discussions during his stay at the Université Libre de Bruxelles. We also thank Gopal Basak for his helpful comments on a previous version of this work.

Currently, the econometric literature offers a wide variety of tests for MV efficiency. Most are designed for universes that include a riskless asset.[2] This represents a considerable constraint when it comes to practical implementation. By contrast, this paper focuses on MV efficiency tests that allow all assets to be risky.

The assumption that all assets are risky is highly relevant given that riskless assets are no longer realistic in modern financial markets. The recent debt crisis has highlighted that even the supposedly safest assets, namely sovereign bonds issued by developed countries, are exposed to default risk. In the same way, the freezing of the money markets and the Lehman Brothers' bankruptcy underlined the counterparty and liquidity risks associated with money market investments (Acharya *et al.*, 2010; Bruche and Suarez, 2010; Krishnamurthy, 2010). Investors can thus meet severe restrictions on borrowing (Black, 1972), and the riskless borrowing rate can largely exceed the Treasury bill rate (Brennan, 1971). For all these reasons, MV efficiency is better tested without assuming the availability of a riskless asset.

Two broad classes of MV efficiency tests for risky-asset universes exist in the literature: likelihood-based tests and geometric tests. The likelihood-based tests are directly inspired by the formulation of the CAPM. While the riskless asset is needed to establish the original CAPM, further refinements by Black (1972) allow the riskless asset to be replaced by the zero-beta portfolio. To address the nonlinearities embedded in the Black CAPM, Gibbons (1982) builds a likelihood-ratio test statistic, for which Kandel (1984, 1986) derives the exact asymptotic chi-square distribution. However, because this test uses the Gauss-Newton

[2] When the investment universe includes a riskless asset, the efficient frontier is a straight line, which makes the derivations far simpler (Gourieroux *et al.*, 1997). Tests falling in this category have been proposed by Gibbons (1982), Jobson and Korkie (1982), and MacKinlay and Richardson (1991), among others. The test introduced by Gibbons *et al*. (1989) has since then become the standard. Michaud (1989) and Green and Hollifield (1992) discuss the limitations of this framework. Besides, MV efficiency tests must be distinguished from MV spanning tests, which examine whether the efficient frontier built from a given set of assets intersects the frontier resulting from a larger set (see De Roon and Nijman (2001) for a survey).

algorithm, practical implementation turns out to be complex (Zhou, 1991). Moreover, Shanken (1985) shows that Gibbons' (1982) test tends to over-reject MV efficiency in finite samples.[3] Levy and Roll (2010) (henceforth, LR) offer a novel likelihood-ratio test for MV efficiency. This test is based on implicitly estimating the zero-beta rate by determining the minimal changes to sample parameters that make a market proxy efficient.[4]

On the other hand, the first geometric test of Basak, Jagannathan and Sun (2002) (henceforth, BJS) is based on the "horizontal distance" between the portfolio whose MV efficiency is in question and its same-return counterpart on the MV efficient frontier.[5] Unfortunately, some portfolios lack such a counterpart (Gerard *et al.*, 2007), which in turn limits the applicability of the BJS test. By contrast, the "vertical test" proposed in this paper circumvents this limitation. Indeed, the vertical inefficiency measure proposed by Kandel and Stambaugh (1995), Wang (1998), and Li *et al.* (2003), namely the difference between the portfolio's expected return and the expected return of its same-variance counterpart on the MV efficient frontier, is well defined for any portfolio.

Our contribution is twofold. First, we define the vertical test statistic for MV efficiency, establish its asymptotic distribution, and compare its size and power performances to those of the LR and BJS tests through Monte Carlo simulations. While no clear hierarchy emerges for small samples, the vertical test outperforms its competitors for large samples as it exhibits equivalent power with a smaller size. Secondly, we re-examine the market portfolio MV efficiency using the three tests under review (LR, BJS and the vertical tests). Irrespectively of the number of stocks in the universe, we find that the market portfolio is never MV efficient

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[3] In reaction to these criticisms, several authors (Shanken, 1985, 1986; Zhou, 1991; Velu and Zhou, 1999; Beaulieu *et al.*, 2008) provide lower and upper bounds to the test p-values.

[4] Small variations in expected returns and volatilities may indeed lead to significant changes in the MV efficient frontier (Best and Grauer, 1991; Britten-Jones, 1999).

[5] The null hypothesis is that the "horizontal distance" is zero. BJS derive the asymptotic distribution of this distance. Interestingly, the BJS test can be implemented with and without restrictions on short-selling. Besides, the BJS test can also be used to compare efficient frontiers (Ehling and Ramos, 2006; Drut, 2010a).

according to both the BJS and the vertical tests. For the LR test, the conclusion depends on the value given to the coefficient α, which determines the relative weight assigned to sample mean changes against standard deviation changes. In other words, the LR test reaches no clear-cut and definitive conclusion regarding the market portfolio's efficiency. Although still frail, the evidence points to the inefficiency of the market portfolio, supporting the Roll's (1977) critique of the CAPM.

The chapter is organized as follows. Section 2 presents the vertical test and its asymptotic properties. Section 3 assesses the size and power of the vertical test and its two competitors. Section 4 tests the Black CAPM on the U.S. equity market. Section 5 concludes.

3.2 The vertical test of mean-variance efficiency

Consider an investment universe composed of N primitive assets with stationary returns characterized by a N-dimensional vector R, with $E(R)=\mu$, and $Cov(R)=\Sigma$. The tested portfolio, P, is composed of primitive assets. Let r denote its return, with $E(r)=\beta$ and $Var(r)=\nu^2$.

Given a sample of returns of size T denoted $(R_t)_{t=1..T}$ for the N primitive assets and $(r_t)_{t=1..T}$ for portfolio P, the empirical counterparts of parameters μ, Σ, β, and ν^2 are respectively given by:

$$\hat{\mu}=\frac{1}{T}\sum_{t=1}^{T}R_t \tag{1}$$

$$\hat{\Sigma}=\frac{1}{T}\sum_{t=1}^{T}R_tR_t'-\hat{\mu}\,\hat{\mu}' \tag{2}$$

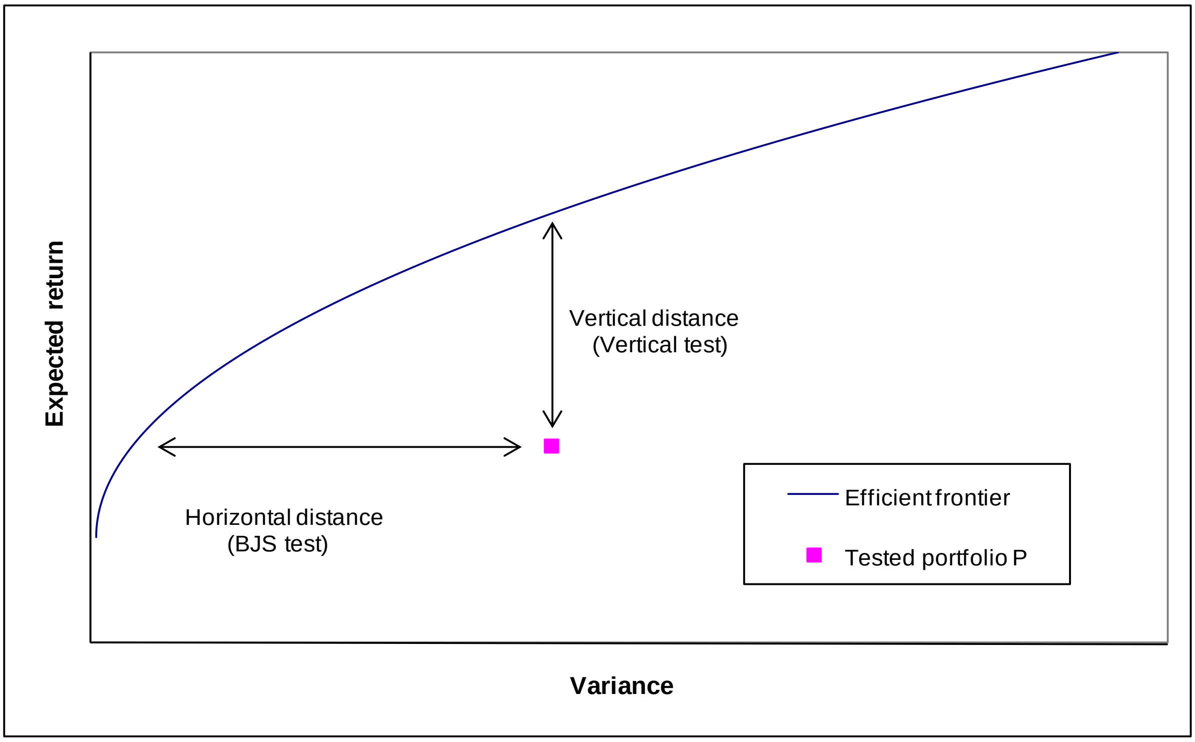
$$\hat{\beta} = \frac{1}{T}\sum_{t=1}^{T} r_t \tag{3}$$

$$\hat{\nu}^2 = \frac{1}{T}\sum_{t=1}^{T} (r_t - \hat{\beta})^2 \tag{4}$$

where R_t and r_t are the date-*t* returns on the *N* primitive assets and on portfolio *P*, respectively.

As illustrated by Figure 1, the "horizontal distance" underlying the BJS test measures of portfolio *P* inefficiency is the difference between the variance of *P* and the variance of its same-expected-return counterpart on the efficient frontier.

Figure 1. Horizontal and vertical distances between portfolio *P* and the efficient frontier



Our vertical test is conceived by transposing the BJS (2002) methodology to the vertical inefficiency measure introduced by Kandel and Stambaugh (1995), Wang (1998), and Li *et al.*

(2003). Hence, the vertical test statistic[6] is the distance between the expected return of portfolio *P* and the expected return of its same-variance MV efficient counterpart. The estimated distance, denoted by $\hat{\theta}$, is the solution to the following program:

$$\hat{\theta} = \begin{bmatrix} \min_{\omega} \left\{ \hat{\beta} - \omega' \hat{\mu} \right\} \\ s.t.\ \omega' \hat{\Sigma} \omega = \hat{v}^2 \\ \sum_{i=1}^{p} \omega_i = 1,\ \omega_i \geq 0,\ for\ i = 1,\dots,p \end{bmatrix} \tag{5}$$

The following proposition states that, under the null that portfolio *P* is MV efficient, estimator $\hat{\theta}$ asymptotically follows a normal distribution:

Proposition 1

$\hat{\theta}$ asymptotically follows a normal distribution:

$$\sqrt{T}(\hat{\theta} - \theta) \to N(0, \phi^2) \text{ as } T \to \infty. \tag{6}$$

with $\phi^2 = \left(\frac{\partial \theta}{\partial \overline{V}}\right)' \Delta \left(\frac{\partial \theta}{\partial \overline{V}}\right)$, where Δ represents the asymptotic covariance matrix of the distinct elements of $\hat{\mu}$, $\hat{\Sigma}$, $\hat{\beta}$, and $\hat{v}$, and $\left(\frac{\partial \theta}{\partial \overline{V}}\right)$ is given by (A2) in Appendix A.

Proof: See Appendix A.

As for the BJS test, this asymptotic result does not require normality assumptions on the asset returns. Moreover, as demonstrated in Appendix A, this result holds both with and without short-selling restrictions.

[6] Another possibility would be to take the minimal Euclidian distance between portfolio *P* and the efficient frontier. This approach would certainly be more elegant, but would also be much more tedious as it would mix up first and second order parameters.

3.3 Power and size performances

In this section, we assess the size and power of the vertical test and compare its performances to those of the BJS and LR tests. To this end, we simulate series of returns drawn from the investment universe imagined by Das *et al.* (2010), including three assets with jointly normal returns having the following parameters:

$$\mu = \begin{bmatrix} 0.05 \\ 0.10 \\ 0.25 \end{bmatrix} \qquad \Sigma = \begin{bmatrix} 0.0025 & 0.0000 & 0.0000 \\ 0.0000 & 0.0400 & 0.0200 \\ 0.0000 & 0.0200 & 0.2500 \end{bmatrix} \tag{8}$$

Das *et al.* (2010) interpret the first asset as a bond, the second as a low-risk stock, and the third as a highly speculative stock. For the sake of comparability,[7] we focus here on the case where short-selling is allowed.

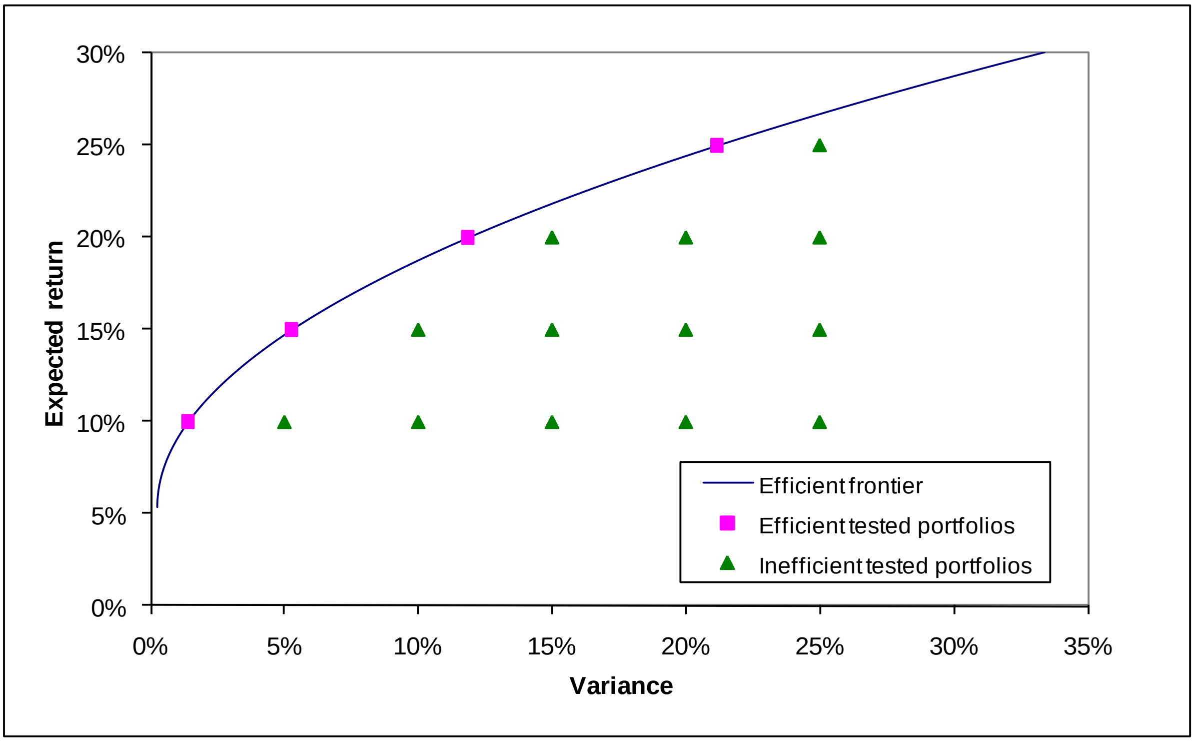
We simulated 1,000 series of returns of lengths 60, 120, 180, and 240, respectively. In each case, two groups of portfolios were composed. The portfolios in the first group were generated on the efficient frontier in order to estimate the risk of type I error (false rejection of the true hypothesis that portfolios are mean-variance efficient). The portfolios in the second group were generated below the efficient frontier to estimate the risk of type II error (failure to reject the false hypothesis).

We follow the assessment of statistical tests suggested by Wasserman (2004). This procedure is based on power maximization (i.e., minimization of the risk of type II error) for a given

[7] LR solely apply their test to cases where short-selling is allowed. Actually, the performances of their test when short-selling is restricted have not been investigated so far.

small size (i.e., risk of type I error). Figure 2 features all tested portfolios on a grid in the MV plane. To each of them, we successively apply the BJS, LR, and vertical tests.

Figure 2. Efficient frontier and tested portfolios



BJS (2002) measure the difference in variances λ between the tested portfolio P and its MV efficient counterpart with same expected return. The estimated horizontal distance is the solution to the following program:

$$\hat{\lambda} = \begin{bmatrix} \min_{\omega} \left\{ \omega' \hat{\Sigma} \omega - \hat{v}^2 \right\} \\ s.t.\ \omega' \hat{\mu} = \hat{\beta} \\ \sum_{i=1}^{p} \omega_i = 1,\ \omega_i \geq 0,\ for\ i = 1,\dots,p \end{bmatrix} \quad (9)$$

Under the null that portfolio P is MV efficient, $\hat{\lambda}$ asymptotically follows a normal distribution: $\sqrt{T}\ \hat{\lambda} \rightarrow N(0, \varepsilon^2)$ as $T \rightarrow \infty$.

The Levy and Roll (2010) test draws on the evidence that slight variations in the sample parameters may make a portfolio MV efficient. More precisely, the LR test statistic is built from asset-return parameters (μ^*, σ^*) that minimize a given distance to the sample parameters $(\hat{\mu}, \hat{\sigma})$ while making portfolio *P* MV efficient:

$$(\mu^*, \sigma^*) = \underset{(\mu,\sigma)\in\left(\Re^N \times \Re^{+N}\right)}{\arg\min} \quad d\big((\mu,\sigma),(\hat{\mu},\hat{\sigma})\big)$$

where distance *d* is defined by:

$$d\big((\mu,\sigma),(\hat{\mu},\hat{\sigma})\big) = \sqrt{\alpha \frac{1}{N}\sum_{i=1}^{N}\left(\frac{\mu_i - \hat{\mu}_i}{\hat{\sigma}_i}\right)^2 + (1-\alpha)\frac{1}{N}\sum_{i=1}^{N}\left(\frac{\sigma_i - \hat{\sigma}_i}{\hat{\sigma}_i}\right)^2} \tag{10}$$

and α is a coefficient determining the relative weight assigned to deviations in means relative to the deviations in standard deviations.[8]

For simplicity, Levy and Roll (2010) reduce the number of parameters to estimate by imposing that covariance matrix Σ^* computed from (μ^*, σ^*) is based on the sample correlation matrix:

$$\Sigma^* = \begin{bmatrix} \sigma^*_1 & 0 & \cdots & & 0 \\ \vdots & \sigma^*_2 & & & \\ & & \ddots & & \vdots \\ & & & & 0 \\ 0 & & \cdots & 0 & \sigma^*_N \end{bmatrix} \hat{C} \begin{bmatrix} \sigma^*_1 & 0 & \cdots & & 0 \\ \vdots & \sigma^*_2 & & & \\ & & \ddots & & \vdots \\ & & & & 0 \\ 0 & & \cdots & 0 & \sigma^*_N \end{bmatrix} \tag{11}$$

Where $\hat{C}$ is the sample correlation matrix. In that way, only the variances have to be estimated.

[8] See Equation (2) in Levy and Roll (2010).

Under the hypothesis that the N original assets follow a jointly normal distribution, the likelihood ratio is given by:

$$T\left\{\log\left(\frac{\hat{\Sigma}}{\Sigma *}\right)-N+trace\left(\hat{\Sigma}^{-1}\left(\Sigma *+\left(\mu *-\hat{\mu}\right)\left(\mu *-\hat{\mu}\right)'\right)\right)\right\} \qquad (12)$$

This test statistic asymptotically follows a chi-square distribution with $2N$ degrees of freedom.

The choice of the trade-off parameter α in Equation (10) is instrumental to the implementation of the LR test. Indeed, a low (resp. high) value of α would create a bias towards standard deviations (resp. means). In extreme cases ($\alpha = 0$ and $\alpha = 1$), the asymptotic distribution of the LR test statistic degenerates into a chi-square with N degrees of freedom. In our performance assessments, we follow Levy and Roll (2010) and set the value of α to 0.75.

3.3.1. False rejection of efficient portfolios

We first assess the type I error. The four simulated efficient portfolios have expected returns of 10%, 15%, 20% and 25%, respectively. The rejection frequencies of the null of portfolio efficiency at the 5% probability level are displayed in Table 1.[9] The results show that the size is uniformly the lowest for the vertical test, followed by the LR test. Nevertheless, the vertical test, and to a lesser extent the LR test, exhibit rejection frequencies that lie below the theoretical threshold of 5%.

[9] The results for the 1% and 10% probability levels are given in Table B1 in Appendix B.

Table 1. Rejection frequencies (in percent) at the 5% probability level for the efficient portfolios

Expected return	T	BJS	Vertical	LR
10%	60	7.6	0.6	3.7
	120	5.5	0.4	1.8
	180	5.1	0.4	1.4
	240	4.1	0.2	1.3
15%	60	6.1	0.6	2.9
	120	6.4	0.4	1.9
	180	5.1	0.0	1.3
	240	4.6	0.0	1.5
20%	60	8.6	0.6	3.1
	120	5.8	0.4	1.7
	180	5.4	0.3	1.5
	240	4.6	0.2	1.6
25%	60	6.4	0.6	2.8
	120	6.3	0.4	1.7
	180	5.6	0.0	1.5
	240	4.9	0.0	0.0

Note: BJS: Basak *et al*. (2002) test; Vertical: vertical test; LR: Levy and Roll (2010) test. *T* is the sample size.

3.3.3. Rejection of inefficient portfolios

We now apply the three MV efficiency tests under review to thirteen portfolios simulated as inefficient in order to assess the probability of falsely concluding that the portfolio was efficient. The results are given in Table 2 for 5% probability.[10]

Table 2. Rejection frequencies (in percent) at the 5% probability level for the inefficient portfolios

		Variance														
		5%			10%			15%			20%			25%		
Expected return	T	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR
10%	60	89.8	49.1	66.6	94.4	62.0	76.4	96.8	69.0	76.7	96.8	70.3	79.9	98.2	72.3	80.6
	120	99.2	85.4	93.9	100.0	93.4	96.4	100.0	94.7	96.2	100.0	96.6	95.9	99.7	96.4	96.1
	180	100.0	96.7	99.1	100.0	98.9	99.6	100.0	99.5	99.7	100.0	99.3	99.3	100.0	99.9	99.4
	240	100.0	99.5	99.9	100.0	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9
15%	60				71.5	24.8	35.1	86.5	38.0	55.4	89.4	49.9	66.7	93.8	55.4	72.3
	120				92.1	51.7	64.5	98.5	72.6	87.2	99.1	83.1	92.5	99.7	86.8	94.9
	180				98.8	75.3	86.5	99.6	92.7	97.4	100.0	96.2	98.9	100.0	97.6	99.5
	240				99.8	88.9	93.8	100.0	97.9	99.5	100.0	99.2	99.9	100.0	99.7	99.9
20%	60							35.6	5.2	5.9	64.5	19.2	27.2	75.7	28.5	44.6
	120							56.3	12.9	12.2	84.2	41.7	53.0	93.8	56.3	71.6
	180							73.6	25.8	24.8	95.7	67.1	75.6	99.5	81.4	90.5
	240							83.8	38.1	36.6	99.0	82.0	89.9	99.8	93.0	97.0
25%	60													31.9	3.3	5.6
	120													44.6	9.2	11.5
	180													58.2	14.7	19.0
	240													72.0	24.0	28.6

Note: BJS: Basak *et al*. (2002) test; Vertical: vertical test; LR: Levy and Roll (2010) test. *T* is the sample size.

[10] The results corresponding to the 1% and 10% probability levels are given in Tables B2 and B3 in Appendix B, respectively.

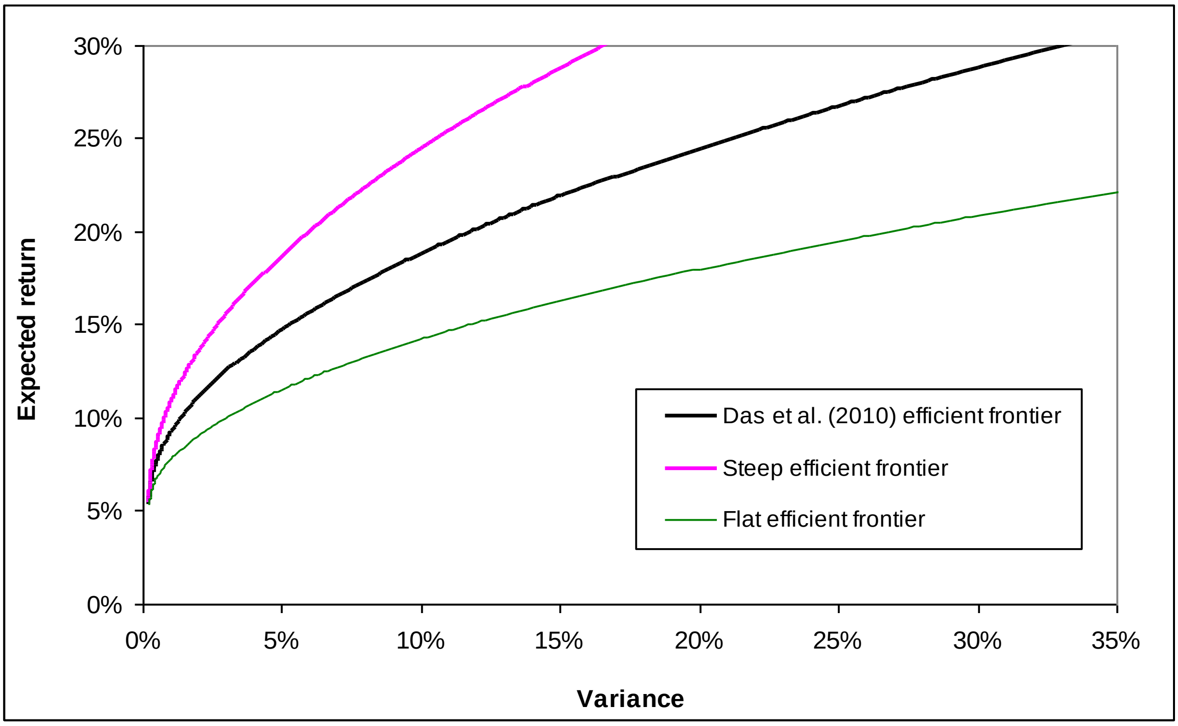
For sample sizes below 180, the power is the lowest for the vertical test, and the highest for the BJS test. However, for larger samples, the vertical test outperforms both the BJS and the LR tests since its size is the lowest for an equivalent power. On the whole, Tables 1 and 2 indicate that the vertical test rejects the null of MV efficiency less frequently than the two other tests.

The differences in power and size between the vertical test and the BJS test might look surprising since both are similar in spirit, namely they are both built from a geometric one-dimensional measure of inefficiency in the MV plane. This counterintuitive result stems from the fact that the standard deviation of the vertical measure of inefficiency is higher than the standard deviation of the horizontal measure used in the BJS test. Indeed, the standard deviations of both tests depend on the absolute values of the weighting loads of the tested-portfolio efficient counterpart. However, the efficient “vertical counterparts” are mostly located on the top of the efficient frontier while the efficient “horizontal counterparts” are mostly located at the bottom of the efficient frontier. Since absolute weighting loads are typically higher on the top of the efficient frontier (riskier portfolios are less diversified), the vertical distance is subject to higher standard deviations than the horizontal BJS test. Consequently, the *t*-statistic generally takes lower values for the vertical test than for the BJS test, and hence the former rejects MV efficiency less frequently than the latter. This feature is particularly relevant when short-selling restrictions are imposed (see Best and Grauer, 1991; Green and Hollifield, 1992; Britten-Jones, 1999).

3.3.3. Robustness checks on the slope of the efficient frontier

Both the horizontal and vertical measures of portfolio inefficiency are restricted to a single dimension in the MV plane. They are, therefore, sensitive to the slope of the efficient frontier. For this reason, we check the robustness of our previous findings by substantially modifying the slope of the efficient frontier. This is achieved by running simulations under two alternative scenarios for the expected return on the speculative stock (15% and 35% respectively instead of 25%) while keeping all other parameters in Equation (8) unchanged. As Figure 3 shows, the first case (15%) produces a flatter efficient frontier, whereas the second (35%) leads to a steeper MV efficient frontier. The minimum-variance portfolios of the three efficient frontiers still remain very close to each other. As previously, we apply the three efficiency tests to a grid of efficient and non-efficient simulated portfolios.

Figure 3. The three efficient frontiers under consideration



The results are reported in Tables C1 to C4 in Appendix C. They can be summarized as follows. For the flat efficient frontier, the BJS test produces the highest size distortions, while the vertical test exhibits the lowest. Given that the BJS test outperforms the other two tests in terms of power irrespective of the sample size, a reasonable procedure for practical use is to combine the BJS and the vertical tests when the MV efficient frontier is flat. In the case of a steep efficient frontier, the results are similar to those obtained in the benchmark case. The vertical test exhibits the lowest size distortions, and its power strongly increases in comparison to the benchmark case, especially for small samples. On the whole, our results show that the vertical test is preferable when the efficient frontier is steep and samples are large.

3.4 Is the market portfolio efficient?

In this section, we apply the BJS, the LR, and the vertical tests of MV efficiency to the capitalization-weighted market portfolio made up of the 100 largest U.S. stocks[11] by market capitalizations as measured on December 31, 2010. The data are monthly returns over the period January 1988 – December 2010 (276 observations). To gauge the sensitivity of our results with respect to the number of available stocks, [12] we also run the tests in stock universes of different sizes ($N = 10, 20, \ldots, 100$).[13] In each case, we select the largest stocks of the sample. For the LR test we follow the original paper when assessing MV efficiency and use a value of α equal to 0.75. As a robustness check, we also test the MV efficiency for a

[11] We selected the 100 largest stocks of the S&P 500 index.
[12] The data are extracted from the Datastream database. Descriptive statistics are given in Appendix D.
[13] In reality, individual investors rarely hold portfolios containing 100 assets (Barber and Odean, 2000; Polkovnichenko, 2005; Goetzmann and Kumar, 2008). The diversification benefits tend to be exhausted once an equity portfolio contains several tens of stocks (Evans and Archer, 1968; Elton and Gruber, 1977; Statman, 1987).

value α (0.98), which gives a similar importance to deviations from variance and mean.[14] Lastly, we apply the three tests to equally-weighted portfolios as robustness checks.

Figure 4 shows the efficient frontiers (without short-selling restrictions) made of 10, 50 and 100 assets, respectively, and the corresponding market portfolios. Noticeably, the MV characteristics of the market portfolio are stable with respect to the number of assets, but the efficient frontier becomes steeper when N increases. In particular, this feature shows that all configurations explored in Section 3 are realistic.

Table 3 summarizes the outcomes of the three tests. Two findings stand out. Firstly, for all sample sizes, both the BJS and the vertical tests reject the null of market portfolio efficiency. Regardless of the number of stocks in the universe, the market portfolio is never MV efficient. Similar results are found for equally-weighted portfolios (see Table 4).

Secondly, for all values of N, the LR test does not reject market portfolio efficiency for α = 0.75, confirming the findings of Levy and Roll (2010).[15] However, for α = 0.98 the LR test rejects market portfolio efficiency. This indicates that the LR test is sensitive to the value taken by parameter α. In fact, for α higher than 0.902 MV efficiency is always rejected by the LR test.

[14] This value is actually very close to the 0.98-value considered in LR as more realistic than the 0.75 used to test the MV efficiency.
[15] Even though our sample period is longer than in Levy and Roll (2010).

Figure 4. Efficient frontiers and market portfolios for the 10, 50 and 100 largest U.S. stocks, respectively. January 1988 – December 2010

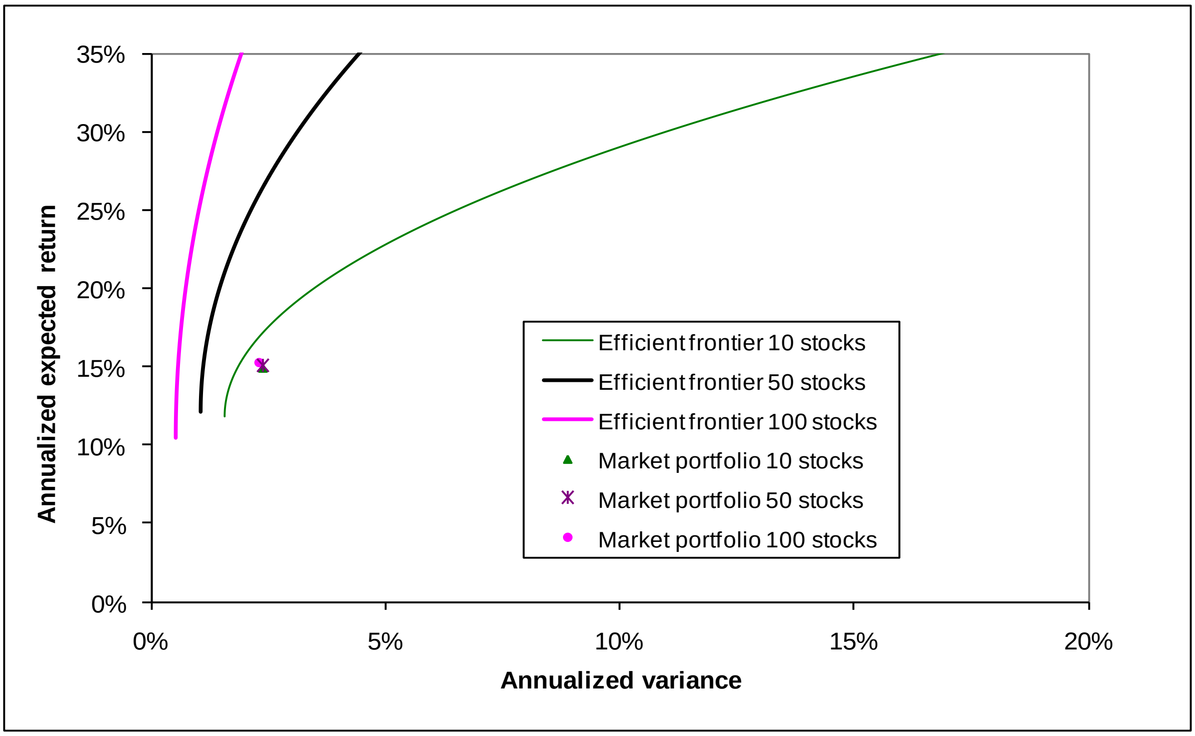


Table 3. MV efficiency tests for the capitalization-weighted market portfolio

Nb. of stocks	Annualized Expected Return (in %)	Volatility (in %)	BJS test	Vertical test	LR test (α = 0.75)	LR test (α = 0.98)
10	14.84	15.49	-3.11(0.00)	1.28 (0.10)	6.09 (1.00)	161.27 (0.00)
20	15.55	16.36	-4.58 (0.00)	2.14 (0.02)	15.54 (1.00)	579.43 (0.00)
30	14.92	15.63	-4.67 (0.00)	2.32 (0.01)	18.87 (1.00)	773.40 (0.00)
40	15.21	15.64	-5.25 (0.00)	2.94 (0.00)	28.49 (1.00)	1597.15 (0.00)
50	15.05	15.48	-5.54 (0.00)	3.25 (0.00)	37.61 (1.00)	2562.73 (0.00)
60	15.20	15.54	-5.90 (0.00)	3.78 (0.00)	48.73 (1.00)	3357.71 (0.00)
70	15.27	15.40	-6.56 (0.00)	4.46 (0.00)	65.54 (1.00)	3106.69 (0.00)
80	15.33	15.31	-6.53 (0.00)	4.58 (0.00)	76.76 (1.00)	3491.16 (0.00)
90	15.23	15.22	-6.83 (0.00)	4.74 (0.00)	89.71 (1.00)	3542.50 (0.00)
100	15.25	15.22	-7.17 (0.00)	5.05 (0.00)	102.27 (1.00)	4045.07 (0.00)

Coefficient α denotes the MV trade-off in the LR test statistic. p-values are given in parentheses.

Table 4. MV efficiency tests for the equally-weighted market portfolio

Nb. of stocks	Annualized Expected Returns (in %)	Volatility (in %)	BJS test	Vertical test	LR test (α = 0.75)	LR test (α = 0.98)
10	14.29	14.95	-3.22 (0.00)	1.33 (0.09)	6.78 (1.00)	197.70 (0.00)
20	15.34	16.79	-4.56 (0.00)	2.18 (0.01)	15.75 (1.00)	706.71 (0.00)
30	14.32	15.50	-4.54 (0.00)	2.39 (0.01)	19.37 (1.00)	979.52 (0.00)
40	15.17	15.72	-4.99 (0.00)	2.90 (0.00)	28.48 (1.00)	1771.03 (0.00)
50	14.79	15.47	-5.27 (0.00)	3.23 (0.00)	36.90 (1.00)	2681.93 (0.00)
60	15.22	15.76	-5.65 (0.00)	3.75 (0.00)	47.80 (1.00)	3381.66 (0.00)
70	15.39	15.46	-6.14 (0.00)	4.36 (0.00)	64.71 (1.00)	3453.09 (0.00)
80	15.53	15.28	-6.00 (0.00)	4.45 (0.00)	75.95 (1.00)	3938.86 (0.00)
90	15.21	15.13	-6.29 (0.00)	4.60 (0.00)	89.03 (1.00)	4137.95 (0.00)
100	15.30	15.17	-6.68 (0.00)	4.92 (0.00)	102.12 (1.00)	4535.09 (0.00)

Coefficient α denotes the MV trade-off in the LR test statistic. p-values are given in parentheses.

On the whole, our findings support Roll (1977) over Levy and Roll (2010). Indeed, while the conclusion of the LR test depends on the trade-off coefficient α, the two other tests unequivocally conclude that the market portfolio is never MV efficient. The validity of the zero-beta CAPM, relying on the efficiency of the market portfolio, is thus strongly called into question. In a nutshell, the fundamental contributions of both Roll (1977) and Ross (1977) remain highly relevant for portfolio management.

3.5 Conclusion

This chapter develops a new test of portfolio MV efficiency based on the realistic assumption that all assets are risky. The test is based upon the vertical distance of a portfolio from the efficient frontier. While the evidence is mixed for small samples, our test outperforms the previous MV efficiency tests proposed by Basak *et al*. (2002) and Levy and Roll (2010) for large samples since it produces lower size distortions for comparable power. The empirical analysis shows that the LR test is sensitive to the value taken by the nuisance parameter determining the relative weight assigned to sample-mean changes against standard-deviation changes. Furthermore, both the vertical and horizontal tests are based on intuitive measures in the MV plane and are, therefore, easy to visualize, which makes them more appealing than the LR test.

The ideally balanced distance in the MV plane remains, however, the orthogonal distance. Even though a test based on this distance is feasible in theory, deriving its closed-form asymptotics could prove challenging. We leave this for further work. Meanwhile, the best alternative for practitioners to test portfolio efficiency is probably the dual approach combining the vertical and horizontal tests. In the final decision, the weight to be allocated to each test should then take into account the curvature of the efficient frontier.

The existing MV efficiency tests could be improved in several ways. The LR test could be generalized by relaxing the short-selling restriction. For all tests, implementing the jackknife-type estimator of the covariance matrix developed by Basak *et al.* (2009) could offer a promising extension since this estimator produces a more accurate covariance matrix than the sample one.

Our empirical application to the U.S. equity market highlights that the market portfolio is not MV efficient, invalidating the zero-beta CAPM. Consequently, regarding the Roll (1977) versus Levy and Roll (2010) controversy, our findings indicate that Roll’s (1977) scepticism on the validity of the CAPM seems to survive the recent rehabilitation attempts made by Levy and Roll (2010).

Appendix A: Proof of Proposition 1

We first derive the asymptotic distribution of the vertical distance, $\hat{\theta}$, defined in Equation (5) in the case where short-selling is forbidden. At the end of this Appendix, we extend the results to the case where short-selling is allowed

Let x be a k-dimensional vector, and denote $x^{(i)} = (x_i, x_{i+1}, ..., x_k)'$. Consider a symmetric matrix B of order k, and $B = [B_1 : B_2 : ... : B_k]$ where B_i is the i^{th} column of B. Let $vec(B)$ be the stacked vector of the columns of B:

$$vec(B) = (B_1^{(1)'}, B_2^{(2)'}, \ldots, B_k^{(k)'})'$$

Next, let $\overline{V}$ be the vector formed by stacking the sample mean of R_t, the elements of $\text{cov}(R_t)$, the sample mean of r_t, and the sample variance of r_t:

$$\overline{V} = (\hat{\mu}', (vec(\hat{\Sigma}))', \hat{\beta}, \hat{\nu}^2)'$$

Vector $\overline{V}$ thus summarizes the first and second moments of the sample returns. Similarly to BJS (2002), we express vector $\overline{V}$ as a function of the sample non-central first and second moments of R_t and r_t. The transformed vector, U_t, is defined by:

$$U_t = (R_t', (vec(R_t R_t'))', r_t, r_t^2)' = (R_t', Y_t', r_t, w_t)'$$

and its sample mean, $\overline{U}$, is:

$$\overline{U} = \frac{1}{T}\sum_{t=1}^{T} U_t = \frac{1}{T}\sum_{t=1}^{T} \left[R_t' : Y_t' : r_t : w_t\right]'$$

Let $g(.)$ denote the function that maps vector $\overline{U}$ to vector $\overline{V}$:

$$g(\overline{U}) = g\begin{pmatrix} \hat{\mu} \\ \overline{Y} \\ \hat{\beta} \\ \overline{w} \end{pmatrix} = \begin{pmatrix} \hat{\mu} \\ \overline{Y} - vec(\hat{\mu}\,\hat{\mu}') \\ \hat{\beta} \\ \overline{w} - \hat{\beta}^2 \end{pmatrix} = \begin{pmatrix} \hat{\mu} \\ vec(\hat{\Sigma}) \\ \hat{\beta} \\ \hat{\nu}^2 \end{pmatrix} = \overline{V}$$

By applying the delta method, when T tends to the infinite, we have:

$$\sqrt{T}\left(\bar{V}-V\right)=\sqrt{T}\left(g(\bar{U})-g(\alpha)\right)\rightarrow N(0,\Delta) \quad \text{(A1)}$$

where $$\Delta = D\Lambda_0 D' \quad \text{(A2)}$$

$D=\left(\frac{\partial g_i}{\partial U_j}\right)$ and Λ_0 being the covariance matrix of U_t, and from BJS (2002, p. 1208):

$$D=\frac{\partial g}{\partial x}\Big|_{x=\bar{U}_T}=\begin{pmatrix} I_p & 0_{p\times pv} & 0_{p\times 2} \\ K_1 & & \\ \vdots & I_{pv} & 0_{pv\times 2} \\ K_p & & \\ 0_{2\times p} & 0_{2\times pv} & \begin{pmatrix} 1:0 \\ -2\hat{\beta}:1 \end{pmatrix} \end{pmatrix} \quad \text{(A3)}$$

Where $pv=\frac{p(p+1)}{2}$; $K_i=-\left[0_{(p-i+1)\times(i-1)}:\hat{\mu}^{(i)}:0_{(p-i+1)\times(p-i)}\right]-\hat{\mu}_i\left[0_{(p-i+1)\times(i-1)}:I_{p-i+1}\right]$; $\hat{\mu}_i$ stands for the i^{th} element of $\hat{\mu}$, and I_Z stands for the identity matrix of rank Z.

The asymptotic distribution of vector $\bar{V}$ is given by (A1). Let us now move to the vertical distance, $\hat{\theta}$, which is a derivable function of vector $\bar{V}$. Consequently, the delta method establishes that the asymptotic variance ϕ^2 of $\hat{\theta}$ is $\left(\frac{\partial\hat{\theta}}{\partial\bar{V}}\right)'\Delta\left(\frac{\partial\hat{\theta}}{\partial\bar{V}}\right)$, where derivative $\frac{\partial\hat{\theta}}{\partial\bar{V}}$ needs to be computed. With this aim, we express that $\hat{\theta}$ minimizes the following Lagrangian function:

$$l=\hat{\beta}-\omega'\hat{\mu}+\delta_1(\omega'\iota-1)+\delta_2(\omega'\hat{\Sigma}\omega-\hat{v}^2)-\phi'\omega \quad \text{(A4)}$$

By differentiation, we have:

$$\frac{\partial\hat{\theta}}{\partial\bar{V}}=\frac{\partial l}{\partial\bar{V}}=(-\hat{\mu}'-\phi'+\delta_1\iota'+\delta_2 2\,\omega'\hat{\Sigma})\frac{\partial\omega}{\partial\bar{V}}$$

$$+\delta_2\left[0_{1\times p}:(\omega_1{}^2:2\omega_1\omega_2:2\omega_1\omega_2:\ldots:2\omega_1\omega_p:\omega_2{}^2:\ldots:\omega_p{}^2):0:-1\right]+\left(-\omega':0_{1\times pv}:1:0\right) \quad \text{(A5)}$$

From the first order condition applied to (A4), we obtain:

$$\frac{\partial l}{\partial \omega} = 0_{p\times 1} = -\hat{\mu} - v' + \delta_1 \iota + \delta_2 (2\hat{\Sigma}\omega)$$

And consequently:

$$\frac{\partial \hat{\theta}}{\partial \overline{\overline{V}}} = \left(-\omega' : 0_{1\times pv} : 1 : 0\right) + \delta_2 \left[0_{1\times p} : (\omega_1{}^2 : 2\omega_1\omega_2 : 2\omega_1\omega_2 : \ldots : 2\omega_1\omega_p : \omega_2{}^2 : \ldots : \omega_p{}^2) : 0 : -1\right] \tag{A6}$$

Combining the results in (A1), (A4) and (A6), we obtain the asymptotic variance ϕ^2 of the vertical distance $\hat{\theta}$:

$$\phi^2 = \left(\frac{\partial \hat{\theta}}{\partial \overline{\overline{V}}}\right)' \Delta \left(\frac{\partial \hat{\theta}}{\partial \overline{\overline{V}}}\right) \tag{A7}$$

When there are no short-selling restrictions, the efficient frontier is modified because the sole constraint applied to ω is that its components add up to one. Let $\hat{\theta}*$ denote the vertical distance in this case. The modified Lagrangian function is:

$$l* = \hat{\beta} - \omega' \hat{\mu} + \delta_1 (\omega' \iota - 1) + \delta_2 (\omega' \hat{\Sigma} \omega - \hat{v}^2) \tag{A8}$$

By differentiating both sides of (A7), we get:

$$\frac{\partial l*}{\partial \overline{\overline{V}}} = \left(-\omega' : 0_{1\times pv} : 1 : 0\right) + \delta_2 \left[0_{1\times p} : (\omega_1{}^2 : 2\omega_1\omega_2 : 2\omega_1\omega_2 : \ldots : 2\omega_1\omega_p : \omega_2{}^2 : \ldots : \omega_p{}^2) : 0 : -1\right] \tag{A9}$$

Lastly, substituting $\frac{\partial l*}{\partial \overline{\overline{V}}}$ in (A8) by $\frac{\partial l*}{\partial \overline{\overline{V}}}$ from (A5) gives the asymptotic variance $\phi^2 *$ of the vertical distance $\hat{\theta}*$ when there are no short-selling restrictions. Its expression stands as:

$$\phi^2 * = \left(\frac{\partial \hat{\theta}*}{\partial \overline{\overline{V}}}\right)' \Delta \left(\frac{\partial \hat{\theta}*}{\partial \overline{\overline{V}}}\right) \tag{A10}$$

Appendix B: Rejection Frequencies at the 1% and 10% Probability Levels

Table B1. Rejection frequencies (in percent) at the 1% and 10% probability levels for the efficient portfolios

Expected return		T	1% probability error			10% probability error		
			BJS	Vertical	LR	BJS	Vertical	LR
	10%	60	1.7	0.0	2.2	16.7	2.2	4.7
		120	0.9	0.0	0.6	12.3	1.3	3.0
		180	0.6	0.0	0.7	12.8	1.3	2.6
		240	0.5	0.0	0.4	11.2	1.2	2.1
	15%	60	2.2	0.0	1.7	13.6	2.3	4.0
		120	1.6	0.0	0.7	14.2	1.5	2.7
		180	1.3	0.0	0.5	12.4	1.6	2.3
		240	0.9	0.0	0.4	12.1	1.0	1.8
	20%	60	2.4	0.0	1.7	17.8	2.3	4.1
		120	1.0	0.0	0.6	14.5	1.3	2.9
		180	0.8	0.0	0.6	13.7	1.3	2.3
		240	0.8	0.0	0.4	12.1	1.2	2.1
	25%	60	2.2	0.0	1.4	14.1	2.4	4.1
		120	1.5	0.0	0.7	14.3	1.6	2.9
		180	1.3	0.0	0.5	12.5	1.4	2.2
		240	0.9	0.0	0.0	12.2	1.1	0.0

Note: BJS: Basak *et al*. (2002) test; Vertical: vertical test; LR: Levy and Roll (2010) test. *T* denotes the sample size.

Table B2. Rejection frequencies (in percent) at the 1% probability level for the inefficient portfolios

			Variance														
			5%			10%			15%			20%			25%		
Expected return		T	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR
	10%	60	78.5	14.7	55.3	86.8	24.4	65.8	92.0	32.4	70.4	92.7	35.7	73.2	95.3	38.8	75.4
		120	96.8	44.1	87.6	99.5	65.4	92.6	99.6	71.1	92.8	99.7	75.0	93.2	99.5	76.5	91.4
		180	99.7	75.2	97.7	99.9	89.2	99.0	100.0	93.0	99.0	99.9	93.2	98.5	100.0	95.6	98.5
		240	99.9	91.1	99.7	100.0	97.9	99.5	100.0	98.5	100.0	100.0	99.0	100.0	100.0	98.7	99.8
	15%	60				49.8	3.2	23.8	68.1	9.0	42.4	78.3	18.0	55.8	84.8	17.7	61.2
		120				76.1	13.7	51.6	92.2	30.7	77.3	96.2	42.9	86.5	98.4	51.2	89.3
		180				91.1	31.9	75.2	98.0	59.2	95.1	99.6	75.2	97.1	99.8	79.2	98.7
		240				96.8	47.5	89.0	99.7	79.6	98.5	100.0	90.5	99.3	100.0	96.0	99.9
	20%	60							17.1	0.7	3.1	41.9	2.5	16.3	56.4	4.9	31.0
		120							32.6	0.7	5.0	64.6	8.3	39.3	81.5	18.6	56.4
		180							46.3	3.1	12.1	83.7	19.1	63.6	95.0	40.9	83.4
		240							59.6	6.5	19.4	94.3	38.2	80.0	98.6	60.5	94.9
	25%	60													13.9	0.1	3.6
		120													20.4	0.8	4.9
		180													31.7	0.9	9.0
		240													44.0	2.0	14.2

Note: BJS: Basak *et al*. (2002) test; Vertical: vertical test; LR: Levy and Roll (2010) test. *T* denotes the sample size.

Table B3. Rejection frequencies (in percent) at the 10% probability level for the inefficient portfolios

			Variance														
			5%			10%			15%			20%			25%		
		T	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR
Expected return	10%	60	94.7	70.6	71.8	96.8	79.5	79.7	98.8	84.5	80.7	98.6	86.8	83.6	98.9	87.9	83.1
		120	99.9	95.1	95.6	100.0	98.7	98.1	100.0	98.7	97.9	100.0	99.2	96.9	99.9	98.9	97.6
		180	100.0	99.4	99.6	100.0	100.0	99.8	100.0	100.0	99.8	100.0	99.7	99.6	100.0	100.0	99.9
		240	100.0	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	15%	60				81.3	45.0	42.9	91.5	60.8	63.0	93.2	69.9	71.3	96.2	76.0	76.4
		120				96.5	74.8	72.4	99.6	89.8	90.8	99.8	94.0	94.9	99.8	96.2	97.2
		180				99.6	90.4	90.1	100.0	97.7	98.2	100.0	99.6	99.4	100.0	99.5	99.6
		240				99.9	97.0	96.4	100.0	99.3	99.6	100.0	99.9	99.9	100.0	100.0	100.0
	20%	60							50.3	15.7	8.8	75.4	37.7	34.0	83.3	51.8	51.0
		120							71.3	35.1	19.4	91.0	66.0	61.8	96.7	77.5	78.8
		180							84.3	48.7	33.5	98.1	84.8	82.8	99.9	93.9	93.5
		240							92.0	63.9	46.2	99.8	95.5	94.0	99.8	98.4	98.4
	25%	60													43.7	14.0	7.8
		120													59.8	22.8	15.4
		180													72.3	34.6	25.0
		240													82.9	49.2	37.1

Note: see Table B1.

Appendix C: Robustness Checks

Table C1. Flat efficient frontier. Rejection frequencies (in percent) at the 5% probability level for the efficient portfolios

Expected return		T	BJS	Vertical	LR
	10%	60	14.8	0.6	5.9
		120	10.0	0.2	2.7
		180	8.3	0.1	1.2
		240	8.9	0.3	1.2
	15%	60	15.5	0.7	3.9
		120	10.7	0.5	2.4
		180	9.8	0.1	1.5
		240	8.6	0.1	0.9
	20%	60	16.2	1.0	6.5
		120	11.4	0.5	2.4
		180	9.7	0.3	2.0
		240	9.5	0.6	1.4
	25%	60	15.1	0.5	4.3
		120	11.3	0.2	2.4
		180	9.8	0.3	2.1
		240	8.8	0.1	0.6

Note: see Table B1.

Table C2. Flat efficient frontier. Rejection frequencies (in percent) at the 5% probability level for the inefficient portfolios

			Variance														
			5%			10%			15%			20%			25%		
		T	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR
Expected return	10%	60	50.8	10.6	24.2	73.1	19.5	21.3	76.7	28.2	30.2	79.4	32.8	35.4	81.3	33.3	37.9
		120	67.7	16.1	20.7	88.3	41.2	30.2	94.1	53.2	43.9	95.2	59.6	51.3	95.1	59.1	53.0
		180	81.2	30.4	31.3	95.9	63.5	51.2	98.4	70.8	60.6	99.0	80.1	71.5	99.4	79.3	71.0
		240	87.6	41.7	42.6	97.9	76.8	67.1	99.3	83.6	76.5	99.8	89.7	84.4	99.9	91.4	85.2
	15%	60				14.5	0.5	3.5	37.5	3.3	15.9	48.7	9.6	15.9	58.5	12.9	15.6
		120				11.9	0.3	2.0	44.8	6.9	19.2	67.8	17.9	21.3	77.2	23.9	15.0
		180				9.7	0.3	1.6	56.3	10.8	21.8	78.9	28.9	31.2	88.4	41.6	27.4
		240				9.5	0.1	0.9	60.5	13.4	25.3	86.5	38.2	39.6	94.8	54.3	41.0

Note: see Table B1.

Table C3. Steep efficient frontier. Rejection frequencies (in percent) at the 5% probability level for the efficient portfolios

Expected return		T	BJS	Vertical	LR
	10%	60	3.0	0.2	4.2
		120	2.1	0.2	3.5
		180	2.6	0.3	3.1
		240	1.0	0.0	1.9
	15%	60	4.1	0.3	5.3
		120	3.5	0.3	3.4
		180	3.5	0.3	3.3
		240	3.6	0.0	3.1
	20%	60	3.6	0.1	5.3
		120	4.5	0.3	4.1
		180	3.6	0.0	4.1
		240	2.5	0.3	2.5
	25%	60	4.2	0.5	4.1
		120	3.4	0.2	3.3
		180	3.4	0.4	3.2
		240	2.6	0.0	2.2

Note: see Table B1.

Table C4. Steep efficient frontier. Rejection frequencies (in percent) at the 5% probability level for the inefficient portfolios

			Variance														
			5%			10%			15%			20%			25%		
		T	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR	BJS	Vertical	LR
Expected return	10%	60	99.7	91.2	98.0	99.6	96.1	98.2	100.0	95.2	98.3	99.9	96.7	97.5	99.6	96.1	98.2
		120	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	100.0	100.0	100.0	100.0
		180	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		240	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	15%	60	85.4	44.6	78.2	97.5	76.8	94.8	99.3	88.0	97.8	99.9	92.1	98.4	99.6	89.5	98.5
		120	98.8	81.3	96.7	100.0	99.2	100.0	100.0	99.8	100.0	100.0	99.8	100.0	100.0	99.9	100.0
		180	99.7	97.2	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		240	100.0	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	20%	60				78.8	37.3	68.8	92.2	61.9	88.2	97.7	74.1	93.9	97.9	80.5	94.7
		120				96.2	71.9	93.9	99.9	94.2	99.6	100.0	97.4	99.9	99.9	99.0	99.9
		180				99.4	93.0	99.4	100.0	99.7	100.0	100.0	99.9	100.0	100.0	100.0	100.0
		240				100.0	98.0	99.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	25%	60							57.9	19.2	46.1	81.2	40.6	73.5	92.5	61.6	87.9
		120							87.5	53.0	79.9	98.2	83.8	97.3	99.5	94.0	99.6
		180							96.2	75.7	94.4	99.9	96.5	99.7	100.0	99.7	99.9
		240							99.1	92.8	98.5	100.0	99.5	100.0	100.0	100.0	100.0

Note: see Table B1.

Appendix D: Descriptive Statistics for the Considered U.S. stocks

Table D1. Descriptive statistics of the stocks' monthly returns over the period January 1988 – December 2010

Company	Annualized mean return (in %)	Annualized volatility (in %)	Market capitalization in billion USD as of December 31, 2010
EXXON MOBIL	9.8	16.1	368.7
APPLE	26.9	47.8	295.9
MICROSOFT	24.6	34.6	238.8
GENERAL ELECTRIC	10.3	25.9	194.9
WAL MART STORES	14.8	23.5	192.1
CHEVRON	11.1	19.7	183.6
INTERNATIONAL BUS.MCHS.	11.3	28.6	182.3
PROCTER & GAMBLE	13.2	20.8	180.1
AT&T	7.7	23.8	173.6
JOHNSON & JOHNSON	13.2	20.5	169.9
JP MORGAN CHASE & CO.	13.9	34.9	165.8
WELLS FARGO & CO	17.1	29.9	162.7
ORACLE	34.6	49.0	158.1
COCA COLA	14.0	22.0	152.7
PFIZER	11.9	24.4	140.3
CITIGROUP	12.7	41.6	137.4
BANK OF AMERICA	12.0	39.4	134.5
INTEL	22.3	39.3	117.3
SCHLUMBERGER	15.2	30.1	113.9
MERCK & CO.	10.1	26.5	111.0
PEPSICO	13.4	21.3	103.5
VERIZON COMMUNICATIONS	6.1	23.6	101.1
CONOCOPHILLIPS	13.1	25.2	100.1
HEWLETT-PACKARD	15.1	35.3	92.2
MCDONALDS	14.0	22.4	81.1
OCCIDENTAL PTL.	12.4	26.3	79.7
ABBOTT LABORATORIES	11.3	20.0	74.1
UNITED TECHNOLOGIES	15.2	23.9	72.7
WALT DISNEY	12.5	26.3	71.0
3M	9.8	20.4	61.7
CATERPILLAR	16.0	31.1	59.4
HOME DEPOT	22.0	29.6	57.5
FORD MOTOR	12.8	46.3	57.1
AMGEN	25.4	35.6	51.9
US BANCORP	15.7	29.2	51.7
AMERICAN EXPRESS	13.2	33.0	51.7
ALTRIA GROUP	15.4	26.7	51.4
BOEING	12.2	28.0	47.9
CVS CAREMARK	10.8	26.2	47.2
EMC	33.5	52.1	47.2
UNION PACIFIC	12.8	23.7	45.7
COMCAST 'A'	15.2	32.8	45.7
E I DU PONT DE NEMOURS	8.7	24.9	45.5

Company	Annualized mean return (in %)	Annualized volatility (in %)	Market capitalization in billion USD as of December 31, 2010
BRISTOL MYERS SQUIBB	6.8	23.2	45.3
APACHE	21.4	35.3	43.5
EMERSON ELECTRIC	10.9	22.1	43.0
TARGET	17.2	28.1	42.6
HONEYWELL INTL.	13.1	30.2	41.5
ELI LILLY	9.3	27.1	40.4
MEDTRONIC	17.7	26.0	39.8
UNITEDHEALTH GP.	30.6	35.1	39.7
DOW CHEMICAL	8.6	35.4	39.6
COLGATE-PALM.	14.5	23.2	38.8
TEXAS INSTS.	19.0	41.8	38.2
ANADARKO PETROLEUM	16.6	34.7	37.7
BANK OF NEW YORK MELLON	13.6	30.9	37.5
HALLIBURTON	15.0	37.5	37.1
WALGREEN	16.9	26.3	35.9
DEERE	15.8	29.5	35.1
LOWE'S COMPANIES	22.7	35.7	34.6
DEVON ENERGY	25.5	39.3	33.9
NIKE 'B'	24.8	33.6	33.2
SOUTHERN	8.8	17.5	32.1
PNC FINL.SVS.GP.	8.8	29.1	31.9
DANAHER	23.1	28.5	30.8
CORNING	19.7	52.0	30.2
NEWMONT MINING	10.9	38.9	29.9
BAXTER INTL.	10.3	24.8	29.5
FEDEX	14.6	31.0	29.3
CARNIVAL	17.6	34.6	28.0
CELGENE	37.1	68.4	27.8
EXELON	8.6	22.9	27.5
GENERAL DYNAMICS	13.8	26.1	26.8
AFLAC	20.1	32.1	26.6
ILLINOIS TOOL WORKS	14.2	24.5	26.5
JOHNSON CONTROLS	16.4	29.7	25.9
HESS	13.6	28.9	25.8
KIMBERLY-CLARK	9.1	20.2	25.7
TRAVELERS COS.	9.8	25.9	25.6
FRANKLIN RESOURCES	22.6	34.2	25.4
DOMINION RES.	5.9	17.3	25.2
BAKER HUGHES	12.2	35.7	24.7
CSX	13.0	26.8	24.2
DUKE ENERGY	6.1	20.4	23.6
STATE STREET	17.6	32.8	23.3
NORFOLK SOUTHERN	11.9	26.8	22.8
AUTOMATIC DATA PROC.	12.2	21.5	22.8
GENERAL MILLS	10.1	18.3	22.6
THERMO FISHER SCIENTIFIC	17.3	30.9	22.0
CUMMINS	20.4	39.0	21.8
NEXTERA ENERGY	6.9	18.5	21.6

Company	Annualized mean return (in %)	Annualized volatility (in %)	Market capitalization in billion USD as of December 31, 2010
STRYKER	23.5	32.6	21.3
MOTOROLA SOLUTIONS	11.5	36.9	21.3
PACCAR	18.3	31.8	20.9
CHARLES SCHWAB	30.7	45.3	20.4
PREC.CASTPARTS	20.2	34.6	19.9
AIR PRDS.& CHEMS.	13.0	26.4	19.5
ARCHER-DANLS.-MIDL.	12.2	27.9	19.2
BECTON DICKINSON	13.6	24.0	19.1
NORTHROP GRUMMAN	10.6	30.0	18.9

Conclusion générale

Le présent manuscrit de thèse a exploré différents aspects de la sélection de portefeuille dans le cadre de l'ISR. Son ambition était d'apporter des éléments de réponses à plusieurs lacunes de la littérature comme l'ISR portant sur les obligations d'Etat ou encore le rôle de l'aversion au risque dans l'ISR. Résumons ici ses principaux résultats et présentons comment ils pourraient être développés et étendus.

Le premier chapitre a consisté en l'étude de portefeuilles socialement responsables investis en obligations d'Etats de pays développés. Etonnamment, les études empiriques antérieures portant sur l'ISR n'avaient pas abordé cette classe d'actifs. Le chapitre 1 montre qu'il est possible d'augmenter la notation socialement responsable moyenne d'un portefeuille d'obligations d'Etat sans perdre significativement en termes de diversification. Ce résultat constitue une bonne nouvelle pour les investisseurs ISR. Cependant, le niveau de notation socialement responsable moyenne du portefeuille accessible sans sacrifice financier significatif varie selon le critère pris en compte. Dans des travaux ultérieurs, il serait très intéressant de tester la robustesse des résultats obtenus dans le chapitre 1 et d'inclure dans la période d'observation les années récentes. En effet, la récente crise de la dette publique dans les pays développés, et en Europe en particulier, pourrait montrer qu'investir préférentiellement dans les pays les mieux notés pour les indicateurs socialement responsables pourrait rapporter significativement plus qu'investir sur les pays les plus mal notés. Enfin, alors que de nombreux portefeuilles sont investis simultanément dans plusieurs classes d'actifs dans un but de diversification, il serait pertinent de réaliser une étude empirique se penchant sur l'établissement de portefeuilles socialement responsables multi-classes d'actifs (actions, obligations d'entreprise, obligations d'Etat).

Le rôle de l'aversion pour le risque dans l'ISR est mis en évidence dans le chapitre 2. Une modélisation de la sélection de portefeuille moyenne-variance dans le cadre du « best-in-class » y est proposée. Le souhait d'investir de façon responsable est introduit par le biais de contraintes linéaires dans l'optimisation de portefeuille. Quatre cas sont susceptibles de se produire : a) la frontière efficiente n'est pas pénalisée, b) seul le bas de la frontière est pénalisée (les investisseurs tolérant le risque ne sont pénalisés), c) seul le haut de la frontière est pénalisée (les investisseurs présentant de l'aversion pour le risque ne sont pas pénalisés), d) toute la frontière est pénalisée (tous les investisseurs sont pénalisés). L'aversion au risque de l'investisseur joue donc un rôle crucial dans l'ISR : dans certains cas, les investisseurs affichant de l'aversion vis-à-vis du risque sont les plus pénalisés par une contrainte ISR et c'est l'inverse dans d'autres situations. Le chapitre 2 expose clairement les conditions dans lesquelles l'ISR est coûteux. Elles dépendent de deux éléments : le lien entre notations socialement responsables et rendements attendus des actifs et le degré d'exigence de l'investisseur par rapport aux notations socialement responsables. Ces résultats ayant été obtenus en faisant l'hypothèse d'efficience des marchés, ce travail pourrait être étendu en faisant l'hypothèse soutenue par de nombreux acteurs de marché que les indicateurs socialement responsables contiennent de la valeur non prise en compte par les marchés. Celle-ci est fréquemment avancée aux investisseurs finaux comme un argument commercial central même si les études empiriques sur le sujet sont encore peu nombreuses. Concrètement, cela reviendrait à faire l'hypothèse d'erreurs d'anticipations des rendements attendus.

Une étude de robustesse des tests d'efficience moyenne-variance lorsqu'il n'existe pas d'actif sans risque est menée dans le dernier chapitre. De plus, un nouveau test fondé sur la distance verticale du portefeuille testé à la frontière efficiente est proposé. Ce courant de la littérature avait été ravivé par le nouveau test proposé par Levy et Roll (2010) qui affirmaient que « le portefeuille de marché pourrait être efficient dans le cadre moyenne-variance après tout ». Ce résultat, à contre-courant de la littérature financière, est très important car il tend à montrer que le « zero beta CAPM » de Black (1972) est valide. A l'aide de simulations de Monte Carlo, nous montrons que notre nouveau test obtient de meilleurs que ses concurrents avec des échantillons de grande taille : la taille de test est en effet plus faible pour une puissance comparable. L'application au marché d'actions américain montre que le portefeuille de marché n'est pas efficient, ce qui invalide *de facto* le « zero beta CAPM » de Black (1972). En particulier, nous montrons que le test de Levy et Roll (2010) est très sensible à un paramètre de nuisance, ce qui limite la portée de ses conclusions. Pour des recherches ultérieures, il serait intéressant d'évaluer la robustesse des tests d'efficience moyenne-variance en l'absence d'actif sans risque lorsque la distribution des rendements des actifs est non-normale. Etant donné la complémentarité théorique de notre test et de celui de Basak *et al.* (2002), il serait pertinent de trouver une manière de les combiner judicieusement. Enfin, en dépit de ses difficultés techniques, la construction d'un test d'efficience fondé sur la plus courte distance du portefeuille testé à la frontière efficiente dans le plan moyenne-variance serait pertinente.

De nombreuses autres pistes de recherche restent à explorer en ce qui concerne l'ISR. Pour l'industrie financière, une des questions les plus importantes est sans doute de mieux comprendre par quels mécanismes les indicateurs extra-financiers peuvent apporter de la valeur dans l'analyse financière. Montrer qu'il est possible d'obtenir de bonnes performances financières en investissant sur les entités, qu'elles soient des entreprises ou des gouvernements, les plus responsables pourrait effectivement permettre d'élargir la base des investisseurs en fonds ISR.

Enfin, alors que de nombreux investisseurs s'engagent dans l'ISR avec pour ambition de favoriser les entités à externalités positives et de jouer un rôle positif par ce biais, on ne peut que déplorer la très faible occurrence voire l'inexistence des études empiriques mesurant l'impact de l'ISR sur la société ou sur l'environnement. La recherche portant sur l'ISR ne se concentre que sur une partie de l'utilité de l'investisseur, c'est-à-dire sur les rendements financiers de son investissement et sur la conscience d'avoir un portefeuille en accord avec ses valeurs. En revanche, elle n'aborde pas la question de son effet sur les entités sous-jacentes des titres financiers. La pression exercée par les fonds ISR mène-t-elle réellement à un changement des politiques d'entreprises et des gouvernements? En d'autres termes, l'ISR est-il réellement utile ? Pour répondre à ces questions, il serait judicieux de s'inspirer de nombreux travaux portant sur la microfinance, courant voisin de l'ISR, et s'attelant à mesurer les effets sociaux et sociétaux de tels investissements. Cela permettrait de donner tout son sens à l'expression « doing well by doing good » tant employée par les promoteurs de l'ISR…

General conclusion

This PhD thesis has explored various aspects of portfolio selection for SRI. It aims to fill several gaps in the literature such as SRI in sovereign bonds and the role of risk aversion in SRI. Here we summarise its main findings and present ideas for developing and extending it.

The first chapter consisted of an examination of socially responsible portfolios invested in developed-country government bonds. Surprisingly, empirical SRI studies have not yet focused on this asset class. Chapter 1 demonstrates that it is possible to increase the government bond portfolio's social responsibility rating without a significant loss of diversification. The amount of increase in the portfolio's average social responsibility rating that is possible without significant loss varies depending on which ESG criteria are used. In future work, it would be very interesting to continue the efforts developed in Chapter 1 and to include the recent crisis years in the observation period. Indeed, the recent government debt crisis in developed countries, especially in Europe, may demonstrate that investing preferentially in the countries with the highest social responsibility indicators may return significantly more than investing in those with the highest credit ratings. Finally, as many portfolios are invested in several asset classes in a purpose of diversification, an empirical study of socially responsible portfolios invested in all asset classes (equities, corporate bonds, government bonds) would also be relevant.

The role of risk aversion in SRI is explored in Chapter 2. A mean-variance portfolio selection model in the best-in-class framework is proposed. The desire to invest responsibly is introduced through linear constraints in the portfolio optimisation. Four outcomes are possible: a) the efficient frontier is not adversely affected; b) only the lower bound of the frontier is impacted (risk-tolerant investors are not penalised); c) only the upper bound of the frontier is impacted (risk-averse investors are not penalised); d) the entire frontier is adversely affected (all investors are penalised). The investor's degree of risk aversion thus plays a crucial role in SRI. In some cases, risk-averse investors are the ones most heavily impacted by an SRI constraint, but in other situations the opposite is true. Chapter 2 clearly exposes the conditions in which SRI is costly. These conditions depend on two factors in the nexus between social responsibility ratings and expected asset returns, as well as the degree to which the investor requires social responsibility ratings. These findings were obtained using the efficient market hypothesis, but the work could be carried out using the assumption that there are errors in estimates for expected returns and that social responsibility indicators contain value that is not taken into account by the markets.

A study of the robustness of mean-variance efficiency tests when no risk-free asset exists is carried out in the final chapter. A new test based on the portfolio's vertical distance from the efficient frontier is proposed. This branch of the literature had been revived in the new test proposed by Levy and Roll (2010), who affirm, "The market portfolio may be mean/variance efficient after all." This finding, which goes against the literature of finance, is very important, because it tends to invalidate Black's Zero-Beta CAPM (1972). With the help of Monte Carlo simulations, we show that our new test obtains better results than its competitors with large sample sizes: our test size is smaller but delivers comparable power. The digital US equity market application shows that the market portfolio is not efficient, thus de facto invalidating the Black Zero-Beta CAPM (1972). In particular, we show that the test developed by Levy and Roll (2010) is very sensitive to a nuisance parameter, and this limits the scope of its conclusions. In a subsequent study, it would be interesting to evaluate the robustness of mean-variance efficiency tests in the absence of a risk-free asset when assets produce non-normal returns. Given the theoretical fit between our test and that of Basak *et al.* (2002), it would be worthwhile finding an appropriate way to combine them. Finally, despite the technical difficulties, constructing an efficiency test based on the tested portfolio's shortest distance to the efficient frontier in the mean-variance framework would be relevant.

Other avenues of research into SRI portfolio selection have yet to be explored. For the financial industry, it is undoubtedly most important to gain a better understanding of how social responsibility indicators can add value to investment research. This would enable researchers to show that good financial performance can be obtained by investing in the most responsible entities, whether companies or governments. Such a finding would help broaden the SRI investor base.

Finally, as many investors opt for ISR in a purpose of favouring entities with positive externalities and contribute to social change, one could regret the lack of empirical studies about the impact of SRI on the society or the environment. Research about SRI only focuses on a fraction of the investor's utility, i.e. the financial returns of her investments and the conscience to have a portfolio consistent with her values. However, it does not tackle the issue of the impact on the assets' underlying entities. Does the pressure of SRI funds lead to policy changes from companies or governments? In other words, is SRI useful? To answer these questions, following the example of many studies about microfinance that gauge the social and societal impacts of these investments would be sound. This would give a real meaning to the expression "doing well by doing good", so much employed by SRI practitioners…

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