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THÈSE

Pour obtenir le grade de
Docteur

Délivré par l'**Université de Montpellier**

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Section 5

Présentée par **François JEANJEAN**

LES INCITATIONS A INVESTIR DANS LES RESEAUX DE TELECOMMUNICATIONS

Sous la direction de : Edmond BARANES

Soutenue le 16 mars 2015 devant le jury composé de

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Les incitations à investir dans les réseaux de télécommunications

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1. Cadre général

1.1 Introduction

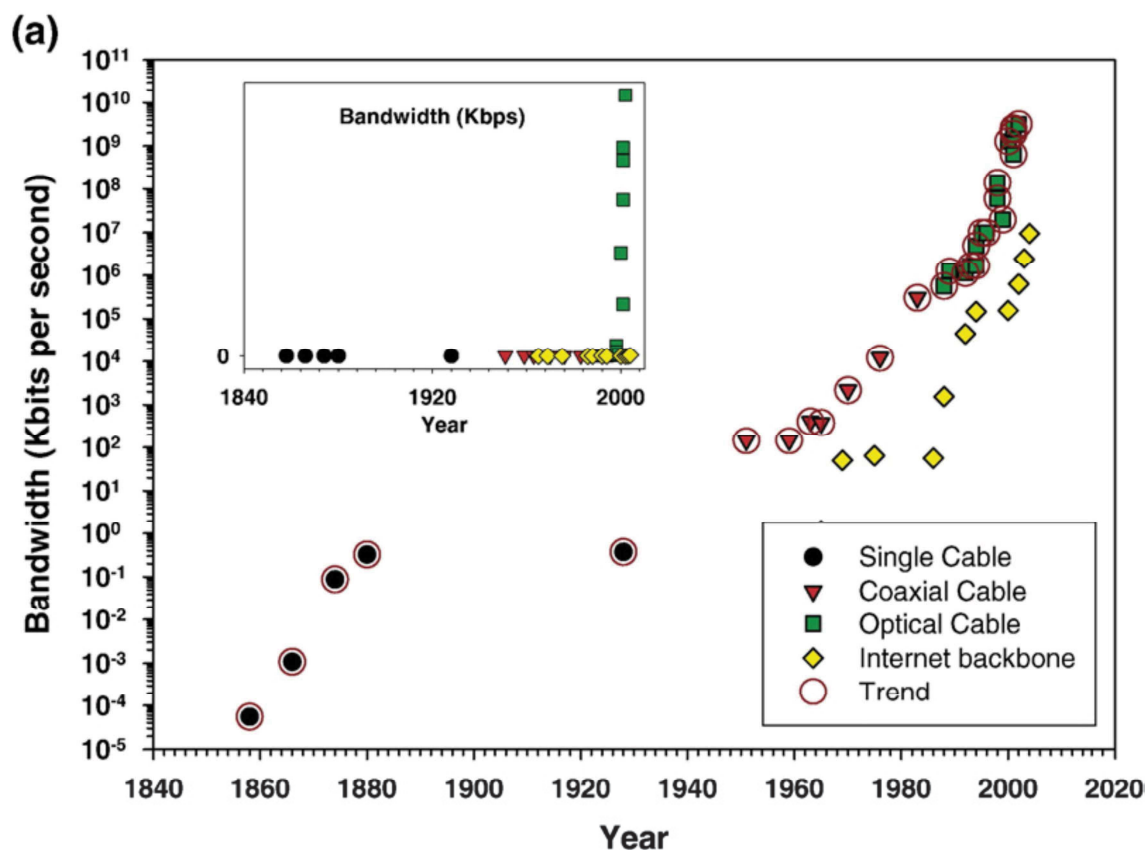
L'industrie des télécommunications mobiles connaît actuellement en Europe un mouvement de concentration. Après la fusion d'Orange et de T Mobile au Royaume Uni en 2010 et le rachat d'Orange par Hutchinson en Autriche en 2012, deux fusions viennent d'être récemment autorisées par la DG Concurrence, l'organe de contrôle des fusions/acquisition de la commission Européenne: Le rachat de O2 par Hutchinson 3G en Irlande et celui de E-Plus par O2, la filiale de telefonica en Allemagne. Sans compter le rachat de SFR par Numéricâble en France, ainsi que d'autres mouvements de concentrations actuellement en discussion. Ce mouvement de concentration semble mettre un terme au processus d'expansion du nombre d'acteurs à l'œuvre depuis la naissance du marché mobile. Le tabou d'un marché passant de 4 à 3 opérateurs est levé titre la tribune du 12 juin dernier. Quelle est la raison de ce mouvement de concentration ? Est-il bénéfique pour le consommateur et pour la société ? Quelle est son effet sur l'investissement, les prix, la croissance et l'emploi ?

Ces questions, ainsi que leurs corollaires concernant l'entrée de nouveaux acteurs sur le marché, ont déjà fait l'objet de débats intenses comme par exemple l'entrée de Free sur le marché français, sans toutefois aboutir à des conclusions consensuelles et tranchées. Cette question en effet est extrêmement délicate et fait intervenir de nombreux paramètres tels que la taille du marché, la disposition à payer des consommateurs, la nature des firmes qui entrent ou qui fusionnent, le nombre d'acteurs sur le marché après l'opération. Cette question peut aussi avoir des réponses différentes selon que l'on étudie les effets de court terme ou les effets de long terme.

Des éléments de réponse figurent dans le rapport « Supercollider » de la banque HSBC, qui soutient l'idée que les fusions entre opérateurs peuvent être favorables aux consommateurs. L'étude, citée dans les échos du 16 février 2014, montre que l'investissement est plus efficace que le nombre d'opérateurs pour faire baisser les prix. Pour cela, elle utilise largement deux des articles présentés dans ce document. Le rapport reprend les hypothèses et les modèles théoriques présentés dans les articles mais utilise les données de la banque pour refaire les études empiriques en retrouvant des résultats analogues. (Supercollider 2014)

Etant donné la nature oligopolistique des marchés de télécommunications, les effets de court terme peuvent être étudiés à l'aide de statiques comparatives utilisant des modèles de concurrence oligopolistiques, modèle de Cournot ou de Bertrand.

Les effets de long terme sont plus difficiles à appréhender parce qu'ils doivent prendre en compte le potentiel d'évolution technologique et organisationnel des firmes sur le marché. Ce potentiel est particulièrement élevé dans les technologies de l'information en général et dans le secteur des télécommunications en particulier qui présentent, d'après Koh et Magee, un taux de progrès technique annuel de l'ordre de 20 à 30% depuis plus d'un siècle (Koh, Magee 2006), ce qui est très supérieur à la plupart des autres secteurs. A titre de comparaison, Koh et Magee ont relevé un taux de progrès technique de l'ordre de 6% dans le secteur de l'énergie (Koh, Magee 2008).



Evolution de la bande passante par technologie en fonction du temps

(D'après Koh & Magee 2006)

Un tel taux de progrès technique, comparable à celui qui sous-tend la loi de Moore (doublement du nombre de transistors dans les circuits électroniques tous les 2 ans), est susceptible d'entraîner des changements rapides de sorte que les effets dits « de long terme », c'est-à-dire résultant des investissements, surpassent en réalité les effets dits « de court terme » au bout d'un temps court, de l'ordre de quelques mois dans les marchés mobiles, comme on le verra par la suite.

Pour se concrétiser, ce potentiel a besoin d'investissements car c'est par l'investissement que le progrès technique s'incorpore dans l'appareil productif. La question des investissements apparaît donc centrale lorsque l'on veut étudier l'effet de la structure du marché dans le secteur des télécommunications sur le bien être des consommateurs, le surplus social, la croissance et l'emploi. En effet, le développement technologique de ce secteur a d'importantes répercussions sur l'ensemble de l'économie, comme le souligne de nombreuses études tant théoriques qu'empiriques. Röller et Waverman (2001) ont mis en évidence un lien causal entre l'investissement dans les infrastructures de télécommunication et la croissance. Calderon et Servén (2004), pour la banque mondiale, soulignent l'importance de toutes les infrastructures mais en particulier les infrastructures de télécommunication sur la croissance et sur la réduction des inégalités. Cet effet est constaté aussi bien sur les infrastructures fixes que mobiles. Koutroumpis (2009) montre l'impact de la pénétration du Haut débit en Europe, Katz et Avila (2010) en Amérique du sud. Au niveau national ou régional, Jensen (2007) montre le gain d'efficacité apporté par le téléphone mobile dans l'allocation des

ressources entre producteurs et consommateurs parmi les pêcheurs du Kerala (Inde) et Katz et Koutroumpis (2014) ont mis en évidence l'impact des technologies de l'information en Afrique de l'ouest.

Cette thèse vise à étudier quels sont les structures de marché et les modes de concurrence qui favorisent le mieux l'investissement dans les infrastructures de télécommunications ainsi que les instruments politiques permettant d'agir sur ces structures : (politique de la concurrence, régulation) afin de transformer en véritable croissance l'immense potentiel de progrès technique du secteur.

1.2 Structure des marchés de télécommunications

La structure des marchés de télécommunications a beaucoup évolué depuis une quarantaine d'années. Né il y a un peu plus d'un siècle, le secteur a été partout dans le monde, rapidement organisé en monopole, souvent monopole d'état, comme en Europe, parfois privé comme aux États unis (ATT) (Cohen, 2000). Cette situation de monopole s'explique par les externalités de réseau et par l'importance et le coût des infrastructures de réseau nécessaires au fonctionnement des services de télécommunications. Les externalités de réseau tendent à favoriser les monopoles. En effet, l'utilité pour un consommateur de se raccorder à un réseau augmente en fonction du nombre d'abonnés joignables sur ce réseau, ce qui tend à favoriser les plus gros réseaux ; et joindre un correspondant sur le réseau d'un autre opérateur nécessite des coûts d'interconnexion supplémentaires. Le monopole permet justement d'éviter ces coûts de transaction et d'interconnexion entre opérateurs. Quant au coût des infrastructures, d'une part, il aurait été inefficace de les dupliquer et d'autre part, les économies d'échelle y étaient telles qu'un monopole était plus efficace qu'un marché concurrentiel. Pendant longtemps, l'homogénéité du service qu'offraient les monopoles ainsi que la relative facilité de leur contrôle par les autorités les rendaient particulièrement indiqués pour assurer un rôle de service public, d'aménagement et de sécurité du territoire.

Cette organisation est remise en cause à partir des années 1980. Progressivement, le secteur s'est ouvert à la concurrence, d'abord aux États unis en 1983, puis au Royaume-Uni et enfin dans l'Union Européenne et le reste du monde.

D'après Leroy-Therville (2000), cette ouverture à la concurrence est, en quelque sorte, la conséquence du progrès technique. En effet, la numérisation des télécom dans les années 1970 a complètement remis en cause l'efficacité du monopole naturel. Ceci pour deux raisons : D'une part, elle a réduit les économies d'échelles en diminuant plus vite les coûts de transmission que les coûts de commutation. Les technologies analogiques utilisées jusque-là étaient en effet caractérisées par des investissements fortement concentrés sur les lignes, générant des rendements d'échelle croissants (multiplexage en transmission), tandis que les techniques numériques, en concentrant davantage leurs investissements au niveau des commutateurs génèrent au contraire des rendements d'échelle décroissants (le nombre de commutations possibles augmente comme le carré du nombre de lignes). D'autre part, la numérisation a considérablement augmenté le potentiel de développement des nouveaux services. Le monopole est apparu de moins en moins efficace pour

transformer ce potentiel en innovations et nouveaux services aux usagers. Un marché ouvert à la concurrence apparaissait alors mieux adapté à un progrès technique rapide.

La numérisation a aussi facilité, d'un point de vue technique, l'émergence de la concurrence. D'après Dang-Nguyen et Penard (2000), les réseaux de télécommunications, comme tous les réseaux de transport de flux, sont constitués en deux parties : une partie dite « réseau d'infrastructure », couche physique dans laquelle transitent les flux transportés, et l'autre dite « réseau de commande », où transite la signalisation de gestion des flux, comme par exemple les feux tricolores pour les chemins de fer. La numérisation a permis de séparer ces deux couches et donc de permettre de découper le réseau en modules où, pour chaque module, le propriétaire de l'infrastructure n'est pas nécessairement le gestionnaire du réseau de commande. C'est par exemple le dégroupage de la boucle locale où l'opérateur historique ne conserve que la couche infrastructure tandis que l'opérateur alternatif gère les flux. Cette évolution a favorisé la concurrence en baissant les barrières à l'entrée et permis à un grand nombre d'opérateurs alternatifs de rentrer sur le marché.

La structure des marchés de service fixes est donc passée du monopole à l'oligopole dans la plupart des pays. Dans les réseaux mobiles, la couche de transport physique étant constituée par l'atmosphère dans laquelle se propagent les ondes hertziennes, l'infrastructure est beaucoup moins coûteuse que pour les réseaux fixes. Elle est seulement constituée des antennes, des supports d'antenne et des liaisons de raccordement au cœur du réseau. Les barrières à l'entrée sont donc naturellement moins élevées (même si les fréquences nécessaires à leur fonctionnement restent des ressources rares gérées par le régulateur). Pour cette raison, ces marchés se sont, dans la majorité des cas, dès le départ, développés dans le cadre d'une concurrence oligopolistique.

1.3 Le cadre réglementaire et son évolution

L'ouverture du secteur à la concurrence a entraîné la mise en place dans chaque pays, d'une régulation spécifique au secteur, dite régulation sectorielle, visant à garantir la disponibilité des infrastructures, l'interopérabilité des réseaux, l'accessibilité des services de base à des tarifs abordables à l'ensemble de la population ainsi qu'une concurrence loyale et dynamique. Au sein de l'Union Européenne, les principes de cette régulation sectorielle sont définis au niveau européen et déclinés ensuite au niveau national par les autorités de régulation. Pour atteindre leurs objectifs, les régulateurs nationaux bénéficient d'un cadre juridique leur procurant des pouvoirs normatifs étendus, ainsi que des pouvoirs de vérification, d'investigation et de sanction qu'ils exercent en rendant compte à la Commission Européenne d'une part, ainsi qu'aux institutions et juridiction d'appel compétentes nationales d'autre part.

Ces pouvoirs couvrent :

- les aspects techniques, notamment pour permettre l'interconnexion des réseaux.
- L'allocation de ressources (licences, spectre de fréquence)
- La régulation économique (en s'assurant que la concurrence sur les marchés du secteur fonctionne loyalement et produit des effets positifs)

- Les obligations de disponibilité et de développement des infrastructures, de service universel et de couverture du territoire.

La mise en œuvre de la régulation économique européenne passe par la définition des marchés pertinents sur laquelle elle peut s'exercer. Un marché pertinent délimite les frontières en termes de produits et de zone géographique. Par exemple, selon la commission Européenne « Un marché pertinent comprend tous les produits et/ou services que le consommateur considère comme interchangeables ou substituables en raison de leurs caractéristiques, de leurs prix et de l'usage auxquels ils sont destinés »

Une fois les marchés pertinents définis, le régulateur évalue les opérateurs intervenant dans le marché pour estimer ceux qui sont « puissants », c'est-à-dire ceux qui ont un pouvoir de marché significatif et bénéficient de ce fait, d'une position dominante qui leur permet de se comporter indépendamment des clients et des concurrents. Cette évaluation porte notamment sur le calcul des parts de marché, les barrières à l'entrée, les relations client fournisseurs. (Directives 2009/140/CE et 2009/136/CE)

Enfin, lorsque sur un marché pertinent, les opérateurs puissants ont été identifiés, le cadre considère que le marché ne peut pas fonctionner correctement, et dès lors, le régulateur cherche à apporter des « remèdes » à cette situation. Ces remèdes sont des obligations « Ex ante », c'est-à-dire des contraintes s'imposant à priori aux opérateurs puissants afin de les empêcher d'utiliser leur puissance de marché pour fausser la concurrence ou de l'utiliser comme effet de levier sur des marchés adjacents. Ces contraintes peuvent être la publication d'une offre de référence ouverte aux concurrents, un contrôle tarifaire, une séparation comptable, ... (Penard & Thirion, 2006).

Le régulateur est également investi d'un pouvoir d'arbitrage. A ce titre, il règle les différends entre opérateurs, en cas de divergence d'interprétation de la réglementation. Il peut aussi disposer d'un pouvoir de sanction en cas d'infraction constatée à la réglementation, comme c'est le cas par exemple en France. En effet, tous les régulateurs européens ne bénéficient pas de ce pouvoir. Par exemple en Belgique, le régulateur n'a pas lui-même le pouvoir de sanction, ce sont les tribunaux qui l'ont.

1.4 La question de l'investissement dans les réseaux de télécommunications

L'introduction de la concurrence en Europe, dans la phase initiale, s'est appuyée sur des règles centrées sur l'ouverture du réseau de l'opérateur historique aux opérateurs tiers: obligations de dégroupage de la boucle locale, obligation de reproductibilité des nouvelles offres. Alors que cette phase se termine, les réseaux des opérateurs historiques étant désormais largement accessibles aux opérateurs tiers, une nouvelle phase est en train de s'ouvrir. Elle concerne la modernisation des réseaux. Cette nouvelle phase est assez différente de la précédente. Là où il s'agissait de partager un réseau existant, il est maintenant question de construire de nouvelles infrastructures. La question de l'investissement est amenée à prendre une importance croissante dans les questions réglementaires, comme le soulignent Cambini et Jiang (2009) dans une revue de la littérature économique sur les

investissements dans les infrastructures et la régulation du haut débit : « *Nowadays, the urgency to spread broadband access calls for a large amount of capital expenditure. Therefore more and more regulatory concerns are attracted to the investment issue in the broadband market* ».

Les questions à propos des investissements ne concernent pas uniquement les infrastructures filaires. Elles ont été présentes dans les infrastructures mobiles depuis le début mais dans un contexte tout à fait différent.

En effet, une grande partie des infrastructures fixes ont été construites sous un régime de monopole. Leur renouvellement, souvent appelé NGN « Next Generation Network » doit se faire sous une structure de marché concurrentielle.

Les infrastructures mobiles, se sont développées dès le début, sous un régime concurrentiel, mais en profitant de la dynamique de croissance du marché. Leur renouvellement (3G, LTE) devra se faire, le plus souvent, comme pour le fixe, dans des marchés matures et très concurrentiels. En Europe, par exemple, le taux de pénétration des services mobiles est très élevé. Le nombre d'abonnements dépasse souvent le nombre d'habitants.

Le renouvellement des infrastructures fixes comme mobiles s'annonce délicat sur des marchés où la concurrence réduit les marges alors que la dynamique de croissance du marché est désormais fortement limitée.

Un des principaux soucis des organismes de régulation dans les années à venir, en particulier en Europe, sera de créer un climat favorisant l'investissement dans les infrastructures de télécommunications tout en préservant le caractère concurrentiel des marchés. Chapin et Lehr (2011) illustrent ce dilemme et préconisent le partage des infrastructures et du spectre pour faire baisser les coûts d'investissement. Toutefois, le partage des coûts d'infrastructure ne permet pas, en général, d'augmenter la couverture totale du réseau. Car, comme le montrent Bourreau et al (2011), les firmes investissent d'autant plus qu'elles espèrent un profit en retour. Or, le profit joint des firmes en concurrence est en général inférieur au profit de monopole, excepté dans le cas où la concurrence permet une forte augmentation de la variété des offres et donc une augmentation de la demande suffisante pour compenser la diminution des marges.

La régulation des infrastructures existantes a un impact non négligeable sur les investissements permettant l'essor des nouvelles technologies qui nécessitent de nouvelles infrastructures.

Suite à l'ouverture progressive à la concurrence, les anciens monopoles, désormais appelés opérateurs historiques, sont restés propriétaires de l'infrastructure du réseau téléphonique en cuivre située entre le répartiteur téléphonique et le consommateur final, appelée boucle locale. Ils ont en revanche, en Europe, l'obligation de mettre cette boucle locale à disposition des opérateurs tiers qui en font la demande pour leur permettre de proposer une offre concurrente. C'est le dégroupage de la boucle locale. Les conditions et les tarifs du dégroupage sont fixés par le régulateur sectoriel.

Ces conditions ont un impact important sur le niveau des tarifs des offres cuivre en technologie xDSL (Cave, 2006 ; Bourreau & Dogan, 2005), mais plusieurs études ont aussi souligné l'impact qu'elles peuvent avoir sur les incitations à investir. Baranes et Bourreau (2005) ont montré que des conditions trop favorables pouvaient inciter les entrants à rester trop longtemps sur l'infrastructure de l'opérateur historique au lieu de construire leur propre infrastructure. Ils ont aussi montré que

l'opérateur historique avait moins d'incitation à investir pour améliorer sa propre infrastructure dans la mesure où il est seul à prendre les risques, tandis que ses concurrents bénéficient autant que lui de ses propres investissements.

Toutefois, la technologie xDSL est limitée en bande passante, ce qui risque à l'avenir de gêner ou d'empêcher le fonctionnement de certaines applications, car les besoins des consommateurs, sous l'effet du progrès technique qui permet le fonctionnement d'applications de plus en plus consommatrices, sont en perpétuelle augmentation.

Cette limite est d'autant plus pénalisante, que les performances de la technologie xDSL, en raison de l'affaiblissement du signal, diminuent fortement avec la distance entre le répartiteur téléphonique, où sont installés les équipements de réseau, et le consommateur final.

La technologie optique est beaucoup plus performante en termes de bande passante et elle est très peu sensible à la distance. Ses performances sont tellement supérieures qu'aujourd'hui on n'en connaît pas la limite. Cependant, cette technologie nécessite de déployer de la fibre optique, qui, à terme, se substituera au cuivre. C'est un investissement considérable, de plusieurs dizaines de milliards d'euros pour équiper un pays comme la France. (21 milliards d'Euro sur 15 ans d'après l'ARCEP)

1.5 Politiques de la concurrence, investissement et croissance

Le cadre réglementaire doit procurer au secteur des télécommunications un environnement favorable à un développement harmonieux permettant à l'industrie de prospérer tout en procurant aux consommateurs et aux citoyens des services de qualité aux meilleurs prix. A cet égard, la politique de la concurrence joue un rôle essentiel. Les régulateurs et les autorités de la concurrence doivent donc veiller à ce que la concurrence fasse baisser les prix tout en permettant à l'industrie d'investir. Ce dernier point, nous l'avons vu, revêt une importance toute particulière dans le secteur des télécommunications où la rapidité du progrès technique rend la question des investissements tout à fait cruciale.

Dans sa contribution à la théorie de la croissance, Solow (1956) a montré que la seule chose qui permettait une croissance de long terme était le progrès technique. Sans progrès technique, il n'y a pas de croissance durable ni d'augmentation du niveau de vie. Dans son modèle, à l'équilibre, à population constante, les taux de croissance de l'économie, du capital et des investissements se règlent sur le taux de progrès technique. Les récentes avancées des sciences économiques, avec la théorie de la croissance endogène, montrent que le progrès technique n'est pas une donnée exogène comme une « manne tombée du ciel », mais dépend du niveau d'investissement. Romer (1986) inclut explicitement l'investissement comme moyen d'augmenter le stock de connaissances permettant l'augmentation de la productivité du capital à long terme. Dans son modèle de croissance, Romer (1990), le progrès technique est rendu endogène, il est généré par l'accumulation du capital humain dédié aux activités de recherche. Il attribue cette accumulation au jeu concurrentiel des firmes qui investissent en capital humain pour augmenter leur profit. Il montre que cette accumulation n'est pas soutenable à long terme en concurrence parfaite. Le profit, et donc

un certain pouvoir de marché, est indispensable à l'accumulation des connaissances. Dans ce modèle, la production de connaissance est financée par les entreprises. Elles doivent donc générer un profit d'autant plus important que la production de connaissance est coûteuse.

Toutefois, le modèle de Romer représente l'économie toute entière. Le secteur des télécommunications n'est qu'une partie de cet ensemble et en réalité, chaque secteur produit des biens ou des services avec un taux de progrès technique différent. Le lien entre progrès technique et rentabilité des entreprises que nous avons vu pour l'économie entière reste-t-il valable dans le cas de l'industrie des télécommunications en particulier ? Nous verrons dans la section 2 que c'est bien le cas. Nous verrons, en particulier dans la section 2.3.2 que le progrès technique, en rendant l'investissement plus efficace, incite les firmes à investir davantage et augmente leur besoin en marge.

Il est essentiel que la politique de la concurrence prenne ces réalités en compte afin de permettre un développement harmonieux du secteur. L'idée qu'une concurrence imparfaite, c'est-à-dire un certain pouvoir de marché, est essentielle à la croissance économique est tout à fait reconnue, comme le montre par exemple le rapport de la commission Européenne sur les déséquilibres macroéconomiques (European Commission 2013): « *the disappointing evolution of firms' profitability is particularly alarming because it may prevent companies from raising their investment in equipment, R&D, marketing, brand* » and « *in the end, may weigh on their potential development of productivity and competitiveness* ». Pourtant, cette reconnaissance semble ne pas toujours se traduire par une mise en œuvre effective d'un soutien à l'investissement au niveau microéconomique. La commission Européenne recommande d'améliorer le plus possible l'efficacité statique en renforçant la concurrence, afin d'inciter à réduire les coûts pour augmenter la productivité (discours de Joaquim Almunia 2012 : « The evolutionary pressure of globalisation on competition control » et de Neelie Kroes : « Achieving self-sustaining competition in telecommunications ») « *we should remember that competition enforcement strengthens the economy, even, perhaps particularly, in times of difficulty* » . Ciriani et Lebourges (2014) ont développé une analyse très complète de la politique de la concurrence de la commission Européenne et de sa difficulté à prendre en compte les enjeux de l'investissement et du progrès technique.

1.6 Progrès technique et information

Dans les modèles de croissance, endogène ou exogène, le taux de progrès technique est souvent considéré comme le taux de croissance du stock de connaissances. L'augmentation des connaissances permet le développement d'outils, de produits et de services plus sophistiqués qui améliorent la productivité des facteurs de production. Mais pour que l'augmentation des connaissances devienne effectivement progrès technique, il est nécessaire qu'elle soit mise en œuvre concrètement dans l'économie. Une étude empirique récente réalisée par Comin et Mestieri (2010) estime que 80% des différences de niveau de vie entre pays au 20^e siècle s'explique par les différences d'intensité de l'usage des technologies. En d'autres termes, la connaissance seule ne suffit pas elle a besoin d'être incorporée dans l'économie pour être efficace. Et pour cela l'investissement est nécessaire.

Le stock de connaissances, pour augmenter, a besoin d'un apport de connaissances nouvelles. Cet apport est fourni par un effort de recherche. Comme cet effort est coûteux, il est entrepris d'autant plus volontiers qu'il est rentable, c'est-à-dire d'autant plus que la technologie est mise en œuvre et qu'elle est incorporée dans l'économie. Les différences de taux de progrès technique entre technologies peuvent s'expliquer par les différences de rentabilité entre les efforts de recherche pour augmenter le stock de connaissances et les gains apportés par l'incorporation des technologies résultantes dans l'économie.

Par ailleurs, l'effort de recherche est d'autant plus efficace, que le stock de connaissances est élevé. En effet, les connaissances accumulées sont utilisées comme des outils ou des matières premières par l'effort de recherche pour le rendre plus efficace. Certains modèles de croissance endogène, et notamment le modèle de Romer (1990), utilisent cette idée en supposant que la variation du stock de connaissances dans le temps est proportionnelle au produit du stock de connaissances par l'effort de recherche. L'effort de recherche étant le capital humain dédié à la recherche: $\dot{A} = \delta H_a A$. A étant le stock de capital, \dot{A} , sa variation dans le temps, H_a le capital humain dédié à la recherche, et δ , une constante. Une telle modélisation pour un effort de recherche régulier dans le temps conduit à une croissance exponentielle du stock des connaissances. Ce type de croissance est compatible avec les observations réalisées par Koh et Maggie sur plus d'un siècle.

Le stockage, la conservation et la diffusion des connaissances jouent un rôle essentiel dans le processus d'accumulation des connaissances comme dans le rendement de l'effort de recherche. Le stockage et la conservation des connaissances permettent de ne pas oublier les connaissances acquises. La diffusion des connaissances permet de renforcer leur impact en les rendant disponibles à un plus grand nombre.

A cet égard, les technologies de l'information jouent un rôle fondamental car la numérisation de l'information facilite le stockage, la conservation, l'accessibilité et la diffusion des connaissances.

Il n'est pas surprenant que les technologies de l'information bénéficient d'un progrès technique rapide. D'une part, elles peuvent utiliser facilement pour elles même les derniers développements technologiques facilitant le stockage et la diffusion de l'information et d'autre part, le rendement de l'effort de recherche y est, en général, plus important qu'ailleurs. En effet, les technologies de l'information traitent, comme leur nom l'indique, l'information. Or, il est plus facile de transformer l'information que la matière ou l'énergie. Par exemple, il est plus facile, et donc moins coûteux, de modifier le plan d'un bâtiment que de modifier le bâtiment lui-même.

1.7 L'information, vecteur de lutte contre l'entropie

Les propriétés néguentropiques de l'information, mises en évidence par Brillouin (1956) à partir des travaux de Shannon (1948) contribuent à expliquer l'impact positif de l'information en général et des technologies de l'information en particulier sur la croissance.

L'entropie, introduite par Clausius (1865) pour la thermodynamique est une fonction d'état indiquant le niveau de désordre d'un système. Le second principe de la thermodynamique stipule que toute

transformation tend à augmenter l'entropie. Ainsi, deux systèmes thermodynamiques mis en contact évoluent spontanément dans le sens d'une augmentation de l'entropie. Par exemple, si deux corps sont mis en contact, le transfert de chaleur se fait spontanément de la source chaude vers la source froide. La réaction s'arrête lorsque la température d'équilibre est atteinte.

Au niveau microscopique, les systèmes évoluent spontanément de l'état le moins probable vers le plus probable. Il y a ainsi moins d'information dans l'état final que dans l'état initial, car l'état final est homogène tandis que l'état initial comporte des éléments différents, par exemple une source chaude et une source froide. Il y a donc perte d'information lors de la réaction et l'entropie a augmenté.

Les phénomènes d'usure sont imputables à l'entropie. La construction d'un objet nécessite une action volontaire qui est extrêmement improbable naturellement. L'usure tend à faire évoluer cet objet vers un état plus probable. Par exemple, un pneu tend à redevenir caoutchouc, ce qui est un état plus probable qu'un pneu avec ses dessins conçus pour adhérer à la route. L'entropie se traduit par une perte d'information. L'information est néguentropique, c'est-à-dire qu'elle diminue l'entropie.

En revanche, la construction d'un objet nécessite l'introduction d'information, par exemple, les dimensions et les dessins du pneu. Cette introduction d'information correspond à une diminution de l'entropie. Le progrès technique, permet de concevoir des objets et des infrastructures de plus en plus complexes incorporant de plus en plus d'informations. Le progrès technique, lorsqu'il est mis en œuvre dans l'économie, grâce à l'investissement, permet d'incorporer de l'information dans l'économie et de faire baisser son entropie.

Les biens matériels constituant le capital tangible s'usent au cours du temps. Les machines et les outils s'usent et le capital se déprécie. L'activité humaine, par une action volontaire, permet d'entretenir et de remplacer ce capital mais, hors progrès technique, pas de l'augmenter. Le modèle de Solow, en effet, montre qu'hors progrès technique, il n'y a pas d'augmentation de la productivité. Seul le progrès technique et l'introduction d'information nouvelle, permet la croissance.

1.8 Information et Croissance

Dans le modèle de Solow, sans progrès technique, le niveau de connaissance moyen de la population n'évolue pas. Chaque individu possède la connaissance nécessaire pour entretenir un capital. L'investissement permet de compenser l'usure du capital et d'ajuster le capital à la population. Il n'y a pas d'apport de connaissances nouvelles dans cet investissement, mais le stock de connaissances existant permet de régénérer l'information nécessaire pour entretenir le capital par travailleur et éviter l'augmentation de l'entropie. Par exemple, un dysfonctionnement sur une machine peut être dépanné grâce à la connaissance de cette machine décrite dans une notice ou une fiche technique d'où l'on peut extraire l'information nécessaire.

Lorsqu'il y a progrès technique, le stock de connaissances augmente dans le temps. Cette fois, en plus de régénérer le capital et de l'ajuster à la population, l'investissement constitue un apport de

connaissances nouvelles qui correspond au progrès technique. Comme le stock de connaissances augmente, la quantité d'informations susceptible d'être régénérée augmente aussi. Il devient possible d'augmenter le capital en construisant des équipements plus sophistiqués nécessitant une plus grande quantité d'information. Lorsqu'il y a du progrès technique, la connaissance moyenne de chaque travailleur augmente, lui permettant de régénérer la quantité d'information suffisante pour entretenir des équipements de plus en plus complexes correspondant à un capital et une production de plus en plus élevés.

L'investissement peut être compris comme l'injection d'information dans l'économie car il finance d'une part la régénération de l'information nécessaire au remplacement du capital physique détruit par l'entropie, et d'autre part l'introduction d'information nouvelle apportée par le progrès technique. Cette information est incorporée au capital physique nouveau sous forme d'équipements de nouvelles générations.

Tout cela souligne l'importance de l'information sur la croissance et l'importance de l'investissement pour entretenir et augmenter cette information.

Dans les modèles de croissance endogène, c'est l'activité des agents qui permet d'augmenter le stock de connaissances: Apprentissage par la pratique (Romer, 1986 ; Lucas, 1988) ; investissement dans le capital humain (Lucas, 1988 ; Rebelo 1992 ; Becker et al, 1994) Investissement en Recherche et Développement (Romer, 1990 ; Grossman & Helpman 1989 ; Aghion & Howitt, 1990). Artus (1993) propose une synthèse de ces différents types de modèle.

Tous ces modèles ont en commun de permettre aux entreprises de générer un profit de façon à couvrir le coût du développement des connaissances. Tant que le profit couvre le coût de l'innovation, une hausse du profit correspond à une hausse du taux de croissance. Si le profit est insuffisant pour couvrir le coût de l'innovation, la croissance est nulle car les entreprises ne veulent plus fournir l'effort de recherche nécessaire à la croissance. Si, par contre, le profit est supérieur à la couverture du coût de l'innovation, le surplus de profit réduit la croissance.

L'endogénéité signifie que l'apport d'information nécessaire à la croissance est généré par l'activité économique elle-même. L'information ne tombe pas du ciel, comme l'énergie solaire. L'information est générée par le travail de recherche ou par l'apprentissage des agents, pourvu qu'ils soient incités à l'entreprendre. L'apport d'information se concrétise grâce à l'investissement qui incorpore l'information sous forme de capital physique. Les incitations à l'investissement et en particulier à l'investissement dans l'innovation sont donc à la source de la croissance. Dans les modèles de croissance endogène, les investissements ne profitent pas seulement à ceux qui les font, mais à tout le monde car ils génèrent des externalités positives. La connaissance étant un bien non rival, et assez peu exclusif, son développement par quelques-uns bénéficie à tous.

1.9 Diffusion du savoir et réduction des inefficacités

L'externalité positive apportée par l'augmentation du stock de connaissances est d'autant plus forte que la connaissance est non exclusive. Les brevets ou les droits de propriété intellectuelle, en

rendant la connaissance plus exclusive, réduisent cette externalité, mais en contrepartie, ils augmentent l'incitation à innover en augmentant la proportion des bénéfices capturés par le producteur de l'innovation. La question de savoir si les droits de propriété intellectuelle renforcent ou pas la croissance fait l'objet depuis plus d'une décennie d'un débat animé. Les modèles du début des années 2000 tendent à répondre positivement (Kwan and Lai 2003 ; Iwaisako & Futagami 2003). Mais des modèles plus récents tendent à modérer ce résultat, montrant qu'au-delà d'un certain point, la baisse des externalités positives induites par la moindre diffusion des connaissances peut compenser le bénéfice de l'incitation à innover (Cysne & Turchick 2012 ; Acemoglu & Akcigit 2012). Furukawa (2010) trouve même une relation en U inversé entre le niveau de protection des droits de propriété et le taux de croissance de l'innovation. Cette relation n'est pas sans lien avec la relation en U inversé entre la concurrence et l'investissement présentée au chapitre 2.3.2.

Pour favoriser l'externalité positive de l'augmentation du stock de connaissances, la diffusion de la connaissance joue un rôle déterminant. Baranes et Tropeano (2003) ont souligné l'importance de la proximité géographique dans l'échange d'informations entre concurrents. La proximité favorisant les échanges informels entre ingénieurs et techniciens de différentes entreprises concurrentes travaillant à proximité. L'échange d'informations est suffisamment avantageux pour compenser les inconvénients de la concurrence accrue par la proximité. Ils ont aussi montré que le développement des technologies de l'information jouait un rôle similaire, même s'il n'est pas totalement équivalent à la proximité géographique.

La diffusion du savoir passe aussi par le développement des infrastructures de télécommunications. De nombreuses études théoriques et empiriques ont souligné leur impact positif sur la croissance, que ce soit les infrastructures fixes dans les pays de l'OCDE (Röller & Waverman, 2001; Datta & Agarwal, 2004; Czernich et al 2011) ou les infrastructures de téléphonie fixes et mobiles dans les pays en développement (Sridhar et Sridhar 2007). Ces études mettent en évidence deux phénomènes. D'une part l'accélération de la diffusion des connaissances et des technologies et d'autre part une amélioration de l'efficacité des agents. Sur ce dernier point, une étude met en évidence la façon dont l'arrivée de l'infrastructure de télécommunication agit et améliore concrètement l'activité économique en réduisant les inefficacités. Elle porte sur le marché de la pêche dans l'état du Kerala en Inde (Abraham 2006). Elle montre que l'arrivée du téléphone mobile a permis aux pêcheurs de connaître la demande en poisson dans chacun des ports accessibles, elle a permis aux vendeurs de poisson à terre de connaître les arrivages de poisson. L'information apportée aux pêcheurs et aux vendeurs de poisson par le téléphone mobile a permis une meilleure allocation entre l'offre et la demande. Les pêcheurs gaspillent moins de poisson, qui est une denrée rapidement périssable et gagnent du temps en joignant directement le port où il y a le plus de demande. Les vendeurs à terre sont plus régulièrement et mieux approvisionnés et les prix sont beaucoup moins fluctuants. En conséquence, le niveau de vie tant des pêcheurs que des vendeurs s'est considérablement amélioré.

Le rôle des technologies de l'information et de la communication (TIC) jouent donc dans la croissance un rôle qui dépasse largement les limites de leur secteur. Outre l'activité économique de leur propre secteur, elles permettent d'une part d'accélérer la diffusion des connaissances et donc le progrès technique dans toute l'économie et d'autre part, d'allouer les ressources de manière plus efficace.

2 Introduction aux articles de recherche

Après avoir souligné le caractère central de l'information, des technologies de l'information en général et des infrastructures de télécommunication en particulier sur la croissance et le bien-être social, après avoir insisté sur le besoin important d'investissement dans ce domaine, nous allons maintenant discuter à partir de quatre articles les moyens d'améliorer les incitations à investir.

Nous verrons, dans un premier temps, à l'aide d'une étude empirique, comment la régulation de l'accès cuivre peut influencer les incitations à investir dans les réseaux à très haut débit (>100 Mbit/s) de nouvelle génération. Nous verrons en particulier qu'un tarif trop bas du dégroupage réduit les investissements et le développement des nouvelles infrastructures.

Nous verrons ensuite comment les investissements dans les réseaux de téléphonie mobile affectent le trafic et contribuent à la baisse des coûts et au développement des usages pour le plus grand bénéfice des consommateurs.

Nous verrons aussi que l'investissement nécessaire est contraint par le niveau de marge des entreprises. L'investissement croît en effet avec le niveau de marge et il existe un certain niveau de marge en dessous duquel, les entreprises ne parviennent pas à atteindre le niveau d'investissement auquel elles sont incitées.

Nous montrerons enfin qu'il existe, sur le marché des mobiles, une relation en U inversé entre l'investissement et l'intensité de la concurrence, mesurée à partir de taux de marge. Le niveau d'investissement maximum est atteint pour un taux de marge d'environ 38 % en moyenne. Un modèle théorique étaye ce résultat en montrant le rôle du progrès technique dans cette relation en U inversé. Hors progrès technique, l'investissement croît avec l'intensité de la concurrence. Plus le taux de progrès technique est élevé, plus la probabilité d'obtenir une relation en U inversé augmente. Ce résultat rejoint la littérature sur la croissance endogène où la croissance n'est pas obtenue en concurrence pure et parfaite mais en concurrence imparfaite avec un taux de marge non nul.

2.1 *Forecasting the fiber penetration based on Copper Access regulation*

L'investissement dans les réseaux de nouvelles générations.

Dans son discours du 12 juillet 2012, Neelie Kroes, vice-présidente de la commission européenne chargée de la société de l'information et de l'agenda numérique, a annoncé un changement de cap significatif concernant la régulation de l'accès sur le marché du Haut-Débit. Deux décisions principales illustrent ce changement. D'une part le maintien de la charge d'accès cuivre entre 8 et 10€ par mois, au moins jusqu'en 2020, et d'autre part l'abandon de l'orientation systématique vers les coûts de la charge d'accès très haut débit (>100 Mbits par seconde) comme par exemple l'accès

en fibre optique. Elle justifie ces décisions par le fait que, selon elle, « il est démontré que la baisse des prix de la charge d'accès cuivre n'entraînera pas plus d'investissement dans le très haut débit » et que plus de flexibilité est nécessaire pour favoriser l'investissement dans le très haut débit (Enhancing the broadband investment environment, 12/07/12).

Cette annonce est en rupture avec la doctrine mise en œuvre jusque-là par la commission Européenne, basée sur le concept de « Ladder of Investment » introduit par Martin Cave (Cave 2006). Ce concept préconise de baisser les barrières à l'entrée pour faciliter aux opérateurs alternatifs l'accès aux infrastructures des opérateurs historiques. Une fois entrés sur le marché, les opérateurs alternatifs peuvent dupliquer l'infrastructure en commençant par les parties les moins chères pour monter « l'échelle des investissements » et aller vers les plus chères. Pour leur permettre de mettre le pied sur le premier barreau de l'échelle, la charge d'accès est orientée vers les coûts.

Les réactions au discours de Neelie Kroes ont été très contrastées. Les investisseurs se sont montrés très satisfaits : « c'est l'évènement le plus important de la décennie dans les télécom » (HSBC) par contre, l'ECTA (European Competitive Telecommunication Association), une association qui défend les intérêts des opérateurs alternatifs a manifesté beaucoup moins d'enthousiasme : « Mme la vice-présidente Kroes tourne le dos à la concurrence » a-t-elle titré dans un communiqué de presse.

Le discours de Mme Kroes marque un tournant dans la controverse animée sur les conditions de vente en gros de l'accès en général et sur le montant de la charge d'accès en particulier.

Les conditions de vente en gros et les tarifs de dégroupage ont-ils un impact sur les investissements dans les infrastructures de nouvelle génération telle que la fibre ? Si oui, faut-il durcir ou assouplir ces conditions ? Faut-il augmenter ou réduire la charge d'accès cuivre ? Faut-il réguler l'accès fibre ?

L'article présenté ci-après s'inscrit dans cette controverse, mais pour une meilleure compréhension, nous allons en retracer les principaux développements.

En avril 2011, le rapport WIK, pour l'ECTA indique qu'une baisse/hausse de la charge d'accès cuivre favorise/décourage l'investissement dans la fibre (WIK consult 2011). En décembre 2011 et en février 2012, deux rapports Plum pour l'ETNO (European Telecommunications Network Operators' Association) critiquent le rapport WIK et concluent dans le sens contraire. En juillet 2012, un rapport de CRA (Charles River Associates) pour la commission Européenne convainc la Commission Européenne de ne pas baisser le prix du dégroupage de la paire de cuivre.

Quelles sont, dans la littérature économique, les éléments qui ont influencé ce débat ?

Au niveau théorique, trois grands effets de la régulation de l'accès cuivre ont été mis en évidence (Bourreau et al 2012) ; (Jeanjean & Liang, 2012):

- L'effet de remplacement (Replacement effect)
- L'effet de migration de l'activité (Business migration effect)
- L'effet de préemption, (preemptive effect) ou effet de revenus de gros (wholesale revenue effect)

L'effet de remplacement indique que le possesseur de l'infrastructure haut débit existante hésite à investir dans une architecture de nouvelle génération dite NGAN « Next Generation Access Network » parce que les revenus tirés de la nouvelle infrastructure risquent de cannibaliser les revenus tirés de l'infrastructure existante. Plus les tarifs de la charge d'accès cuivre sur le réseau existant sont élevés, plus les revenus tirés de cette infrastructure sont importants et plus le possesseur de l'infrastructure risque de perdre. Il est donc d'autant moins incité à investir que le montant de la charge d'accès est élevé. L'effet de remplacement joue aussi de la même manière mais en sens inverse pour les opérateurs alternatifs. Plus la charge d'accès est élevée, plus ils sont incités à développer leur propre infrastructure.

L'effet de migration de l'activité joue de la même façon pour le possesseur de l'infrastructure existante et pour les opérateurs alternatifs. Les accès sur la nouvelle infrastructure, comme par exemple les accès en fibre optique, sont des substituts imparfaits des accès cuivre. C'est pourquoi les tarifs de gros de l'accès cuivre influencent positivement les tarifs de détail des offres très haut débit sur la nouvelle infrastructure. Par conséquent, une baisse des tarifs d'accès cuivre entraîne également une baisse des prix de détail sur la nouvelle infrastructure et donc les incitations à y investir.

L'effet de préemption (ou de revenus de gros) tend à diminuer l'importance de l'effet de remplacement pour le possesseur de l'infrastructure lorsque le possesseur de l'infrastructure n'est pas le seul à pouvoir investir. En effet, dans ce cas, il perd les revenus de gros sur l'infrastructure existante même si ce n'est pas lui qui investit. Or, les opérateurs alternatifs sont d'autant plus incités à investir que la charge d'accès est élevée, c'est-à-dire, lorsque l'effet de remplacement est peu incitatif à l'investissement pour le possesseur de l'infrastructure. La possibilité qu'un opérateur alternatif investisse diminue l'effet de remplacement pour le possesseur de l'infrastructure et augmente son incitation à investir.

Le rapport WIK présente un modèle mathématique de concurrence oligopolistique par les prix avec différenciation. Ce modèle fait deux hypothèses majeures : seul le possesseur de l'infrastructure existante a la possibilité d'investir dans une infrastructure de nouvelle génération et le réseau cuivre existant est démonté dès que la nouvelle infrastructure est déployée. Ces deux hypothèses ont pour conséquence de neutraliser à la fois l'effet de préemption et l'effet de migration de l'activité. Ce faisant, seul l'effet de remplacement subsiste ce qui entraîne la conclusion que la baisse des tarifs de dégroupage favorise l'investissement dans les infrastructures de nouvelle génération. Ce résultat est présenté comme général alors qu'il est contingent aux hypothèses.

Les rapports Plum et CRA indiquent d'ailleurs que si ces deux hypothèses sont relâchées, les conclusions peuvent s'inverser. Le rapport CRA montre même, à l'aide d'un modèle mathématique analogue à celui du rapport Wik, que, dans les conditions moyennes conformes à celles observées dans les marchés européens, ces conclusions s'inversent effectivement.

Or, il semble que les hypothèses du rapport wik ne sont pas réalistes. D'une part, beaucoup d'opérateurs alternatifs ont déjà investi dans une infrastructure de nouvelle génération et d'autre part, il semble peu vraisemblable que les consommateurs acceptent tous immédiatement de payer un supplément pour migrer de l'ancienne infrastructure vers la nouvelle. S'il n'y a pas de supplément à payer, alors, il n'y a pas non plus de revenus supplémentaires apportés par la nouvelle

infrastructure et donc peu d'incitations à investir. En outre, même si les consommateurs acceptent tous de migrer, la migration nécessite techniquement un délai non négligeable.

L'article présenté au paragraphe suivant montre empiriquement le lien entre la régulation de l'accès cuivre et le développement des infrastructures de nouvelle génération permettant le très haut débit : La fibre optique d'une part et le câble d'autre part.

Présentation de l'article :

Cet article empirique est basé sur les données détaillées de 12 marchés haut-débit européens entre 2007 et 2012. Il met en évidence le fait qu'une régulation trop forte de l'accès cuivre a un impact négatif sur l'adoption des infrastructures de nouvelle génération permettant le très-haut-débit, fibre optique ou câble. Il permet d'estimer dans quelle mesure les conditions de la régulation du cuivre influencent le niveau de pénétration du très-haut-débit à l'horizon 2020, date cible de l'agenda numérique pour l'Europe.

Il analyse l'impact de l'intensité de la régulation de l'accès cuivre sur l'adoption du haut-débit en fonction des trois principales familles de technologies utilisées : les technologies xDSL construites sur paire de cuivre torsadée, les technologies FTTx, construites sur fibre optique et les technologies réseaux câblés construites sur câble coaxial.

L'intensité de la régulation de l'accès cuivre est évaluée selon deux paramètres :

La part de marché des opérateurs alternatifs dans les technologies xDSL utilisant l'infrastructure cuivre appartenant à l'opérateur historique.

Le tarif de la charge d'accès que les opérateurs alternatifs doivent payer pour dégrouper la boucle locale et accéder au réseau de l'opérateur historique.

La proportion d'accès xDSL que possèdent les opérateurs alternatifs sur le marché est un signe de l'importance des mesures de régulation mises en œuvre sur l'accès cuivre. Le tarif de la charge d'accès du dégroupage est aussi un des principaux éléments de cette régulation. Une proportion d'accès xDSL élevée associée à une charge d'accès basse est le signe d'une forte régulation de l'accès cuivre.

L'analyse empirique montre qu'une régulation plus forte de l'accès cuivre conduit à une diminution de l'adoption des technologies sur les autres plates-formes FTTx et câble qui permettent le très haut débit.

Cette analyse utilise un modèle d'adoption basé sur une progression logistique. Cette technique permet de capturer la dynamique du marché Broadband. La précision des estimations concernant les effets de la régulation sur l'adoption permettent de tenter un exercice de prévision à l'horizon 2020.

Cet exercice de prévision montre qu'en gardant les mêmes régimes de régulation dans tous les pays, jusqu'en 2020, toutes choses égales par ailleurs, on obtiendrait un taux de pénétration de 30% du très-haut-débit (>100 Mbit/s), ce qui est loin des 50 % affichés comme objectif de l'agenda

numérique. Relâcher la pression réglementaire sur l'accès cuivre pour favoriser l'essor du câble et de la fibre optique permettrait sinon de l'atteindre, du moins de se rapprocher de cet objectif.

Comment peut-on expliquer ces résultats? Les différents types d'accès constituent des substituts imparfaits. Il existe donc une forte concurrence technologique entre eux. La régulation du cuivre tend à diminuer le prix des accès cuivre (xDSL). Les accès cuivre deviennent donc plus attractifs aux dépens des autres types d'accès (FTTx et câble). L'adoption de la fibre et du câble ralentit tandis que celle du cuivre est stimulée. Dans les pays où l'adoption du cuivre est en croissance, cette croissance s'accélère, et dans les pays où elle tend à décliner, ce déclin est freiné, voire inversé.

Ce résultat montre que les effets de migration de l'activité et de préemption ensemble, l'emportent sur l'effet de remplacement.

La régulation de l'accès cuivre produit des effets non seulement sur l'adoption des consommateurs mais aussi sur les incitations à investir. Un plus faible taux d'adoption sur une technologie réduit le taux de rentabilité de l'infrastructure propre à cette technologie ce qui diminue les incitations à investir dans cette technologie. La baisse des investissements ralentit l'incorporation du progrès technique dans cette technologie et diminue son attractivité pour les consommateurs. C'est un cercle vicieux.

L'adoption des accès Broadband haut-débit ou très-haut-débit, quel que soit la technologie n'est pas impactée de manière significative car la poussée du cuivre compense les pertes sur les autres plates formes. Toutefois, les accès FTTx et câble permettent des débits plus élevés qu'xDSL. L'augmentation de la proportion de cuivre par rapport aux autres technologies à nombre d'accès Broadband égal est donc une mauvaise affaire pour les consommateurs en termes de débit moyen. Même si, à court terme, cela peut sembler une bonne affaire avec la baisse des prix, à long terme, le manque d'investissement dans les réseaux de nouvelle génération risque de les pénaliser. Au chapitre suivant, on montre que l'investissement est la principale cause de la baisse des prix du Mégaocet dans le mobile. Bien que cet article ne le montre pas explicitement, il est probable qu'il en soit de même dans le fixe.

2.2 What causes the fall in prices of mobile telecommunications services?

La recherche de la baisse des prix des services de télécommunication

Les dépenses consacrées aux technologies de l'information et de la communication représentent une part importante du budget des ménages. En France, par exemple, d'après l'Insee, cette part est passée de 3,8% en 1960 à 6% en 2012. Elles représentent également une part importante des dépenses des entreprises et influencent leur productivité. Les prix des services de télécommunications ont donc un impact très important sur le bien-être social et la croissance. C'est

pourquoi les autorités de régulation et de la concurrence les surveillent de près et s'efforcent de les faire baisser.

Mais de quel prix parle-t-on ? Le prix d'un forfait mobile n'évolue pas nécessairement de la même façon que le prix de la minute de communication ou du gigaoctet. Quel est donc finalement le prix le plus pertinent à considérer pour pouvoir évaluer au mieux son impact sur la consommation ? Les indices de prix à la consommation évaluent l'évolution des prix « à qualité constante ». Qu'y-a-t-il de plus constant comme qualité qu'une unité de consommation ? Une minute de communication reste une minute de communication et un gigaoctet reste un gigaoctet quel que soit le type d'abonnement.

Le prix de l'unité de consommation semble plus pertinent que le prix de l'abonnement, surtout dans le secteur des télécommunications où le contenu de l'abonnement varie très rapidement dans le temps sous l'effet du progrès technique particulièrement dynamique qui le caractérise. Peu de choses en commun, en effet, entre les possibilités offertes pour le même prix, dans un abonnement mobile actuel et il y a dix ans. L'essor de la 3G, du LTE et des smartphones a depuis, complètement changé la donne.

On constate d'ailleurs, qu'alors que les tarifs des abonnements évoluent relativement peu, les volumes de données, dans le mobile comme dans le fixe, augmentent eux de façon quasi-exponentielle ainsi que le montre le « networking index » de Cisco. Cette croissance de nature exponentielle des volumes associée à la relative stabilité des prix entraîne une baisse spectaculaire des prix unitaires.

Cette croissance exponentielle des volumes est due au progrès technique. Le progrès technique fait baisser les coûts de production des données. Koh & Maggie ont souligné le caractère exponentiel de ce progrès technique, que l'on retrouve aussi dans la loi de Moore. La baisse des coûts de production entraîne une baisse des prix unitaires. Par contre, elle n'entraîne pas une baisse correspondante des dépenses des consommateurs, car leurs besoins augmentent, stimulés par les nouveaux terminaux, comme les smartphones, et par les capacités croissantes des infrastructures de réseaux.

Pour se manifester et faire baisser les coûts de production, le progrès technique nécessite des investissements, et en particulier des investissements dans les infrastructures de réseaux. Ces investissements requièrent une incitation suffisante, c'est-à-dire un espoir de gain suffisant.

Présentation de l'article :

Cet article présente une étude empirique qui met en évidence le lien entre les investissements dans la téléphonie mobile et la baisse du prix unitaire du Mégaoctet de data mobile. Les investissements dans les infrastructures de téléphonie mobile permettent d'augmenter les capacités du réseau et d'augmenter les débits disponibles et donc le trafic de données sur le réseau. Les consommateurs sont demandeurs de capacité et on constate, en tous cas jusqu'à maintenant, qu'ils utilisent toujours assez rapidement les capacités qui leur sont offertes. Le progrès technique augmente l'impact de l'investissement sur les capacités du réseau. A taux de progrès technique et investissement constant,

les capacités et le trafic augmentent à un rythme exponentiel, tandis que le prix des abonnements fluctue beaucoup moins rapidement. De ce fait, les prix unitaires du Mégaoctet diminuent très rapidement.

L'article présente un modèle paramétrique d'augmentation du trafic de data mobile en fonction de l'investissement et du progrès technique. Ce modèle est testé empiriquement sur un ensemble de 20 pays (France, Allemagne, Italie, Espagne, Royaume-Uni, Suède, République Tchèque, Pologne, Russie, Etats unis, Canada, Argentine, Brésil, Mexique, Australie, Japon, Corée du sud, Chine, Inde et Afrique du Sud) en données annuelles de 2006 à 2012.

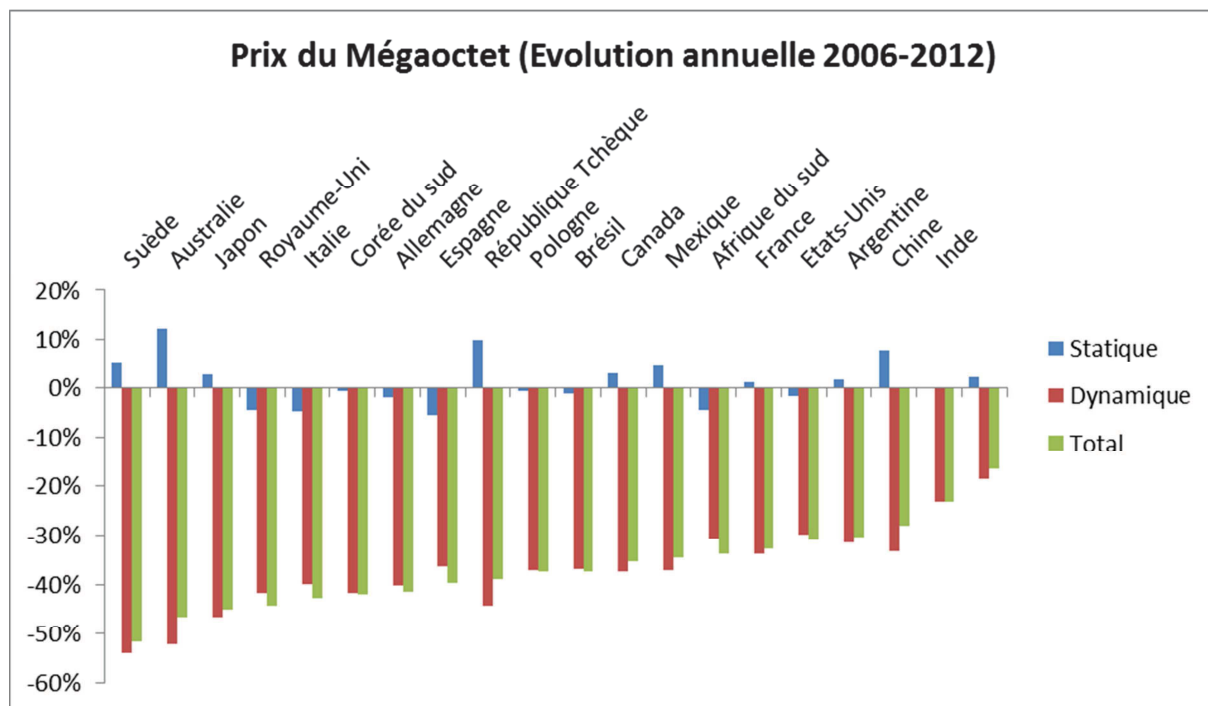
Les résultats montrent que le modèle paramétrique a un très bon pouvoir explicatif et que l'investissements est bien la variable déterminante de l'augmentation du trafic et donc de la baisse des coûts du Mégaoctet.

Le trafic obtenu avec le modèle paramétrique permet de calculer le prix moyen du Mégaoctet en divisant les revenus par le trafic. Le revenu est décomposé en faisant intervenir les coûts de production et le taux de marge, ce qui permet d'exprimer le prix moyen du Mégaoctet en fonction des coûts, du taux de marge et de l'investissement. Cette expression nous donne la possibilité d'estimer la contribution de ces différents paramètres à la baisse des prix du Mégaoctet : (Coûts de production, Marge d'Ebitda et Investissement). Le résultat montre que les investissements dominent largement les autres paramètres. Cette domination se renforce dans le temps. A terme, au bout de quelques années, les autres paramètres apparaissent négligeables.

Les coûts tendent à augmenter les prix tandis que la concurrence et l'investissement cumulé tendent à les faire baisser. Mais les effets des coûts et de la marge sont limités, car on ne peut pas les diminuer plus que leur valeur, tandis que les effets de l'investissement n'ont pas de limite, ils se cumulent dans le temps. Les coûts et la marge ont des effets statiques sur le prix du Mégaoctet, indépendants du temps, alors que l'investissement a un effet dynamique. Au bout d'un certain temps, l'effet dynamique dépasse les effets statiques. L'effet de l'investissement augmente aussi avec le taux de progrès technique. Plus le taux de progrès technique est élevé, plus l'effet dynamique est fort et plus vite il dépasse les effets statiques.

D'autre part, la marge et les coûts peuvent augmenter ou diminuer, alors que l'investissement cumulé ne peut qu'augmenter ce qui renforce encore les effets dynamiques par rapport aux effets statiques.

Le tableau ci-dessous montre la contribution des effets statiques et dynamiques à la baisse des prix du Mégaoctet dans les différents pays étudiés.



Comparaison entre les effets statiques et dynamiques sur la baisse du prix du Mégaoctet

En conclusion, nous pouvons dire qu'en 6 ans, de 2006 à 2012, les effets dynamiques ont très nettement dépassé les effets statiques.

Pour permettre une baisse rapide des prix, il est donc indispensable de favoriser un bon niveau d'investissement. La concurrence semble aussi être un bon moyen de faire baisser les prix, car elle tend à diminuer la marge, mais, sur le long terme, son effet est ambigu. A court terme, son effet déflateur sur les prix est très net, mais, à plus long terme, la baisse de la marge peut peser négativement sur l'investissement et donc sur la croissance du trafic et en fin de compte sur les prix du Mégaoctet.

Les données empiriques permettent de mettre en évidence la relation en U inversé entre concurrence et investissement. Cela signifie que lorsque l'intensité de la concurrence est faible, la renforcement tend à augmenter l'investissement. Dans ce cas, les effets statiques et dynamiques agissent dans le même sens et contribuent à la baisse du prix du Mégaoctet. Par contre, lorsque l'intensité de la concurrence est forte, la renforcement tend à diminuer l'investissement. Et cette fois, les effets statiques et dynamiques agissent en sens contraire. Comme les effets dynamiques dominent assez rapidement les effets statiques, cela tend à ralentir la baisse du prix du Mégaoctet.

2.3 Incentives to Invest in Improving Quality in the Telecommunications Industry

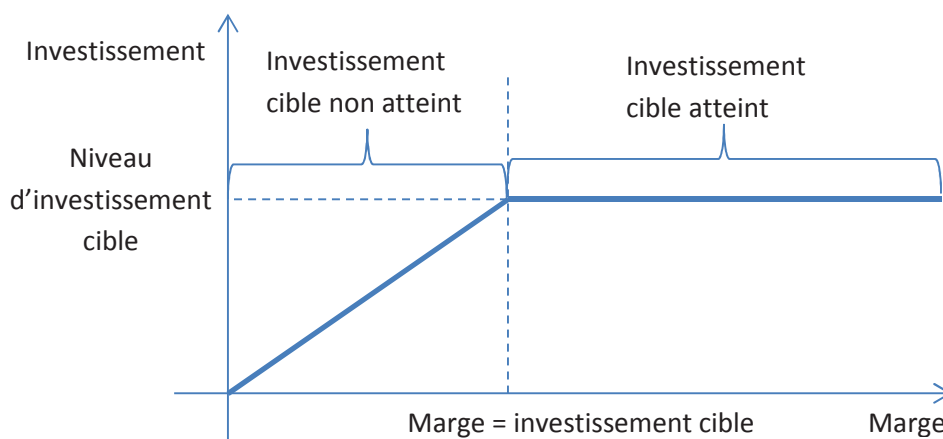
La relation entre marge et investissement dans la qualité.

L'influence de l'investissement sur la baisse des prix met en lumière l'importance de la relation entre marge et investissement. L'article suivant détaille cette relation dans le marché des mobiles. Alors que la relation entre le taux de marge et l'investissement est en U inversé, la relation entre la marge et l'investissement est croissante.

Présentation de l'article :

Cet article est composé de deux parties, une partie théorique et une partie empirique. La partie théorique est construite à partir d'un modèle radial ou « Spoke model » (Chen & Riordan 2007). C'est un modèle de concurrence oligopolistique avec différenciation horizontale des offres entre les concurrents.

Ce modèle montre que sous l'hypothèse que le marché est symétrique et entièrement couvert, il existe un niveau d'investissement par utilisateur qui maximise le profit dynamique des firmes. L'investissement est utilisé comme variable stratégique. Investir améliore la qualité des offres et la propension à payer des consommateurs. Les firmes cherchent à maximiser leur profit dynamique, c'est-à-dire le profit compte tenu de l'amélioration des offres que permet l'investissement. Avec les hypothèses de symétrie et de couverture du marché, la marge se confond avec le paramètre de différenciation des offres, souvent appelé paramètre de Hotelling. Les firmes cherchent à atteindre ce niveau d'investissement optimal. Lorsqu'elles dégagent une marge suffisante, elles peuvent l'atteindre, par contre, lorsque la marge est insuffisante, elles ne le peuvent pas et investissent à un niveau inférieur, ce qui tend à ralentir l'amélioration de la qualité pour les consommateurs.



Relation entre marge et Investissement

On suppose que les coûts marginaux sont constants. Les investissements permettent d'améliorer la qualité des offres (débit, services) et donc l'utilité des consommateurs. L'hypothèse de symétrie implique que toutes les firmes investissent le même montant, de ce fait, aucune n'acquiert d'avantage concurrentiel. L'hypothèse de couverture totale du marché empêche ces investissements d'augmenter les profits de l'industrie. Pourtant les firmes investissent car elles veulent éviter d'être dépassées par leurs concurrents. Elles font face à un dilemme du prisonnier : puisque les investissements ne permettent pas d'augmenter les profits, elles auraient intérêt à ne pas investir. Mais si les concurrents investissent quand même et obtiennent un avantage concurrentiel, et si, cet avantage se traduit, pour la firme qui n'investit pas, par une perte de profit supérieure au coût de l'investissement, alors, investir devient une stratégie dominante pour toutes les firmes. Ces investissements, sous les hypothèses de symétrie et de couverture totale, ne profitent pas aux firmes mais exclusivement aux consommateurs. En effet, Les firmes ne voient pas leurs profits augmenter, par contre, les consommateurs profitent de l'amélioration de la qualité du service, de l'augmentation du débit et du trafic à prix constant.

La concurrence qui pousse les firmes à investir est une concurrence hors prix, une concurrence par la qualité en quelque sorte. Les hypothèses de symétrie et de couverture totale du marché permettent d'isoler entièrement la concurrence en prix de la concurrence hors prix. Pourtant les deux types de concurrence ne sont pas complètement indépendants. La concurrence en prix tend à réduire la marge, et si la marge descend en dessous du niveau d'investissement cible, l'investissement diminue. Plus la concurrence en prix est forte, plus la marge est faible et plus il est difficile pour les firmes d'atteindre le seuil d'investissement cible, c'est-à-dire celui qui maximise le profit dynamique qui tient compte de l'arbitrage entre le coût des investissements et l'amélioration de la qualité qu'ils apportent. En d'autres termes, on peut dire que plus la concurrence en prix est forte, plus le niveau maximum possible de la concurrence hors prix est faible.

Le surplus des consommateurs est maximum lorsque la marge est juste suffisante pour atteindre le seuil d'investissement cible. Lorsque la marge est inférieure, le prix aussi est inférieur mais l'investissement diminue, ce qui affecte négativement la qualité perçue par les consommateurs. Ce dernier effet domine l'effet bénéfique de baisse du prix ce qui diminue finalement le surplus des consommateurs. Lorsque la marge est supérieure, l'investissement n'est pas affecté mais le prix augmente ce qui diminue le surplus des consommateurs.

Bien entendu, empiriquement, les hypothèses de couverture totale et de symétrie ne sont pas complètement réalisées. On parvient cependant à approcher ces résultats. A l'aide d'un test de Chow, l'article met en évidence, une rupture du comportement d'investissement des firmes entre les marchés à faible marge et les marchés à forte marge. Dans les marchés à faible marge, l'investissement est très sensible aux variations de la marge. La marge est trop faible pour atteindre le seuil d'investissement cible et donc, toute augmentation de la marge se traduit par une augmentation relativement forte de l'investissement car les firmes cherchent à se rapprocher le plus possible du niveau cible. Dans les marchés à forte marge, l'investissement est beaucoup moins sensible aux variations de la marge. Le niveau d'investissement cible ayant été atteint, une augmentation de la marge ne se traduit pas par une augmentation forte de l'investissement. Toutefois, le relâchement des hypothèses de couverture totale et de symétrie font que, dans ce cas, la pente de la relation entre marge et investissement, au lieu d'être, comme sur le graphe précédant, tout à fait plate, elle présente une légère pente ascendante.

Le niveau de marge par utilisateur, pour lequel a lieu la rupture est estimé par le test de Chow autour de 117\$/an, ce qui correspond à un taux de marge d'Ebitda proche de 36%.

Cette pente ascendante s'explique, en particulier par le fait que le marché n'est pas entièrement couvert. Dans ce cas, investir dans la qualité permet d'augmenter la taille du marché en incitant les consommateurs non encore présents à entrer dans le marché. L'augmentation de la taille du marché tend à augmenter les revenus et les profits.

La concurrence, le nombre de firmes et le niveau technologique augmentent le seuil d'investissement cible. Le niveau de marge par utilisateur n'a pas d'influence significative quand le marché est entièrement couvert, par contre il a une influence positive lorsque le marché possède un potentiel de croissance non nul.

Les autorités en charge de la réglementation sectorielle et les autorités de la concurrence devraient s'assurer que, dans les marchés de télécommunications mobiles, les firmes ont les moyens d'atteindre le seuil d'investissement cible, faute de quoi l'investissement diminue, entraînant une moindre amélioration de la qualité du réseau, et finalement un ralentissement de la croissance du surplus des consommateurs et du bien-être social.

2.4 "Is There a Level of Competition Intensity that Maximizes Investment in the Mobile Telecommunications Industry?"¹

La relation entre taux de marge et investissement dans la qualité.

Présentation de l'article :

Cet article étudie empiriquement la relation entre la concurrence et l'investissement dans les infrastructures de télécommunications mobiles. Il utilise un panel mondial de données d'opérateurs mobiles pour mettre en évidence une relation en U inversé.

La concurrence est mesurée au niveau firme. Elle est définie comme 1 moins l'indice de Lerner et l'investissement est défini comme la dépense annuelle en biens durables. La stratégie d'identification utilise une estimation par variable instrumentale qui s'appuie sur le rôle de la politique du spectre pour déterminer le nombre d'opérateurs et leur année d'entrée dans le marché mobile.

La courbe en U inversé signifie que l'investissement atteint un maximum pour un niveau de concurrence intermédiaire entre le monopole et la concurrence parfaite. Ce niveau de concurrence qui maximise l'investissement est estimé à 62 %, avec un intervalle de confiance de 58% à 66%, ce qui correspond à un taux de marge de 38%. On remarque que ce résultat n'est pas très éloigné de celui obtenu dans le chapitre précédent.

¹ Coécrit avec Georges Vivien Hounbouon

L'estimation s'appuie sur une nouvelle base de données construite en agréant des informations provenant de plusieurs sources. La première est la «World Cellular Information Service » (WCIS) fournie par Informa Telecom. Cette base de données fournit les informations sur le revenu des firmes, les profits et l'investissement. La seconde est la base de données Wireless Intelligence qui fournit les dates de lancement des services commerciaux sur une bande de fréquence spécifique. Les informations supplémentaires sur le niveau de vie (PIB par habitant), densité de population et population active proviennent des indicateurs de développement de la banque mondiale. La compilation de ces informations aboutit à un panel non cylindré de 187 firmes sur 10 ans, de 2003 à 2012. Ces firmes ont été choisies parmi 77 marchés nationaux répartis dans toutes les régions du monde. Il y a 1075 observations au total.

Le résultat est robuste aux différentes spécifications fonctionnelles de la relation entre concurrence et investissement. Il est également robuste aux différences de niveaux de vie entre pays, aux dynamiques de marché comme les entrées, les fusions ou les sorties, aux valeurs extrêmes et aux instruments alternatifs.

Pour expliquer la courbe en U inversé, l'article propose également un modèle théorique dans lequel l'investissement dans une nouvelle technologie génère un flux de profit pendant un certain temps. Ce temps diminue avec la concurrence. Ce modèle met en évidence le rôle du progrès technique dans la forme de la relation entre concurrence et investissement. Lorsque le progrès technique est faible, la relation entre concurrence et investissement est croissante, lorsqu'il est suffisamment fort, la relation n'est plus monotone mais en U inversé, d'abord croissante pour des niveaux de concurrence faibles puis décroissants pour des niveaux de concurrence forts. Le progrès technique tend à décaler le sommet de la courbe vers la gauche, c'est-à-dire vers plus de marge. Deux effets contraires agissent simultanément, le premier effet, dit effet d'échappement à la concurrence, ou «escape competition effect » augmente l'investissement avec la concurrence en prix. Les firmes ont d'autant plus besoin d'investir que la concurrence est forte, car elles ont d'autant plus besoin d'échapper à la concurrence.

Le deuxième effet, appelé effet Schumpétérien, diminue l'investissement avec la concurrence en prix. Les firmes investissent d'autant plus que leur marge est élevée ou qu'elles espèrent une marge élevée. Ces deux effets coexistent et se combinent. Selon les cas et les secteurs, le résultat de cette combinaison peut être différent. Dans le secteur des télécommunications, le résultat donne une courbe en U inversé. L'article montre que le progrès technique joue un rôle important dans la combinaison de ces deux effets, car il a tendance à renforcer l'effet Schumpétérien. En effet, lorsque le progrès technique est fort, les changements sur le marché sont rapides et importants, ils nécessitent plus d'investissement et donc plus de marge pour assurer un retour sur investissement suffisant. Le renforcement de l'effet Schumpétérien a tendance à décaler le sommet de la courbe en U inversé dans le sens d'une moindre intensité de la concurrence en prix.

En absence de progrès technique, la relation entre concurrence et investissement est croissante. Le progrès technique augmente la probabilité d'avoir une courbe en U inversé. Il n'est donc pas étonnant que l'industrie des télécommunications mobiles, qui connaît, comme l'ensemble des technologies de l'information, un progrès technique très important ait effectivement une relation entre concurrence et investissement en U inversé.

3. Articles de recherche

Forecasting the Fiber penetration based on copper access regulation

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June 28, 2013

Abstract

This paper investigates the impact of copper access regulation on broadband adoption for each technology (xDSL on copper infrastructure, FTTx on fiber infrastructure and cable modem). We modeled adoption using a logistic function. Using a dataset covering 15 European countries, we found that copper access regulation has a negative impact on fiber and cable modem adoption. Copper access regulation is measured by two variables: copper access charge and copper wholesale access share, i.e. the ratio of copper wholesale access provided by the incumbent to alternative operators out of the total number of copper accesses). The model allows us to forecast the penetration rate of broadband access for each technology (copper xDSL, fiber, FTTx and cable modem) through 2020. An increase in copper access charges or a decrease in copper wholesale access shares could help to achieve the objectives of the digital agenda.

1 Introduction

The adoption of fast or ultra-fast Broadband (>100 Mbits/s) is a major issue for the telecommunications policy in the coming decades, particularly in European countries which tend to lag behind other OECD countries. The digital agenda for Europe sets a target of a more than 50% of households with ultra-fast broadband by 2020.

This paper aims to estimate the impact of copper access regulation on NGA (FTTx and Cable) adoption in order to determine which form of copper regulation would support the achievement of the Digital Agenda objectives.

Access Regulation plays a crucial role in this issue. Its impact on Broadband and Ultra-fast broadband internet has been both theoretically and empirically demonstrated. It does not necessarily have the same impact on broadband and ultra-fast broadband. Ultra-fast broadband should not be developed at the expense of broadband; the Digital Agenda also sets a target of 75% of the population using the internet regularly in 2015.

For Broadband, the Ladder of investment hypothesis (Cave 2006) theoretically encourages alternative operators to enter the broadband market where the network is owned by an incumbent operator. The alternative operator pays an access charge to unbundle the incumbent's local loop, i.e. to install its own equipment, in order to offer its own services on the retail market. The last step is building a complete alternative network, including a local loop. Each step forms a rung of the Ladder. Incentive mechanisms are supposed to encourage alternative operators to climb the ladder of investment. In reality, local loop unbundling policies appear to have a mitigated impact on broadband penetration. Some empirical frameworks have found a positive impact (Lee et al 2011), while others have found a negative or no significant impact (Distaso et al 2005), (Wallsten 2006). This ambiguous effect may be due to the negative impact of unbundling policies on incentives to invest both from the incumbent and on alternative platforms. A decrease in copper access charges encourages alternative operators to remain on the incumbent's infrastructure instead of building their own. (Bourreau and Dogan 2006), (Gayle and Weissman 2007), (Bouckaert et al. 2008), (Grajek and Röller 2009).

Copper access regulation also has an impact on ultra-fast broadband adoption. Copper access charges increase the incentive for alternative operators to invest by decreasing the opportunity cost of building an alternative infrastructure. However the impact on incentives for incumbents to invest is ambiguous. The wholesale revenue effect hampers the incumbent's investment and copper access charges increase the incumbent's wholesale revenues, meaning that wholesale losses increase if consumers migrate to another infrastructure. However, the business migration effect encourages the incumbent to make investments, and copper access charges increase retail prices and encourage consumers to migrate from the "old" copper infrastructure to the "new" fiber infrastructure (Bourreau et al 2011). Empirically, Briglauer et al, found that tight copper access regulation has a negative impact on fiber infrastructure roll-out (Briglauer et al 2012). Is there a tradeoff between the adoption of broadband and ultra-fast broadband? Does copper access regulation promote Broadband at the expense of ultra-fast Broadband? Crandall, Jeffrey and Ingraham found that, in the long run, copper unbundling has a negative impact on broadband penetration. They suggest that various forms of wholesale unbundling could create a temporary surge in penetration by providing entrants with low-cost access to incumbents' networks, but that surge is soon offset by the reduction in network investment and the corresponding reduction in availability, capacity and/or service quality caused by low wholesale rates (Crandall et al 2013).

In order to avoid the negative impact of technological competition on ultra-fast broadband adoption, WIK-consult suggests a mandatory cut-off of the copper network or very low WIK-copper access charges. This would force incumbents to invest and customers to migrate to the new technology (Wik report 2011). However, as Plum consulting observed, the WIK study considers foregone copper revenues only, and focuses exclusively on the case of a copper network operator who is also the fiber investor. The WIK model does not take customer migration incentives into account, but acknowledges that a lower copper price

would discourage customers from switching to next generation access. The Plum report also examines the business migration effect and dynamic issues related to investor confidence. (Plum report 2011)

Another finding in the economic literature is the impact of copper access regulation on competition. Tight copper access regulation increases service-based competition and decreases facility-based competition (Bender and Götz 2009), and facility-based competition increases broadband and ultra-fast broadband adoption (Distaso et al. 2005).

This article, in turn, highlights the negative impact of copper access regulation on the adoption of fiber and other types of access. Its originality is the fact that it takes into account not only the price of the access charge but also the percentage of the total number of xDSL accesses purchased on the wholesale market by alternative operators. The Copper Wholesale Access Share is an index that indicates the level of copper access regulation. A logistic-shaped model is used to model each type of broadband adoption. The accuracy of the results allows us to attempt to forecast the future penetration rate of different types of broadband access.

Each type of access defined by a particular technology (copper (xDSL), fiber (FTTx), cable modem) faces fierce competition from the others. Each type of access can easily be replaced by the others, meaning that a price variation on one type of access has a significant impact on the others. A theoretical model of this type of technological competition, whose intensity increases with the substitutability of the technologies, was developed by Jeanjean and Liang (Jeanjean and Liang 2012). Fiber technology allows much higher connection speeds than copper technologies, although the difference in consumers' willingness to pay is relatively low: approximately \$3 according to a recent study for the FCC (Rosston et al 2010). This leads to high levels of technological competition between fiber and copper technologies.

The remainder of the paper is organized as follows. Section 2 describes the data, section 3 highlights the static impact of copper access regulation, section 4 integrates dynamics and describes and estimates the logistic model, section 5 forecasts the broadband adoption and section 6 concludes the paper.

2 Data

2.1 Broadband penetration rate

This paper aims to assess and forecast the impact of copper access regulation on the FTTx penetration rate, F . However, in order to forecast FTTx penetration, we also need to forecast xDSL access on a copper infrastructure, C , other types of fixed broadband access: (Cable modem, Wimax, satellite, powerline, etc.) that we will call Cm , because they are mainly Cable modem access and Total Broadband access, B , such that $B = F + Cm + C$.

The Broadband penetration rates for all types of access come from the informa WBIS (World Broadband Information Service). WBIS is a quarterly

database. This paper uses data from Q1 2007 to Q2 2012, a total of 22 quarters for each broadband provider in each country.

Penetration rates are defined as the penetration for households, i.e. the number of accesses divided by the number of households H .

2.2 Regulation and control variables

Two regulation variables are used: the unbundling access charge, UAC , expressed in €/line/month and provided by Cullen-international, and the copper wholesale access share, $CWAS$. The $CWAS$ is the ratio of xDSL accesses provided through the wholesale market to the total number of copper xDSL accesses. $CWAS$ is calculated using the WBIS database. $CWAS$ is representative of the level of copper access regulation. The tighter the copper access regulation, the higher the $CWAS$.

Intensity of competition is measured using the Herfindahl index, HHI , as a proxy. The Herfindahl index is calculated using the corporate market shares provided by the WBIS database. In order to determine the impact of copper access regulation on incumbent and alternative operators, we have defined another variable: the Fiber Incumbent Market Share, $FIMS$. This is the ratio of FTTx accesses provided by the incumbent to the total number of FTTx accesses.

15 European countries are analyzed: Austria, Belgium, Czech Republic, Denmark, France, Germany, Italy, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland and the United Kingdom. A total of 330 observations are provided by the 15 countries. However, 23 observations are missing, so only 307 observations are available.

The table below provides descriptive statistics (table 1):

	B	F	C	Cm	$CWAS$	HHI	UAC	$time$
Mean	63,00%	3,03%	43,65%	16,33%	35,28%	0,285	9,33	11,87
Standard Error	0,84%	0,27%	0,74%	0,55%	0,79%	0,004	0,12	0,36
Median	63,61%	0,44%	45,64%	14,81%	32,72%	0,288	9,29	12,00
Standard Deviation	14,69%	4,78%	12,95%	9,65%	13,78%	0,069	2,12	6,35
Sample Variance	2,16%	0,23%	1,68%	0,93%	1,90%	0,005	4,48	40,35
Kurtosis	-0,518	2,209	0,078	-0,409	-0,385	-0,828	2,835	-1,198
Skewness	-0,287	1,776	-0,153	0,264	0,569	0,088	0,867	-0,084
Range	0,643	0,199	0,609	0,394	0,582	0,322	13,590	21,000
Minimum	28,11%	0,00%	17,94%	0,00%	9,09%	0,141	5,20	1
Maximum	92,39%	19,92%	78,84%	39,42%	67,27%	0,462	18,79	22
Sum	193,425	9,288	133,991	50,147	108,319	87,388	2865	3645
Count	307	307	307	307	307	307	307	307
Confidence Level(95,0%)	1,65%	0,54%	1,45%	1,08%	1,55%	0,0078	0,2376	0,7134

Table1: Descriptive statistics

The 15 countries studied can be divided roughly into three groups in terms of copper access regulation. The first represents the most tightly regulated countries: France, Germany, Italy and the United Kingdom, where the unbundling access charges are moderate but copper wholesale access charges are very high.

These countries experienced very low growth in ultra-fast broadband over the period. The second category is that of countries with middle of the road regulations: Austria, Denmark, Poland, Portugal, Netherlands, Spain and Sweden, where the two parameters are average (Denmark, Portugal, Spain, Sweden) or have conflicting effects which result in a mid-range effect (Austria; Netherlands, Poland). These countries experienced moderate growth in ultra-fast broadband. The third category represents the most least regulated countries: Norway, Switzerland, Belgium and the Czech Republic, where unbundling access charges are high and the Copper Wholesale Access Share is moderate (Norway and Switzerland) or Unbundling Access Charges are moderate and Copper Wholesale Access charges are low (Belgium, Czech Republic). These countries experienced strong growth in ultra-fast broadband.

Broadband deployment is already quite advanced in all of the countries studied. Household broadband penetration is still increasing, but its growth is slowing as it approaches to full coverage. Growth rates are increasing for all technologies. Copper is the most used technology, but its growth is slowing although it remains relatively far from full coverage. Cable modem growth is almost constant while FTTx growth is increasing. The table below shows the variable correlation matrix (Table 2):

	<i>B</i>	<i>F</i>	<i>C</i>	<i>Cm</i>	<i>CWAS</i>	<i>HHI</i>	<i>UAC</i>	<i>time</i>
<i>B</i>	1							
<i>F</i>	0,28503	1						
<i>C</i>	0,66855	-0,152951538	1					
<i>Cm</i>	0,48434	0,143544655	-0,248319562	1				
<i>CWAS</i>	0,07949	-0,072110177	0,581661972	-0,6241	1			
<i>HHI</i>	0,03262	-0,176451532	0,144962312	-0,0574	-0,394607054	1		
<i>UAC</i>	0,09018	0,183524159	0,135360126	-0,1354	0,176344132	-0,046636717	1	
<i>time</i>	0,3242	0,208086133	0,114236845	0,23728	-0,161770784	-0,082720128	-0,2057	1

Table 2: Correlation matrix

All technologies are significantly correlated with the total Broadband variable. Cable modem and FTTx are positively correlated, but are negatively correlated with xDSL. More generally, Cable modem and FTTx have the same signs of correlation with all the variables, while xDSL has the opposite sign with the exception of time. This suggests fierce technological competition between xDSL and the other technologies. As expected, total Broadband, FTTx and Cable penetration tend to decrease with the concentration index *HHI* while xDSL tends to increase. This suggests that competition benefits fiber and cable modem at the expense of copper. This is consistent with Distaso et al.'s work, which showed that inter-platform competition among technologies has a positive impact on broadband penetration while intra-platform competition on xDSL has a negative impact (Distaso et al. 2005).

The copper access charge, *UAC* is not significantly correlated with adoption, with the exception of FTTx adoption. It is also negatively correlated with *FIMS* and *HHI*. This suggests that *UAC*, which tends to increase FTTx

adoption, has a stronger impact on alternative operators than on the incumbent. Unbundling access charges, UAC , increase the incentives for alternative operators to invest in a new fiber infrastructure and have an ambiguous impact on the incumbent because the wholesale revenue effect is compensated by the business migration effect (Bourreau et al. 2011). The overall outcome of these two contrary effects appears to be positive for FTTx adoption, which has a significant positive correlation with UAC . The copper wholesale access share, $CWAS$, has a strong positive correlation to xDSL adoption and a strong negative correlation to Cable modem adoption and to a lesser extent FTTx adoption. This suggests that copper access regulation increases copper adoption at the expense of adoption on other platforms. The overall outcome for the period studied appears ambiguous, as the correlation between $CWAS$ and total Broadband adoption is not significant (Wallsten 2006).

We will take a more detailed look at the impacts of copper access regulation when estimating the parameters for logistic models in the next section.

3 Impact of copper access regulation

As we noted in the introduction, copper access charge regulation has a significant impact on FTTx adoption. This section aims to produce a broad and static estimation of this impact. The next section will include dynamics in the specification. We express the penetration rate $X \in \{B, F, C, Cm, f, c, cm\}$ according to regulation variables UAC , $CWAS$ and HHI , taking into account the fixed effects of country and time:

$$X_{i,t} = \alpha_{1,i} + \alpha_{2,t} + \beta_1 UAC_{i,t} + \beta_2 CWAS_{i,t} + \beta_3 HHI_{i,t} + \varepsilon_{i,t} \quad (1)$$

i denotes the country index and t the time index $\alpha_1, \alpha_2, \beta_1, \beta_2$ and β_3 are constant coefficients. The following table (table 3) presents the result of the linear regression using the Huber/White/Sandwich robust estimation procedure. This procedure takes into account both heteroskedasticity and autocorrelation. Country and time effects are included but not reported for brevity.

VARIABLES	B	F	Cm	C	f	cm	c
UAC	-0.00114 (0.00121)	0.00135** (0.000582)	-0.000711 (0.000729)	-0.00179 (0.00150)	0.00232*** (0.000771)	0.00290*** (0.00109)	-0.00522*** (0.00124)
CWAS	0.148* (0.0771)	-0.325*** (0.0375)	-0.437*** (0.0678)	0.909*** (0.116)	-0.531*** (0.0439)	-0.495*** (0.0939)	1.026*** (0.0922)
HHI	0.229** (0.111)	-0.547*** (0.0654)	-0.568*** (0.102)	1.344*** (0.164)	-0.771*** (0.0703)	-0.818*** (0.128)	1.589*** (0.152)
Observation:	307	307	307	307	307	307	307
R-squared	0.981	0.953	0.978	0.954	0.967	0.985	0.984

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Linear regression of equation 1

As expected, UAC , $CWAS$ and HHI significantly impact the FTTx penetration rate. UAC has a positive impact, while $CWAS$ has a negative one. Copper access charges tend to increase xDSL prices, while unbundling obligations tend to decrease them. Both an increase in UAC and a decrease in $CWAS$ improve the competitiveness of fiber compared to copper and thus accelerate the migration from copper to fiber. On the other hand, xDSL penetration, C , is positively impacted by $CWAS$ and negatively affected by UAC , although the coefficient is not significant. The overall impact of UAC on total broadband is negative but not significant and the impact of $CWAS$ is positive but relatively weak and barely significant. This reflects the opposite effects of copper access regulation on xDSL access and other types of access. The technological competition appears more clearly when considering the reduced forms $f = F/B$, $c = C/B$ and $cm = Cm/B$. In that case, all the coefficients are very significant and have the expected signs. Furthermore, as we have $F + C + Cm = B$, thus $f + c + cm = 1$ and as a result: $f + cm = 1 - c$. This relation can be verified for the coefficients of all the parameters (UAC , $CWAS$, and HHI). We can then note that the overall impact of copper access regulation is roughly equally shared between fiber, f and cable modem, cm . Competition, analyzed using the Herfindahl index, HHI , acts like an unbundling charge, UAC . It fosters FTTx and Cable modem adoption (coefficient of $HHI < 0$) at the expense of xDSL (coefficient of $HHI > 0$). The overall impact of competition on total broadband penetration, B , is negative (coefficient $HHI > 0$). The estimated coefficients for B have the same sign as xDSL, C , but they are lower and less significant, reflecting the fact that copper accesses currently outnumber the other type of access. Consequently, one might reasonably expect a reversal of sign if the number of fiber and cable modem accesses eventually exceeds that of copper accesses.

4 The dynamic model

4.1 Description

In this section we present the principles of the forecasting model.

The innovation process in the telecommunications industry often leads to S-shaped adoption curves (Fides 2002).

The adoption of a new product follows a process where the number of newcomers depends on the number of existing customers and the number of potential customers who have not yet purchased it but may decide to.

$$\frac{dX(t)}{dt} = g(t)X(t)(1 - X(t)) \quad (2)$$

Where $X(t)$ represents the type of access studied, $X \in \{F, B, C, Cm, f, c, cm\}$ with $f = \frac{F}{B}$, $c = \frac{C}{B}$, $cm = \frac{Cm}{B}$ the reduced forms, and $g(t)$ a time function.

Let us denote z such that:

$$z(t) = \ln \left(\frac{X(t)}{1 - X(t)} \right) \quad (3)$$

Equations 2 and 3 lead to $g(t) = \frac{dz(t)}{dt}$ and $X(t)$ can be expressed in a logistic form:

$$X(t) = \frac{1}{1 + e^{-z(t)}} \quad (4)$$

In order to estimate the impact of each variable, we assume that $z(t)$ can be expressed by a linear function of the variables UAC , $CWAS$, HHI and $FIMS$.

$$z(t) = a + bt + \lambda_1 UAC_{i,t} + \lambda_2 CWAS_{i,t} + \lambda_3 HHI_{i,t} + \lambda_4 FIMS_{i,t} + \varepsilon_{i,t} \quad (5)$$

where $a, b, \lambda_1, \lambda_2, \lambda_3$ and λ_4 are constant parameters that depend on the type of access and $\varepsilon_{i,t}$, the error term.

We can also estimate the model with aggregate data. The aggregate variables are the sum of the variables for each country at time t , weighted by the number of households. Subscript ag denotes the aggregate variables.

$$\forall X_{ag} \in \{B_{ag}, F_{ag}, Cm_{ag}, C_{ag}, UAC_{ag}, CWAS_{ag}, FIMS_{ag}\}$$

$$X_{ag}(t) = \frac{\sum_i X_{i,t} \cdot H_{i,t}}{\sum_i H_{i,t}} \quad (6)$$

In that case, $z_{ag}(t)$ writes:

$$z_{ag}(t) = a_{ag} + b_{ag}t + \sum_{i=1}^4 \lambda_{i,ag} V_{i,ag} + \varepsilon_{ag,t} \quad (7)$$

with $a_{ag}, b_{ag}, \lambda_{1,ag}, \lambda_{2,ag}, \lambda_{3,ag}$ and $\lambda_{4,ag}$, constant parameters that depend on the type of access, $V_1 = UAC$; $V_2 = CWAS$; $V_3 = HHI$; $V_4 = FIMS$; and $\varepsilon_{ag,t}$, the error term¹.

4.2 Estimation

When using the logistic models described in the previous section, we must remove observations for which FTTx or Cable modem deployment has not started, $F = 0$ or $Cm = 0$, where it is not possible to calculate equation 4. This leaves us 230 usable observations to calculate the logistic form of $f = F/B$ and 285 observations to calculate the logistic form of $cm = Cm/B$. *FIMS* can be calculated only if $F \neq 0$. This leaves 230 usable observations for the regressions, including *FIMS* for all types of broadband access with the exception of cable modem, for which we also have to remove the observations where $Cm = 0$, leaving 208 useable observations.

The estimated coefficients for the model of equation 5 are reported in the table below (Table 4). Country and time effects are included but not reported for brevity:

VARIABLES	ln (B/(1-B))	ln (B/(1-B))	ln (f/(1-f))	ln (f/(1-f))	ln (cm/(1-cm))	ln (cm/(1-cm))	ln (c/(1-c))	ln (c/(1-c))
time	0.0495*** (0.00431)	0.0498*** (0.00341)	0.114*** (0.0356)	0.135*** (0.0339)	0.0104 (0.00706)	0.00546 (0.00456)	-0.0139** (0.00548)	-0.00923** (0.00413)
UAC	-0.00608 (0.00807)	-0.00999 (0.00608)	0.0669 (0.0802)	0.0565 (0.0804)	0.0257* (0.0130)	0.0306*** (0.00986)	-0.0271** (0.0135)	-0.0362*** (0.00976)
CWAS	1.193** (0.515)	0.994*** (0.378)	-7.029* (3.644)	-5.269 (3.435)	-3.252*** (0.837)	-2.903*** (0.623)	5.696*** (0.726)	4.879*** (0.564)
HHI	1.396** (0.678)	1.006* (0.565)	3.456 (3.602)	5.901 (3.635)	-3.972*** (0.886)	-4.363*** (0.730)	6.163*** (0.853)	6.454*** (0.747)
FIMS	0.284*** (0.0830)		1.817*** (0.662)		-0.173* (0.0989)		0.0544 (0.112)	
Observation	230	307	230	230	208	285	230	307
R-squared	0.974	0.977	0.914	0.909	0.968	0.970	0.986	0.983

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Linear regression of equation 5

All the parameters have the expected signs, as for equation 1 (Table 3). Time tends to increase fiber adoption and decrease xDSL adoption. The impact on cable seems to be positive though not significant. This suggests that fiber and cable adoption are still in a growth phase and copper has begun its decline, while the overall impact on total broadband adoption is positive. The

¹From equation 2, we can write: $\frac{dX_{ag}(t)}{dt} = \frac{dz_{ag}(t)}{dt} X_{ag}(t) (1 - X_{ag}(t))$ and $\frac{dz_{ag}(t)}{dt} = b_{ag} + \sum_{i=1}^4 \lambda_{i,ag} \frac{dV_{i,ag}}{dt} + \mu_{ag,t}$ with $\mu_{ag,t}$, the error term.

impact of the Fiber Incumbent Market Share, $FIMS$, is significant and positive for Total Broadband and Fiber adoption. Equation 5 takes into account the changes in adoption over time. This reduces the statistical significance of the other variables (UAC , $CWAS$, HHI) in table 4 compared to table 3. Moreover, fiber adoption remains low during the period, which may explain why the fiber coefficients appear less statistically significant than the coefficients of the other technologies. However, the coefficients in table 3 clearly indicate each variable's type of impact on adoption. Country and time fixed effects allow a high level of R-squared.

The coefficients for equation 5 in table 4 are mean coefficients that do not allow us to forecast broadband adoption in each country. To do so, we will use the aggregated data and equation 7.

In equation 7, aggregated penetration rates represent broadband penetration for an "average country". We are now looking at how the different penetration rates behave in this average country.

$\Delta z_{ag}(t)$ plays the role of $g(t)$ in equation 2. This means that $\Delta z_{ag}(t)$ is the standard deviation of the logistic adoption curve. However, in that case, $\Delta z_{ag}(t)$ is not a constant parameter: it varies around b_{ag} depending on the quarterly variations in UAC , $CWAS$, HHI and $FIMS$. The variations of these parameters represent the effect that modulates the time effect. We can therefore test how the adoption curve is impacted when the regulation changes, for example, if the copper access charge increases by €1/month or if the Copper wholesale access share increases by 10%.

How does the model fit with empirical data? We can model direct variables F , Cm and C , or their reduced forms f , cm and c . The direct forms provide good results, but the reduced forms provide a better fit. We choose to model the reduced forms as well as total broadband, B , then we calculate $F = fB$, $Cm = cmB$ and $C = cB$.

The following table (table 5) shows the results of the estimation of equation 7 with the linear regression using the Huber/White/Sandwich robust estimation procedure: the variable explained is $\Delta z_{ag}(t)$ for the household penetration rate of B , $f = F/B$, $cm = Cm/B$ and $c = C/B$

VARIABLES	ln (B/(1-B))	ln (f/(1-f))	n (cm/(1-cm))	ln (c/(1-c))
time	0.0400*** (0.00844)	0.0367*** (0.00580)	0.0104*** (0.00339)	-0.0162*** (0.00325)
UAC	-0.196** (0.0759)	0.117*** (0.0373)	0.107** (0.0412)	-0.115*** (0.0347)
CWAS	1.105 (1.875)	-0.0257 (1.573)	-7.138*** (0.938)	5.934*** (0.677)
HHI	2.601 (3.216)	-7.238*** (2.369)	-5.092*** (1.330)	5.713*** (1.229)
FIMS	0.395 (0.343)	-0.514** (0.189)	0.00911 (0.157)	0.0411 (0.136)
Observations	22	22	22	22
R-squared	0.990	0.995	0.995	0.997

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5: Linear regression of equation 7 (average country)

As expected, we find the same signs as in table 3 for the variables UAC , $CWAS$ and HHI and for all the reduced forms of broadband access f , cm , c , and also for B . This confirms that copper access charges tend to decrease xDSL adoption C in favor of the other types of access: FTTx, F , and cable modem Cm . On the other hand, copper wholesale access charges $CWAS$ tend to encourage adoption of xDSL at the expense of other technologies. Aggregation decreases the number of observations, so the coefficients in table 5 are less consistent those in table 4. However, table 5 allows us to build a forecast of a mean country which is representative of Europe.

Using an iterative process² between time t and $t+1$ and the coefficients estimated in table 5, as well as the values of the regulation variables, $UAC_{ag,t}$, $CWAS_{ag,t}$ and also $HHI_{ag,t}$ and $FIMS_{ag,t}$ we can reconstitute the quarterly evolution of Broadband diffusion, B , F , Cm and C whatever the technology, until Q2 2012 from the first values of Q1 2007.

We know that $F + Cm + C = B$. We can therefore calculate the penetration rate of each technology from the other technologies. Fiber's low penetration rate during the period and data aggregation may cause a decrease in accuracy when

²Let us denote $\Delta z_{ag}(t) = b_{ag} + \lambda_{1,ag}\Delta UAC + \lambda_{2,ag}\Delta CWAS + \lambda_{3,ag}\Delta HHI + \lambda_{4,ag}\Delta FIMS$, with ΔUAC , $\Delta CWAS$, ΔHHI and $\Delta FIMS$, the respective variations of UAC , $CWAS$, HHI and $FIMS$ between time t and time $t+1$. Assuming that time between two observations (a quarter) is sufficiently short, and neglecting the error term, we can calculate: $X_{ag}(t+1) = X_{ag}(t) + \Delta z_{ag}(t)X_{ag}(t)(1 - X_{ag}(t))$

estimating the coefficients of f . In order to improve the accuracy of the forecast, we can build several models. We can calculate F in two ways: $F = B - Cm - C$, (model 1) or $F = fB$, but in this case, we have to adjust another type of broadband access to ensure that the total broadband access penetration rate for households does not exceed one. In that case, we can adjust xDSL penetration C , such that: $C = B - Cm - F$, rather than $C = cB$, (model 2) or we can adjust Cable modem Cm , such that $Cm = B - C - F$ rather than $Cm = cmB$ (model 3). We can also build a model that is the average of the 3 models where $F = (B - Cm - C + 2fB)/3$; $Cm = (B - F - C + 2cmB)/3$ and $C = (B - F - Cm + 2cB)/3$ (Model 4)

In order to compare those models, we calculate the Mean square error on the 21 time periods, $MSE = \frac{1}{21} \sum_{t=1}^{21} (X_{ag}(t) - X(t))^2$ with $X_{ag}(t)$. The table below (table 6) summarizes the results:

X	Model 1	Model 2	Model 3	Model 4
F	$4.11 \cdot 10^{-7}$	$9.77 \cdot 10^{-7}$	$9.77 \cdot 10^{-7}$	$7.52 \cdot 10^{-7}$
Cm	$4.18 \cdot 10^{-7}$	$4.18 \cdot 10^{-7}$	$7.01 \cdot 10^{-7}$	$4.76 \cdot 10^{-7}$
C	$7.86 \cdot 10^{-5}$	$7.47 \cdot 10^{-7}$	$7.86 \cdot 10^{-5}$	$7.73 \cdot 10^{-5}$
B	$8.50 \cdot 10^{-5}$	$8.50 \cdot 10^{-5}$	$8.50 \cdot 10^{-5}$	$8.5 \cdot 10^{-5}$
$Total$	$1.645 \cdot 10^{-4}$	$1.611 \cdot 10^{-4}$	$1.653 \cdot 10^{-4}$	$1.636 \cdot 10^{-4}$

Table 6: Mean square error

The three models provide a very accurate forecast. The differences among the models are very low. Model 2 provides better overall results, but accuracy for FTTx, F is lower. Model 4 seems to be a good compromise between accuracy on FTTx and the other broadband access technologies.

The graph below (figure 1) shows the comparison between the observations and calculated model (The four models provide very similar results that are difficult to distinguish on the graph. That is why we choose to show only Model 4 in figure 1)

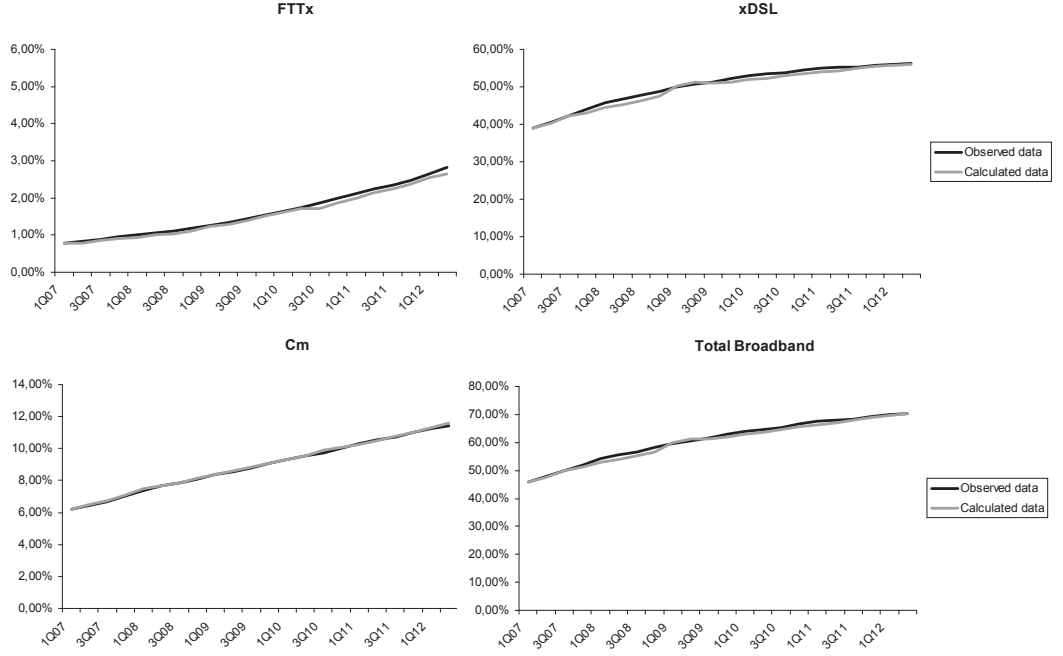


Figure 1: Comparison between observed and forecast data

The fit is quite accurate; although only the first value is common, the model does not deviate much from the observed values during the 21 quarters. However, we would like to know what the regulation variables contribute to the fit. In order to do so, we use exactly the same modeling process with two alternatives: the first alternative, A1, uses only the variable time. In that case, $\Delta z_{ag}(t) = b_{ag}$ and the second alternative, A2, where UAC and $CWAS$ variables are removed. In that case, $\Delta z_{ag}(t) = b_{ag} + \lambda_{3,ag}\Delta HHI + \lambda_{4,ag}\Delta FIMS$. This allows us to focus on what UAC and $CWAS$ contribute to the model.

For the alternatives A1 and A2, we obtain the following results (table 7):

VARIABLES	ln (B/(1-B))	ln (B/(1-B))	ln (f/(1-f))	ln (f/(1-f))	ln (cm/(1-cm))	ln (cm/(1-cm))	ln (c/(1-c))	ln (c/(1-c))
time	0.0441*** (0.00245)	0.0416*** (0.00575)	0.0338*** (0.00280)	0.0339*** (0.00465)	0.0304*** (0.00134)	0.0282*** (0.00365)	-0.0327*** (0.000925)	-0.0303*** (0.00338)
HHI		3.756* (2.098)		-8.701*** (1.434)		2.335 (1.379)		-0.123 (1.269)
FIMS		0.477 (0.369)		-0.600* (0.319)		0.355* (0.199)		-0.227 (0.191)
Observations	22	22	22	22	22	22	22	22
R-squared	0.963	0.984	0.872	0.991	0.961	0.981	0.985	0.987

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 7: Alternatives A1 and A2

To compare the model with alternatives A1 and A2, we calculate the Mean square error for the 21 periods of time. The table below (table 8) summarizes the results:

\bar{X}	Model 4	A1	A2
F	$7.52 \cdot 10^{-7}$	$1.84 \cdot 10^{-6}$	$4.42 \cdot 10^{-7}$
Cm	$4.76 \cdot 10^{-7}$	$2.05 \cdot 10^{-5}$	$7.48 \cdot 10^{-6}$
C	$7.73 \cdot 10^{-7}$	$8.26 \cdot 10^{-4}$	$2.90 \cdot 10^{-4}$
B	$8.50 \cdot 10^{-7}$	$9.64 \cdot 10^{-4}$	$2.52 \cdot 10^{-4}$
$Total$	$1.64 \cdot 10^{-4}$	$1.81 \cdot 10^{-3}$	$5.50 \cdot 10^{-4}$

Table 8: Mean square errors MSE

The forecast model with all the variables is significantly more accurate than alternatives A1 and A2, which means that the regulation variables greatly improve the accuracy of the model. The addition of the variables *HHI* and *FIMS* in alternative A2 as compared to alternative A1 divides the MSE by 3.31 and the addition of the regulation variables *UAC* and *CWAS* in the model as compared to alternative A2 divides the MSE by 3.41.

5 Forecasting

In this section, we will extend Model 4 beyond Q2 2012 to forecast the adoption of each technology through 2020, all things being equal (to compare to the digital agenda target). We know that many elements will change by 2020, and the forecast given here is not intended to be very accurate but simply to show the impact of regulation. We will consider 3 scenarios: the first scenario is the trend scenario, where the variables *UAC*, *CWAS*, *HHI* and *FIMS* retain the value they had in Q2 2012 through 2020. The second scenario assesses the impact of a regular increase in the copper access charge, *UAC*, by €1 between Q3 2012 and Q4 2020; the other variables retain their Q2 2012 value. The third scenario assesses the impact of a regular decrease in the copper wholesale access

share, *CWAS*, by 5% between Q3 2012 and Q4 2020; the other variables retain their Q2 2012 value.

The graph below (figure 2) represents the trend scenario:

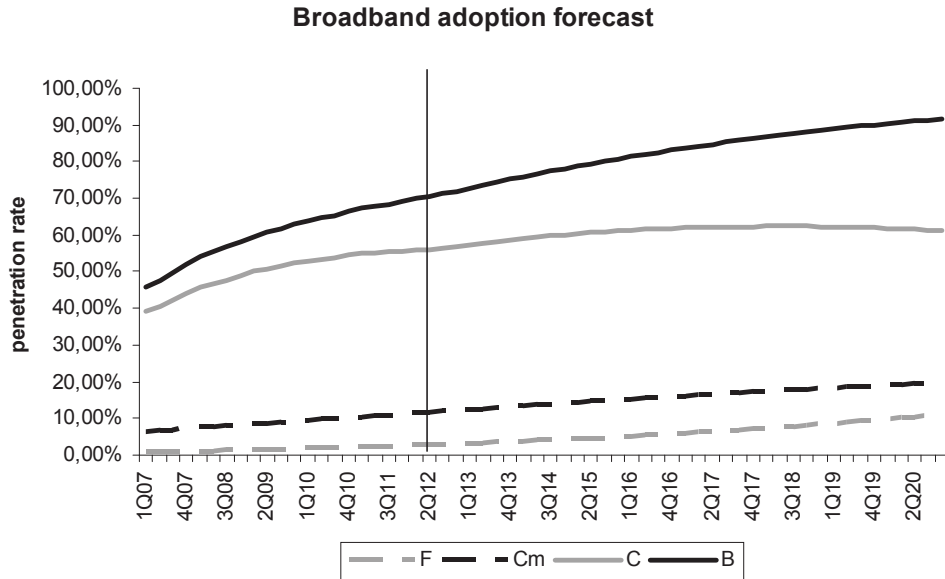


Figure 2: Trend scenario

Scenarios 2 and 3 tend to decrease xDSL adoption and increase adoption of other technologies. An increase in copper access charges, *UAC*, seems to favor FTTx over Cable modem while a decrease in copper wholesale access shares, *CWAS*, favors Cable modem over FTTx. They both tend to decrease xDSL access, *C*. As a result, the overall impact on total broadband is low.

The graph below (figure 3) illustrates the impact of scenarios 2 and 3 on the different types of broadband access.

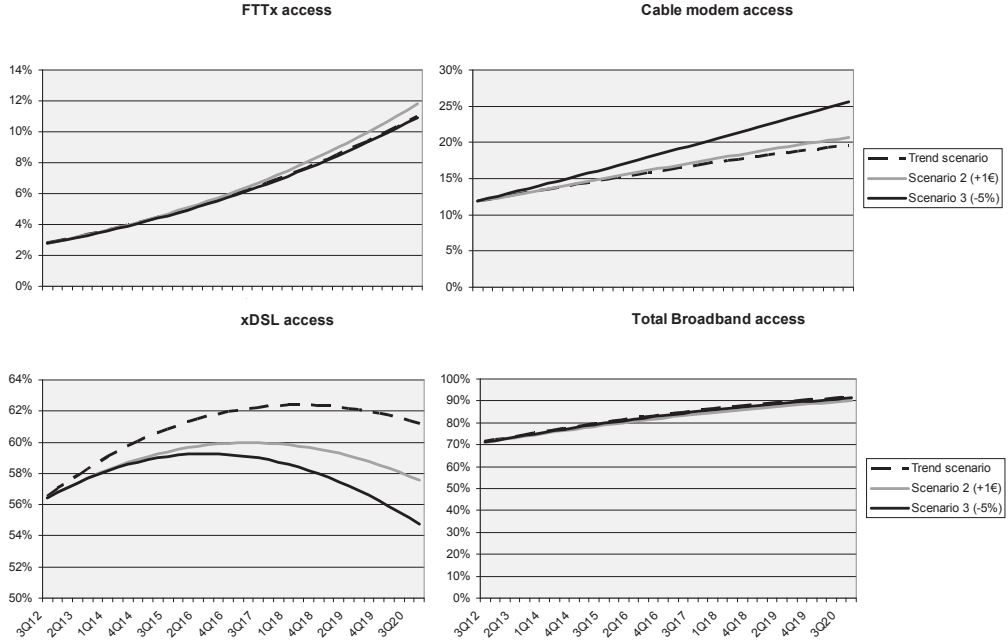


Figure 3: Broadband adoption forecast

Assuming that only cable modem Cm and FTTx, F , could offer ultra-fast broadband in 2020, the digital agenda's target (50% of households have purchased an ultra-fast broadband offer $\geq 100\text{Mbit/s}$) will not be achieved according to the trend scenario. How much would regulations have to change in order to achieve the digital agenda's target?

The model estimates that copper wholesale access shares, $CWAS$ would have to decrease by 15.11% if copper access charges, UAC , remain at their 2012 level or 13.74% if UAC increases by €1/month or 12.49% if UAC increases by €2/month.

6 Conclusion

Ultra-fast broadband adoption depends on copper access regulation. Tight copper access regulation decreases the speed of adoption for FTTx and cable adoption. The impact of copper access regulation is very high and may be crucial for achieving the digital agenda's targets for ultra-fast broadband. An increase in copper access charges and a relaxation of the obligations imposed on the classical broadband market would improve the adoption of ultra-fast broadband on both fiber infrastructures and by cable modem.

The impact of copper access regulation on total broadband adoption is less obvious. It seems to be positive as long as copper access is predominant, how-

ever, in the long term, it tends to become negative as soon as alternative platforms become predominant.

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What causes the fall in prices of mobile telecommunications services?

François Jeanjean

October 8, 2014

Abstract

Mobile industry is characterized by a sharp fall in megabyte price which highly benefits to consumers. This article aims to identify the main parameters that lead to such a fall and shows that the growth of traffic is by far the main cause. It proposes a parametric model that explains the growth of traffic from investment. Using a 20-countries wireless market dataset to calibrate the model, it shows that investment actually drives the exponential growth of traffic. As the growth of revenues are much lower, the price of megabyte decreases sharply. The role of competition is ambiguous. On the one hand it reduces margin and thus prices, on the other hand, as the relationship between investment and competition turns to be inverted-U shaped, it may reduce investment and therefore slow down the fall in unit price.

Keywords: mobile telecommunications, data traffic growth, investment, price of megabyte.

JEL Codes: D24, L96, O31.

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1 Introduction

Prices of telecommunication services is a key issue for competition and regulatory authorities. They have a high impact on the whole economy and influence the rate of growth (Röller, 2001; Datta, 2004; Wavermann & Meschi, 2005). To compare prices of telecommunication services across countries and over time, it seems more appropriate to consider the price of a unit of consumption than simply comparing the subscription prices. Indeed, the services offered in a subscription can vary widely over time, across countries and even between consumers while a unit of consumption (minute of communication or quantity of data) is much more suited to the comparison. Usage (in minutes or megabytes) better characterizes the amount of useful service for users than subscription, either as intermediate consumption for business, or as final consumption for households. The subscription today includes many more services than a few years ago while the price has not changed in the same proportions. Focusing on the price of the subscription does not account for this huge growth in usage. The unit price of uses better reflects market developments.

The unit price of telecommunications services fall sharply over time, which benefits consumers as they highly increased their consumption. What are the causes of such a fall? Is this the result of increased competition? or drastic reduction in operating costs? or rather the effect of technological progress embodied in the network through investment? All these reasons may contribute to lower prices, but not all in the same proportions. To what extent each of them contributes? This paper attempts to answer this question from both a theoretical and an empirical point of view. The paper proposes a model that explains the growth of traffic as a function of Investment. It shows that the impact of investment in successive generations of network technologies is predominant in the permanent trend of price reduction of telecommunication services, over time. Static effects like competition and cost reduction are by nature limited. Indeed, competition can not sustainably decrease the rate of margin under 0% and costs can not become negative. Dynamic effects, by contrary, are not limited. Cumulative investments always increase traffic and therefore always decrease unit prices. Using a 20 national mobile markets dataset provided by Yankee Group and Strategy Analytics from 2006 to 2012, empirical evidence from mobile markets stresses that the impact of competitive intensity and operating costs are almost negligible compared to the impact of investment in a period of just seven years.

The fact that investment is the main driver of unit-price reduction leads to important policy implications. In particular, the price cost margin issue is particularly relevant. On the one hand, the current margin has a direct and increasing impact on unit price, on the other hand, the expected margin spurs investment and tends to increase traffic which has a decreasing impact on unit price. Empirical evidence shows that, as expected, the dynamic impact on traffic dominates the static impact on price in the data which have been studied. Empirical evidence also highlights an inverted U relationship between competi-

tion and investment that culminates for an intensity of competition which yields a rate of Ebitda margin close to 40% . As a result, strengthened competition which result in lower margin may accelerate or slow down the decrease in unit-price according as Ebitda margin is lower or higher than the threshold of 40%. Therefore, competition and regulation authorities should be wondering how to invest more rather than how to enhance competition. The intensity of competition should be carefully settled in order to maximize investment and reduce unit prices.

The rest of the paper is organized as follows. The second section is an economic literature review. The third section presents the dataset, the fourth section shows that traffic growth is mainly driven by investment. The fifth section explains the evolution of price per Megabyte according to margin, costs and traffic growth and concludes that traffic growth highly dominates margin and costs. The sixth section discuss on the competition ambiguous impact and the seventh section is the conclusion and the policy implications.

2 Related Literature

Information Technologies in general and telecommunication industry in particular experience an exponential technological progress growth for more than a century according to (Koh & Magee, 2006). They highlighted a relatively steady annual rate of technical progress in information technologies around 20 to 30 % from the end of the nineteenth century to 2004. The annual rate of technical progress is even higher between 1940 and 2004, around 25 to 40%, highly above that of energy sector which is around 6% (Koh & Magee, 2008). In particular, Koh and Magee highlights an exponential growth of performances for a given spent amount. For example, in data storage, the number of Megabits stored per US \$, or in data transportation, the number of Kbits per second per Km per US \$.

This high technical progress spurs investment. Doms highlights that the sharp increase in telecommunication service providers' investments, in the late 1990s, corresponds to an acceleration of the technical progress rate (Doms, 2004). Technical progress generates opportunities to improve the quality of service for consumers and encourages telecom operators to invest. (Jeanjean F. 2011).

Thanks to technological progress and investment, wireless industry data traffic is experiencing exponential growth for several years (Cisco Networking Index). Such growth, highlighted by Price (Price 1963) has been largely observed in information technologies (Moore's law) and even in other sectors (Tague J. &., 1981), (Schummer 1997).

Chapin & Lehr (2011) also note this growth in traffic. They indicate that this growth may lead to an increase in infrastructure costs and a shortage of spectrum. They are concerned about the harmful impact that this could have on competition. To cope with this problem, they suggest infrastructure and

spectrum sharing. In its report "Supercollider" HSBC suggest market consolidation rather than network sharing. HSBC argues that network sharing is a complement but not an alternative to consolidation. Network sharing reduces costs while consolidation, to a certain extent, supports heavier investment in infrastructure (HSBC, 2014).

Many papers acknowledge the role of investment in the growth of traffic, however, to my knowledge, none explains how investment generates traffic.

Competition has an ambiguous impact on investment incentives. On the one hand, competition encourages investment with the "escape competition effect" mentioned by (Arrow,1962), and on the other hand, it deters investment reducing the future expected profits. (Shumpeter,1942) pointed out that incentives to invest are higher in a monopoly than in a competitive market. (Gilbert & Newbery, 1982) underlined that a monopoly firm is more encouraged to invest in innovation than a potential entrant firm. As a result, there seems to be an inverted U relationship between competition and investment in the telecommunication industry. This relationship highlighted by (Aghion, Bloom, Blundell, & Griffith, 2005) between competition and innovation has been extended between competition and investment in several empirical studies (Friederiszick, Grajek, & Röller, 2008; Kim, Kim, Gaston, Lestage, & Kim & Flacher, 2011;Houngbonon & Jeanjean 2014).

3 Data set

The dataset gathers annual financial information from 20 countries around the world between 2006 and 2012.

Total revenues, Capex and Ebitda per country in millions \$US are provided by Yankee group mobile Carrier Monitor. Four reports have been used according to the world area of the country: "EMEA Mobile Carrier Monitor", "North America Mobile Carrier Monitor", "Latin America Mobile Carrier Monitor" and "Asia-Pacific Mobile Carrier Monitor". In the rest of the paper, Ebitda is treated as profit and Capex as Investment.

Traffic per country in Petabytes is provided by Strategy Analytics on an annual basis. Our purpose is to explain the relationship between investment and data traffic. To do so, we need the total traffic carried out on the mobile infrastructure in each country whatever the type of traffic: tablet, PC, Handset and even the voice traffic because voice traffic, regardless of the technology 2G, 3G or LTE, is part of the customer experience and consumes network resources and hence investment. As the voice is counted in minutes, it is necessary to convert them into bytes for addition on to other types of traffic. Total traffic is the sum of Handset data traffic, PC/Modem data Traffic, Tablets data Traffic and Voice traffic. Handset traffic is provided by The "Global Mobile Media Forecast; Handset Data Traffic (2001-2017)" file, Tablets data traffic is provided by the "Global Active Mobile Broadband Tablet Subscription Forecast: 2010-2017" file, PC/Modem data traffic is provided by the "Global Active

Mobile Broadband PC/Modem Subscription Forecast: 2007-2017" file and the voice traffic is estimated from the number of voice minutes. It is assumed that one minute of voice represents 95 Kbytes. This is the case using an Adaptive Multi-Rate Wideband AMR-WB (G.722.2) that codes the voice at a 12,65 Kbits/s rate. This is not the only rate used, however, it is a medium rate which provides a good quality. The number of voice minutes as well as the number of users per country are provided by the "Worldwide Cellular User Forecasts, 2013-2018".

The number of users seems more relevant than the number of subscribers because the number of subscription per user highly varies across country. The table below (Table.1) represents the descriptive statistics for the whole sample of 20 countries.

20 countries	Revenues	Ebitda	Capex	Traffic	Users	ARPU	Traffic/User	Price/Mbyte
	US\$ (millions)	US\$ (millions)	US\$ (millions)	Petabyte	millions	US\$	Mbyte	US\$
2006	487 514	194 235	95 319	580	1390	351	417	0,84
2007	568 230	214 544	102 016	843	1571	362	536	0,67
2008	574 545	242 699	106 042	1290	1740	330	741	0,45
2009	627 545	244 457	104 175	2071	1921	327	1078	0,30
2010	662 736	262 986	113 502	3624	2107	315	1720	0,18
2011	690 893	275 881	119 548	6071	2261	306	2685	0,11
2012	716 914	276 268	142 149	9461	2391	300	3958	0,08
CAGR	6,64%	6,05%	6,89%	59,25%	9,46%	-2,58%	45,48%	-33,04%

Table.1: Descriptive Statistics (Global)

In all the countries, during the studied period, traffic increases exponentially, while the variations of the other variables are much more moderate. As a result, the average revenue per megabyte (price/Mbyte) decreases sharply. Growth of revenues, Ebitda and Capex are mainly driven by the growth of users. Revenues, Ebitda and Capex per user slightly decreased over the period while Traffic per user increased exponentially. In only 6 years, consumers enjoyed a 10-fold increase in traffic for a nearly constant price. This trend is common to all countries. The table below (Table.1bis) describes the evolution in terms of Compounded Annual Growth rate (CAGR) for each country.

Country	Revenues	Ebitda	Capex	Traffic	Users	ARPU	Traffic/User	Price/Mbyte
South Africa	7,63%	6,45%	1,68%	61,85%	6,30%	1,25%	52,26%	-33,50%
Argentina	13,18%	20,25%	10,05%	56,56%	4,94%	7,85%	49,19%	-27,71%
Brazil	13,77%	22,82%	10,43%	71,51%	10,38%	3,08%	55,38%	-33,66%
Mexico	5,67%	3,95%	8,26%	59,11%	10,50%	-4,37%	44,00%	-33,59%
Australia	14,42%	18,92%	15,53%	88,18%	1,96%	12,22%	84,56%	-39,20%
China	16,05%	9,24%	20,01%	49,93%	16,01%	0,03%	29,24%	-22,60%
India	23,30%	22,39%	-5,38%	46,89%	20,53%	2,30%	21,87%	-16,06%
Japan	5,34%	7,38%	5,70%	85,07%	2,56%	2,71%	80,46%	-43,08%
Korea	0,62%	3,52%	13,42%	64,36%	1,24%	-0,61%	62,34%	-38,78%
Czech Republic	0,32%	1,29%	2,61%	56,72%	0,92%	-0,59%	55,30%	-35,99%
Poland	0,68%	-0,62%	-0,93%	60,18%	1,71%	-1,01%	57,49%	-37,15%
Russia	12,99%	10,88%	15,11%	73,59%	2,68%	10,04%	69,07%	-34,91%
France	1,25%	-2,35%	-4,92%	55,97%	3,05%	-1,75%	51,35%	-35,08%
Germany	-0,83%	0,09%	-6,71%	71,66%	0,98%	-1,80%	69,99%	-42,23%
Italy	-3,52%	-4,18%	-6,81%	68,02%	1,23%	-4,69%	65,97%	-42,58%
Spain	-3,95%	-5,80%	-6,26%	61,23%	1,49%	-5,36%	58,86%	-40,43%
Sweden	6,70%	7,25%	13,44%	93,23%	1,54%	5,09%	90,31%	-44,78%
UK	-3,11%	-5,66%	-1,66%	71,34%	1,55%	-4,58%	68,73%	-43,45%
Canada	10,87%	6,70%	12,47%	70,76%	6,17%	4,43%	60,84%	-35,07%
USA	6,69%	6,82%	1,84%	54,74%	4,86%	1,74%	47,57%	-31,05%

Table.1bis: Evolution 2006-2012 per country

In all countries, the growth of Traffic is much higher than the growth of Revenues; even in the emerging countries where the growth in the number of users is fairly high, like India and China and to a lesser extent Brazil and Mexico.

4 Traffic is driven by investment

One wonders what is driving this growth? Investment by mobile operators or the increasing use of consumers over time, driven by experience and imitation? Obviously, both are necessary. Investment is necessary to install the capacity required to carry the traffic and consumers' demand is necessary to increase the traffic. What is the relative importance of time and investment in traffic growth? This question is even more difficult because the investment is relatively stable over time, making the cumulative investment strongly correlated with the time, however as Romer said: *"no economist, so far as I know, has ever been willing to make a serious defence of the proposition that technological change is literally a function of elapsed calendar time"* (Romer P. 1994).

In order to disentangle this problem, let us consider a basic model that represents the investment in the infrastructures of telecommunication. The operators of telecommunication invest in infrastructure equipments in order to be able to carry the traffic with a good quality of service. New generation equipments are generally developed and commercialized by equipment providers, not by the telco themselves. This is the reason why, in this model, it is assumed that the technical progress is regular and exogenous. Thus the technical progress rate per unit of time is a constant, θ . This is a simplification. As explained Christensen (1992), technological performance curves are S-shaped and therefore

the rate of technical progress is not constant. However, the different generations of technology are intertwined so that the rate of technical progress, by choosing the most efficient technology, is much more stable.

At a point of time, t , the level of technological knowledge in telecommunication infrastructure is A_t . At time $t + 1$, the level of technical knowledge becomes $A_{t+1} = A_t(1 + \theta)$

At the origin of time, the initial level of knowledge is A_0 . Thus, the level of knowledge at time t writes $A_t = A_0(1 + \theta)^t$.

Investment allows to incorporate the technical progress into the infrastructure. At time t , an amount of investment I_t allows to add new capacity, $A_t \cdot I_t$ in the network according to the level of knowledge. However, the oldest equipments in the network become obsolete and are removed. Let us assume that the equipment lifetime is, δ , at time t , all the equipments installed at time $t - \delta$ are removed. The variation of the network capacity at time t writes $\Gamma_t - \Gamma_{t-1} = A_t I_t - A_{t-\delta} I_{t-\delta}$ for $t \geq \delta$ and $\Gamma_t - \Gamma_{t-1} = A_t I_t$ otherwise. Indeed, when $t \leq \delta$, there are no obsolete equipments.

At $t = 0$, it is assumed that $\Gamma_0 = A_0 I_0$. At time t , the accumulation and the removal of equipments lead to the capacity:

$$\Gamma_t = A_0 \left[\sum_{i=0}^t (1 + \theta)^i I_i - \sum_{i=\delta}^t (1 + \theta)^{i-\delta} I_{i-\delta} \right] \quad (1)$$

The carried traffic in the infrastructure can be deduced from the capacity with the occupancy rate, α . the traffic writes $T_t = \alpha \Gamma_t$. In order to allow a good quality of service and to avoid network congestion, the occupancy rate needs to be sufficiently low. However, in order to optimize investment, the occupancy rate needs to be sufficiently high. As a result, the occupancy rate must remain in a relatively tight range. In the following, we assume that the occupancy rate of the infrastructure remains constant over time.

Variations of investment over time in each country can be approximated by the Compound Annual Growth rate during the period $t_0 = 2006$ and $t_f = 2012$, $\lambda = (I_{t_f}/I_{t_0})^{(\frac{1}{t_f-t_0})} - 1$, such that for each country at time t , Investment writes: $I_t = I_{t_0}(1 + \lambda)^{t-t_0} + \mu_t$. μ_t is the difference between actual investment and the approximation: $I_{t_0}(1 + \lambda)^{t-t_0}$. It is noteworthy that $\mu_{t_0} = \mu_{t_f} = 0$, because $I_{t_0} = I_{t_0} + \mu_{t_0}$ and $I_{t_f} = I_{t_f} + \mu_{t_f}$. This provides a good approximation of investment. The graph below represents for all countries the difference between actual Investment and approximation.

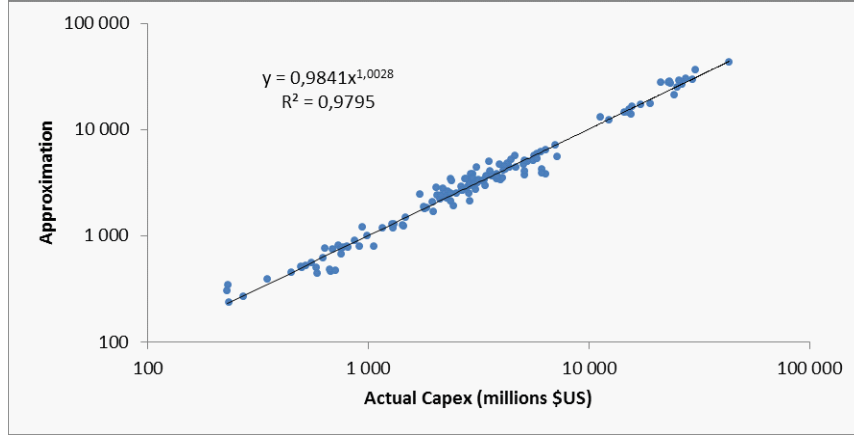


Figure.1: Approximation of Capex

The average difference between actual investment and approximation is under 11,3 %. The distribution of the relative difference, for $t \in [t_0, t_f]$, $\frac{\mu_t}{I_t}$, according to both the Shapiro-wilk and the Kolmogorov-Smirnov tests, can be considered as a standard normal distribution with a 0.195 standard deviation (see annex 7.2). Therefore, μ_t is considered as a random error term. For simplification, in equation (1), I_t is replaced by its approximation: $I_{t_0}(1 + \lambda)^{t-t_0}$. As $E(\mu_t/t) = 0$, the approximation does not change the value of $E(T_t/t)$ and does not impact the estimation of T_t . By defining $(1 + \theta') = (1 + \theta)(1 + \lambda)$, traffic at time t writes (see proof in annexes):

$$T_t = T_{t_0} (1 + \theta')^{t-t_0} \quad (2)$$

If this expression is a good approximation of the growth of traffic in each country, it allows to estimate the level of technical progress.

For each country, we consider the following equation:

$$\ln \left(\frac{T_t}{T_{t_0}} \right) = (t - t_0) \ln (1 + \theta') + \varepsilon_t \quad (3)$$

with ε_t , the error term such that $\varepsilon_t = f(\mu_t) + \varepsilon'_t$. $f(\mu_t)$ is the part of error term due to the approximation on the growth in investment and ε'_t is the part of error term due to other unknown factors. As $\frac{\mu_t}{I_t}$, distribution of ε_t can be considered as a standard normal distribution(see annex 7.2).

t_0 represents the year 2006, and t takes all the values from 2006 to 2012, giving 7 observations per country. The estimation of θ' for each country is obtained with the OLS. At time t_0 , $T_t = T_{t_0}$, thus there is no constant term. The following table, (Table.2) reports the results for each country.

Countries	θ'	t statistic	R^2	λ	θ	95% confidence interval	
						min	max
South Africa	59%	65,41	0,999	2%	57%	54%	60%
Argentina	54%	27,85	0,992	10%	40%	35%	45%
Brazil	75%	25,26	0,991	10%	58%	50%	67%
Mexico	56%	53,85	0,998	8%	44%	42%	47%
Australia	102%	20,96	0,987	16%	75%	61%	90%
China	46%	21,91	0,988	20%	21%	16%	27%
India	50%	31,77	0,994	-5%	59%	54%	64%
Japan	88%	97,50	0,999	6%	78%	75%	81%
Korea	66%	91,46	0,999	13%	46%	44%	48%
Czech Republic	63%	21,93	0,988	3%	59%	51%	68%
Poland	64%	51,90	0,998	-1%	66%	62%	70%
Russia	78%	24,30	0,990	15%	55%	46%	64%
France	48%	14,61	0,973	-5%	56%	46%	66%
Germany	72%	73,50	0,999	-7%	84%	81%	87%
Italy	71%	53,79	0,998	-7%	84%	79%	88%
Spain	62%	59,86	0,998	-6%	72%	69%	76%
Sweden	107%	24,48	0,990	13%	83%	70%	96%
UK	74%	52,42	0,998	-2%	77%	73%	82%
Canada	64%	18,80	0,983	12%	46%	37%	55%
USA	51%	29,56	0,993	2%	48%	43%	53%

Table.2: Estimation of Annual Technical Progress Rate θ

Even with a low number of observations, the model fits quite well with observations with $R^2 > 0.97$ in all country and $R^2 > 0.99$ in most of countries. This model of traffic growth can be used to calculate the evolution of the price of Megabyte.

5 The price of the Megabyte

Unit price, up , may be expressed as the ratio between Revenue, R , and traffic, T : $up = \frac{R}{T}$. Unit price is thus inversely proportional to the traffic. The relationship between Ebitda, E , operating costs, C , and revenues writes $E = R - C$, the Lerner index L is defined by $L = \frac{E}{R}$. As a result, the Revenue is: $R = \frac{C}{1-L}$, where $(1 - L)$ represents a proxy of competition intensity. Equation (2) provides the expression of traffic growth:

$T_t = T_{t_0} (1 + \theta')^{t-t_0}$. Therefore, unit price writes:

$$up = \frac{C (1 + \theta')^{-(t-t_0)}}{T_{t_0} (1 - L)} \quad (4)$$

The contribution of each variable to the unit price change is driven by the elasticities:

$$\begin{aligned}
\eta_C &= \frac{\partial up}{\partial C} \frac{C}{up} = 1 \\
\eta_{(1-L)} &= \frac{\partial up}{\partial(1-L)} \frac{(1-L)}{up} = -1 \\
\eta_{t-t_0} &= \frac{\partial up}{\partial(t-t_0)} \frac{t-t_0}{up} = -(t-t_0) \ln(1+\theta')
\end{aligned} \tag{5}$$

It is possible to express η_{t-t_0} according to the technical progress rate θ and the CAGR of Capex, λ :

$\eta_{t-t_0} = \eta_\theta + \eta_\lambda$ with $\eta_\theta = -(t-t_0) \ln(1+\theta)$ and $\eta_\lambda = -(t-t_0) \ln(1+\lambda)$. η_λ represents the elasticity of unit price according to the variations of investment. When Investment increases, λ is positive and η_λ is negative which means that Investment has a decreasing impact on unit prices. In the same manner, technical progress has a decreasing impact on unit price. However, in this model, the possible impact of investment on technical progress is not studied since technical progress is exogenous and supposed to be constant in each country during the period under study. Notice that η_θ also depends on Investment. It depends on the steady part of Investment I_{t_0}

It is noteworthy that the elasticities of operating costs and competition are constant while the elasticity of investment η_{t-t_0} depends negatively on time with an increasing absolute value. This means that the impact of operating costs and competition on unit price are static while impact of investment is dynamic.

The sign of the elasticity of operating costs is positive. An increase in operating costs, all things being equal increases the unit price. The sign of the elasticity of competition is negative. An increase in competition intensity, all things being equal, reduces the Ebitda margin and then the unit price. The sign of Investment elasticity is negative because investment increase traffic which reduces unit price.

The impacts of operating costs and competition are static. Their elasticities remain equal to unity. The impacts of investment are dynamic, they increase over time. As a consequence, the impact of dynamic effects becomes predominant after a while. Moreover, operating costs and competition can increase or decrease over time while cumulative investment always increases. Specifically, the dynamic effects outweigh the static effects after only a few months. On the entire 7-year period between 2006 and 2012, the static effects appear almost negligible compared to the dynamic effects.

Using the dataset, it is possible to determine the actual contribution of each parameter to the fall in unit price during the period 2006-2012. $t_0 = 2006$ and $t_f = 2012$ After some transformations (see annex 7.3), equation (4) yields:

$$\ln \left(\frac{up_{t_f}}{up_{t_0}} \right) = \ln \left(\frac{C_{t_f}}{C_{t_0}} \right) - \ln \left(\frac{(1-L)_{t_f}}{(1-L)_{t_0}} \right) - 6 \ln(1+\theta) - 6 \ln(1+\lambda) \tag{6}$$

The value of each term represents the relative change of one parameter during 2006 and 2012. The following table, (Table.3) provides the results for each country:

Country	$\ln(U_{ptf}/U_{pto})$	$-\ln(C_{tf}/C_{to})$	$-\ln(1-L_{tf})/(1-L_{to})$	$-6\ln(1+\theta)$	$-6\ln(1+\lambda)$	Σ
South Africa	-2,45	0,48	-0,04	-2,70	-0,10	-2,36
Argentina	-1,95	0,58	0,16	-2,01	-0,57	-1,84
Brazil	-2,46	0,58	0,20	-2,75	-0,60	-2,58
Mexico	-2,46	0,43	-0,09	-2,21	-0,48	-2,35
Australia	-2,99	0,64	0,17	-3,35	-0,87	-3,41
China	-1,54	1,56	-0,67	-1,16	-1,09	-1,36
India	-1,05	1,27	-0,01	-2,78	0,33	-1,19
Japan	-3,38	0,26	0,05	-3,47	-0,33	-3,49
Korea	-2,94	-0,07	0,10	-2,29	-0,76	-3,01
Czech Republic	-2,68	-0,03	0,05	-2,79	-0,15	-2,93
Poland	-2,79	0,07	-0,03	-3,03	0,06	-2,94
Russia	-2,58	0,81	-0,08	-2,62	-0,84	-2,73
France	-2,59	0,17	-0,09	-2,66	0,30	-2,28
Germany	-3,29	-0,09	0,04	-3,66	0,42	-3,29
Italy	-3,33	-0,17	-0,04	-3,65	0,42	-3,44
Spain	-3,11	-0,17	-0,07	-3,27	0,39	-3,12
Sweden	-3,56	0,37	0,02	-3,61	-0,76	-3,98
UK	-3,42	-0,14	-0,05	-3,44	0,10	-3,53
Canada	-2,59	0,81	-0,19	-2,25	-0,71	-2,34
USA	-2,23	0,38	0,00	-2,36	-0,11	-2,09

Table.3: Contribution to the fall in megabyte price

The model's prediction after 7 years (column Σ) is close to the observed changes in megabyte price (column $\ln\left(\frac{up_{2012}}{up_{2006}}\right)$). The fit between prediction and observed values brings up a $R^2 = 0.94$.

The growth of the number of users affects the growth of operating costs as well as Traffic especially in developing countries. It seems relevant to have per user figures in addition to total figures . Without changing the result, it is possible to express the price of Megabyte according to the operating costs per user and the Traffic per user: $up = \frac{C/U}{(1-L)T/U}$

From year t_0 and year t_f , static effect, Se , is composed of operating cost and competition intensity such that: $\ln\left(\frac{Se_{t_f}}{Se_{t_0}}\right) = \ln\left(\frac{C_{t_f}}{C_{t_0}}\right) - \ln\left(\frac{(1-L)_{t_f}}{(1-L)_{t_0}}\right)$ and dynamic effect, De , is composed of the impact of the growth of traffic such that: $\ln\left(\frac{De_{t_f}}{De_{t_0}}\right) = -(t_f - t_0) [\ln(1 + \theta) + \ln(1 + \lambda)]$. Same manner, Static effect per user, Se_{pu} , writes: $\ln\left(\frac{Se_{pu_{t_f}}}{Se_{pu_{t_0}}}\right) = \ln\left(\frac{C_{t_f}}{C_{t_0}}\right) - \ln\left(\frac{(1-L)_{t_f}}{(1-L)_{t_0}}\right) - \ln\left(\frac{U_{t_f}}{U_{t_0}}\right)$ and Dynamic effect per user, De_{pu} ,: $\ln\left(\frac{De_{pu_{t_f}}}{De_{pu_{t_0}}}\right) = -(t_f - t_0) [\ln(1 + \theta) + \ln(1 + \lambda)] + \ln\left(\frac{U_{t_f}}{U_{t_0}}\right)$ Total impact on unit price can write: $\ln\left(\frac{up_{t_f}}{up_{t_0}}\right) = \ln\left(\frac{Se_{t_f}}{Se_{t_0}}\right) + \ln\left(\frac{De_{t_f}}{De_{t_0}}\right) = \ln\left(\frac{Se_{pu_{t_f}}}{Se_{pu_{t_0}}}\right) + \ln\left(\frac{De_{pu_{t_f}}}{De_{pu_{t_0}}}\right)$. Growth of users decreases static effect and increases (decreases in absolute value) dynamic effect by the same value, and consequently does not change unit price.

The Compounded Annual Growth Rate (CAGR) of the change in megabyte price is $CAGR_{up(t_f-t_0)} = \left(\frac{up_{t_f}}{up_{t_0}}\right)^{\frac{1}{t_f-t_0}} - 1 = e^{\frac{1}{(t_f-t_0)} \ln\left(\frac{up_{t_f}}{up_{t_0}}\right)} - 1$. Same manner, for a type of effect, $X \in \{Se, Sepu, De, Depu\}$, the contribution in term of Compounded Annual Growth Rate (CAGR) to the change in megabyte price is: $CAGR_{X(t_f-t_0)} = e^{\frac{1}{(t_f-t_0)} \ln\left(\frac{X_{t_f}}{X_{t_0}}\right)} - 1$. For the whole period $t_f = 2012$ and $t_0 = 2006$.

The following table, Table.3bis, provides the contributions to the change in unit price in Compounded Annual Growth Rate.

Country	Static	Dynamic	Static (per user)	Dynamic (per user)	Total	Unit price
South Africa	8%	-37%	1%	-33%	-33%	-34%
Argentina	13%	-35%	8%	-32%	-26%	-28%
Brazil	14%	-43%	3%	-37%	-35%	-34%
Mexico	6%	-36%	-4%	-29%	-32%	-34%
Australia	14%	-50%	12%	-50%	-43%	-39%
China	16%	-31%	0%	-20%	-20%	-23%
India	23%	-34%	2%	-20%	-18%	-16%
Japan	5%	-47%	3%	-46%	-44%	-43%
Korea	1%	-40%	-1%	-39%	-39%	-39%
Czech Republic	0%	-39%	-1%	-38%	-39%	-36%
Poland	1%	-39%	-1%	-38%	-39%	-37%
Russia	13%	-44%	10%	-42%	-37%	-35%
France	1%	-33%	-2%	-31%	-32%	-35%
Germany	-1%	-42%	-2%	-41%	-42%	-42%
Italy	-4%	-42%	-5%	-41%	-44%	-43%
Spain	-4%	-38%	-5%	-37%	-41%	-40%
Sweden	7%	-52%	5%	-51%	-48%	-45%
UK	-3%	-43%	-5%	-42%	-44%	-43%
Canada	11%	-39%	4%	-35%	-32%	-35%
USA	7%	-34%	2%	-31%	-29%	-31%

Table 3bis: Static and dynamic effect (CAGR)

The "Total" column represents the cumulation of static and dynamic effects. In CAGR the cumulation is calculated following: $CAGR_{Total} = (1 + CAGR_{Dynamic})(1 + CAGR_{Static}) - 1$. Negative signs mean a decreasing contribution to the megabyte price and positive signs mean an increasing contribution. According to the theoretical model, Total might represent the CAGR of unit price. Empirically, the adjustment between Total and Unit price CAGR columns is $R^2 = 0.943$ which means that the model provided by equation (4) fits quite well with observations. Contributions of static effects (operating costs and competition) are relatively low compared to contributions of dynamic effects. In the case of South Africa, for example (first line), static effects have entailed a increase by 8% per year of Megabyte price, while dynamic effects entailed a decrease by 37%. Static (per user) effects increased unit price by 1% while dynamic (per user effect) decreased it by 33%. The graph below (figure.2)

compares the contributions of static and dynamic effects to the fall in Megabyte price.

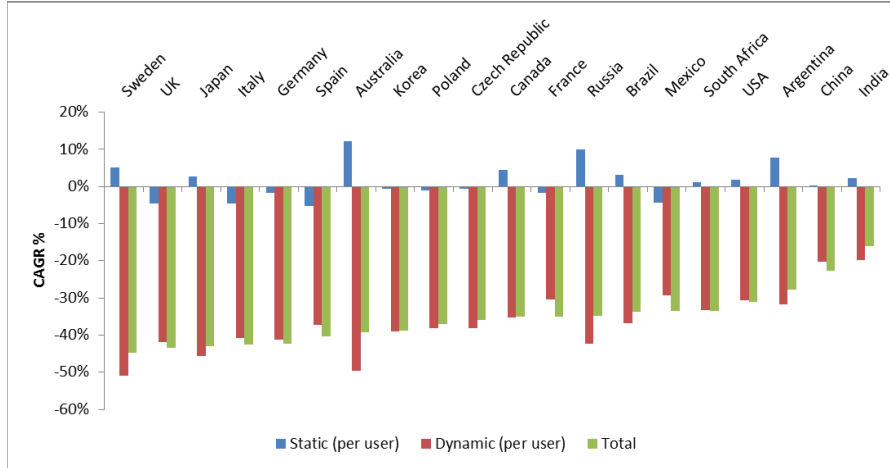


Figure.2: Contributions to the fall in Megabyte price (CAGR 2006-2012)

The contribution of static effects may be positive or negative. Indeed, during the period 2006-2012, competitive intensity has increased in some countries and decreased in others. Same for operating costs (see Table.3). While static effects can increase or decrease unit prices, dynamic effects always contribute to decrease them. During the period 2006-2012, dynamic effects have had a much greater impact than the static effects, and this difference increases over time. Indeed, the elasticities of dynamic effects increase over time while elasticities of static effects remain steady (see equation 5). Moreover, the potential for change of static effects are limited; indeed, it is not possible to increase competition intensity beyond perfect competition ($1 - L = 1$), operating costs can not sustainably exceed revenues, revenue per user can not exceed consumers' willingness to pay and the number of users (different from subscribers) can not exceed the population while cumulated investment regularly increases. This is the reason why, on the long run, static effects become negligible compared to dynamic effects.

6 In wireless industry, fierce competition may slow down the decrease in megabyte price.

Fierce competition reduces Ebitda margin. If reduced margin increases investment, then static and dynamic effects act in the same direction and tend to decrease megabyte price. however, if reduced margin decreases investment, then

static and dynamic effects act in opposite direction. In that case, since the dynamic effect outweighs the static effect, the overall effect should slow down the decline in unit price.

This section empirically highlights that the relationship between competition and investment turns to be inverted-U shaped, in the wireless industry. It is found that the slope of the rate of growth of Investment (Capex) as a function of the intensity of competition measured as (1-L) is significantly and negatively correlated to the average intensity of competition during the period 2006-2012. The slope is positive for the countries with low intensity of competition and becomes negative for the countries with high intensity of competition. This suggests that Investment tends to increase with the intensity of competition when competition is weak and to decrease when it is fierce. As a result, this suggests an inverted-U relationship between competition and Investment. The intensity of competition at which the slope is flat is close to 60%. This corresponds to the intensity of competition that maximizes investment.

The rate of growth of investment at time t is defined by $\rho_t = \frac{I_t - I_{t_0}}{I_{t_0}}$. The slope of the rate of growth as a function of the intensity of competition is: $\frac{\sum_{i=t_0}^t (\rho_i - \bar{\rho})((1-L)_i - \overline{(1-L)})}{\sum_{i=t_0}^t (\rho_i - \bar{\rho})^2}$ with $\bar{\rho} = \frac{1}{t-t_0+1} \sum_{i=t_0}^t \rho_i$ and $\overline{(1-L)} = \frac{1}{t-t_0+1} \sum_{i=t_0}^t (1-L)_i$. For each country, the slope is calculated for the whole period $t_0 = 2006$ and $t_f = 2012$.

The figure below, Figure.3, represents the relationship between the slope of the rate of growth of Investment as a function of the intensity of competition.

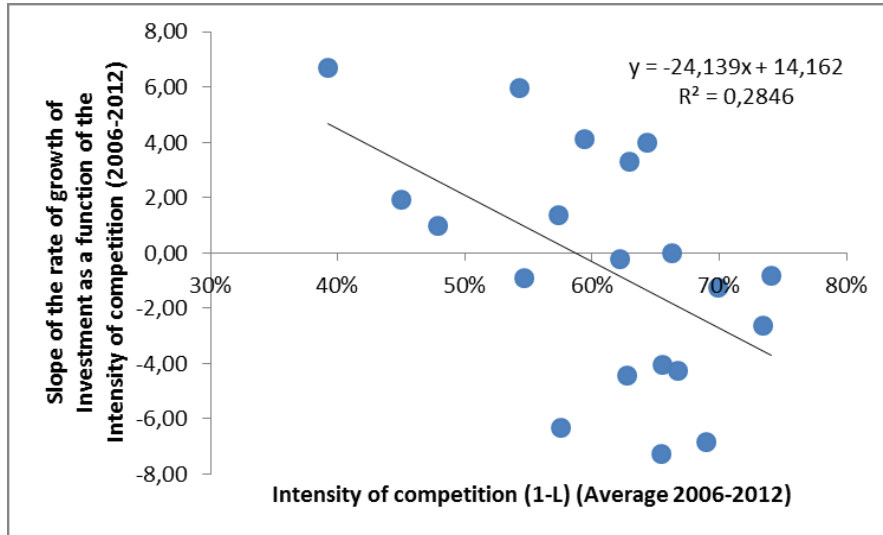


Figure.3: Relationship between competition and investment

Countries whose intensity of competition has tended to move away from 60% (increasing or decreasing) also tended to reduce their investment and therefore to slow down the fall in megabyte price. By contrast, countries whose intensity of competition has tended to get closer to 60% (increasing or decreasing) tended to increase investment and to accelerate the fall in megabyte price. The graph below, Figure.4, shows the contribution of the change in competition intensity to the megabyte price evolution.

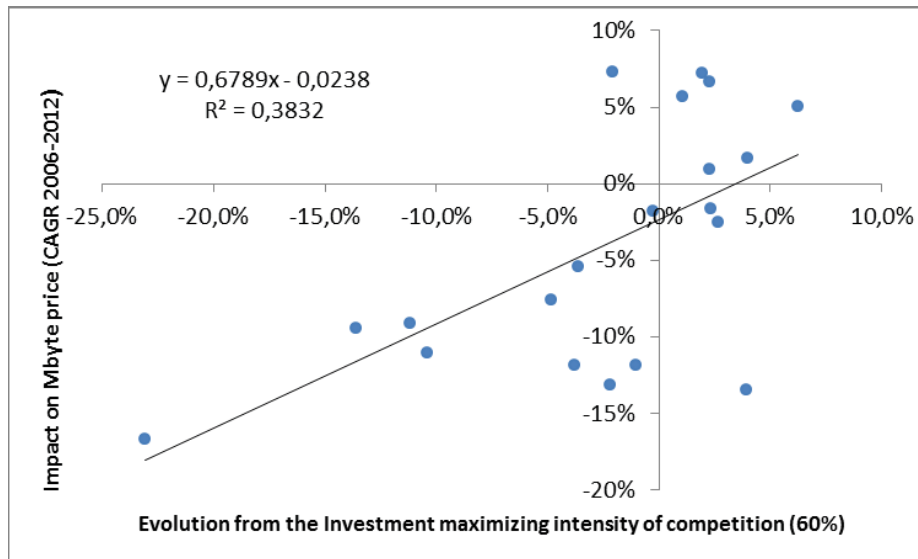


Figure.4: Impact of the evolution of the intensity of competition on Megabyte price

In the figure 4, x-axis is defined by: $|(1 - L)_{2012} - 60\%| - |(1 - L)_{2006} - 60\%|$, and the y-axis by $\frac{-\lambda}{1+\lambda}$ (see annex 7.4). The positive values on the x-axis corresponds to a moving away from the intensity of competition that maximizes Investment ($1-L = 60\%$), and the negative values correspond to a coming closer toward the maximizing level. The positive values on the y-axis correspond to a slow down of the fall in Megabyte price and the negative values correspond to an acceleration of the fall in Megabyte price.

Countries where the intensity of competition moves away from 60% tend to slow down the fall in megabyte price. Those where the intensity of competition get closer to 60% tend to accelerate it. This is because a moving away reduces investment while a coming closer increases it.

As a result, strengthening competition in countries where $1 - L < 60\%$ helps accelerate the fall in megabyte price by both static and dynamic effects working in the same direction. By contrast, strengthening competition in countries where $1 - L > 60\%$ may slow down the fall in unit price because in this case, static and dynamic effects work in opposite direction. Static effect accelerates the fall

in price while dynamic effect slows down it. But dynamic effect, in the long run, tends to become predominant. Hence, finally, enhanced competition, in this case tends to slow down the fall in megabyte price.

7 Conclusion

In a highly innovative industry, like telecommunication and particularly wireless industry, where the technical progress is tremendous, investment becomes the key issue. Investment drives the growth of traffic in an exponential relationship, while competition avoids such a growth of subscription price. Competition tends to decrease price cost margin, however, even perfect competition can not bring down the price below marginal costs, and marginal costs can not be negative. As a result, static effects as competition and cost reduction are limited. Dynamic effects, mainly driven by cumulative investment, by contrary, continuously increase exponentially the traffic. There is theoretically no limit, and in practice, consumers demand continue to support this growth. Traffic increases much faster than revenues, as a result, price of megabyte decreases sharply allowing consumers to benefit from a higher bit rate for a pretty steady price. This improvement also benefits to service and content providers that may provide more services and more contents.

However, There may be a drawback. Investment requires some margin and the increased margin reduces consumer surplus. However, increased margin also may increase investment and accelerate the fall in prices of megabyte. This occurs when the intensity of competition is above the investment maximizing level. In that case, increased investment rapidly compensates for the increased price caused by increased margin, and, as a result, accelerates the fall in megabyte price. by cons, when the intensity of competition is under the investment maximizing level, increased margin reduces investment and consequently, static and dynamic effects mutually reinforce each other to slow down megabyte price.

Competition and regulatory authorities should carefully monitor the rate of Ebitda margin in order to maximize investment. Indeed, Investment is the key driver of price decrease in mobile industry and it is the reason why it is welfare enhancing. In the wireless industry, the price of megabyte depends more on dynamic effects of investment than on static effects of competition and operating costs. Dynamic effects outweigh static effects after only a few months. Thereby, the positive impact of investment far dominates the harmful impact of margin on welfare.

However, it should be noted that this result is specific to very innovative industry. In sectors with a lower technical progress, impact of investment is lower, and the inverted-U relationship between competition and investment may not occur or with a different shape. It is then possible that investment never outweighs the negative impact of increased margin.

8 Annexes

8.1 Proof of equation (2):

Let us denote $j = i - \delta$, from equation (1), using the approximation of investment $I_t = I_{t_0}(1 + \lambda)^{t-t_0}$, the traffic writes:

$$T_t = A_0 \alpha I_{t_0} (1 + \lambda)^{-t_0} \left[\sum_{i=0}^t (1 + \theta)^i (1 + \lambda)^i - \sum_{j=0}^{t-\delta} (1 + \theta)^j (1 + \lambda)^j \right]$$

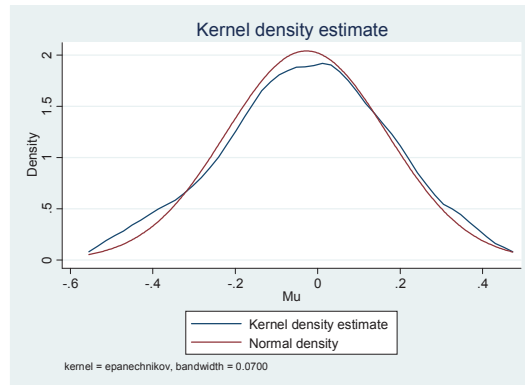
We know that $(1 + \theta') = (1 + \theta)(1 + \lambda)$, thus $\theta' = \theta + \lambda + \theta\lambda$. Notice that $I_0 = I_{t_0}(1 + \lambda)^{-t_0}$, the expression becomes: $T_t = A_0 I_0 \alpha \left[\sum_{i=0}^t (1 + \theta')^i - \sum_{j=0}^{t-\delta} (1 + \theta')^j \right]$.

According to the sum of the terms of a geometric sequence: $T_t = A_0 I_0 \alpha (1 + \theta')^t \left(\frac{(1 + \theta') - (1 + \theta')^{1-\delta}}{\theta'} \right)$.

At time t_0 , the initial traffic is $T_{t_0} = A_0 I_0 \alpha (1 + \theta')^{t_0} \left(\frac{(1 + \theta') - (1 + \theta')^{1-\delta}}{\theta'} \right)$. As

a result, traffic at time t writes: $T_t = T_{t_0} (1 + \theta')^{t-t_0}$. This is equation 2.

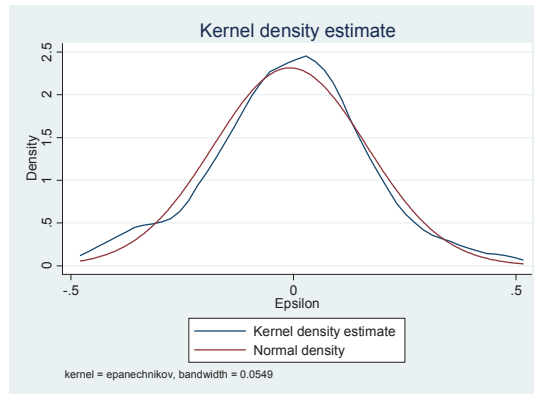
8.2 Distributions $\frac{\mu_t}{I_t}$ and ε_t :



Distribution of $\frac{\mu_t}{I_t}$

S Wilk test	obs	W	V	z	prob>z
μ	100	0.99104	0.740	-0.669	0.74838
ε	120	0.98954	1.006	0.014	0.49451

KS test	obs	pr(skewness)	pr(kurtosis)	adj χ^2	prob> χ^2
μ	100	0.5545	0.5191	0.78	0.6774
ε	120	0.8778	0.3863	0.79	0.6749



Distribution of ε_t

Shapiro-Wilk test. Null hypothesis: The distribution is normal.

Probability of null hypothesis > 0.1 , it can not be rejected.

Kolmogorov-Smirnov test. Null hypothesis: The distribution is normal.

Probability of null hypothesis > 0.1 , it can not be rejected.

8.3 Proof of equation (6):

From equation (4): $up_t = \frac{C_t(1+\theta')^{-(t-t_0)}}{T_{t_0}(1-L)_t}$

$$\ln(up_t) = \ln(C_t) - \ln(1-L)_t - \ln(T_{t_0}) - (t-t_0)\ln(1+\theta')$$

For $t_f = 2012$ and $t_0 = 2006$

$$\ln(up_{t_f}) = \ln(C_{t_f}) - \ln(1-L)_{t_f} - \ln(T_{t_f}) - 6\ln(1+\theta')$$

Same manner: $\ln(up_{t_0}) = \ln(C_{t_0}) - \ln(1-L)_{t_0} - \ln(T_{t_0})$

$$\text{Thus } \ln(up_{t_f}) - \ln(up_{t_0}) = \ln(C_{t_f}) - \ln(1-L)_{t_f} - 6\ln(1+\theta') - \ln(C_{t_0}) + \ln(1-L)_{t_0}$$

We know that $(1 + \theta') = (1 + \theta)(1 + \lambda)$, therefore $\ln\left(\frac{up_{t_f}}{up_{t_0}}\right) = \ln\left(\frac{C_{t_f}}{C_{t_0}}\right) - \ln\left(\frac{(1-L)_{t_f}}{(1-L)_{t_0}}\right) - 6\ln(1 + \theta) - 6\ln(1 + \lambda)$
This is equation (6)

8.4 Figure.4, y-axis:

Dynamic effect has two parts, on the one hand, the impact of regular investment according to the rate of technical progress, θ , in the other hand, the impact of the growth in investment, λ . Dynamic effect writes $\ln\left(\frac{De_{t_f}}{De_{t_0}}\right) = -(t_f - t_0)[\ln(1 + \theta) + \ln(1 + \lambda)]$. Denoting the impact of regular investment $De\theta$, and the impact of the growth in investment $De\lambda$, such that $\ln\left(\frac{De\theta_{t_f}}{De\theta_{t_0}}\right) = -(t_f - t_0)\ln(1 + \theta)$ and $\ln\left(\frac{De\lambda_{t_f}}{De\lambda_{t_0}}\right) = -(t_f - t_0)\ln(1 + \lambda)$, we can write: $\ln\left(\frac{De_{t_f}}{De_{t_0}}\right) = \ln\left(\frac{De\theta_{t_f}}{De\theta_{t_0}}\right) + \ln\left(\frac{De\lambda_{t_f}}{De\lambda_{t_0}}\right)$. The contribution of the growth of investment to the change in unit price in CAGR is $CAGR_{De\lambda(t_f-t_0)} = e^{\frac{1}{(t_f-t_0)}\ln\left(\frac{De\lambda_{t_f}}{De\lambda_{t_0}}\right)} - 1 = \frac{1}{1+\lambda} - 1 = \frac{-\lambda}{1+\lambda}$.

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Incentives to Invest in improving Quality in the Telecommunications Industry

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Abstract:

This paper investigates the incentives to invest in improving quality (as opposed to investments in new activities) in the telecommunications industry, based on the example of wireless markets. We highlight the fact that investment incentives are positively related to potential for technical progress. They also depend on market structure, competition intensity and penetration rate. We show that for each national market, there is a target level of investment which companies strive to achieve. From a social perspective, this target level is the best amount that companies are encouraged to invest. Non-achievement of the target level entails underinvestment and a decrease in consumer surplus and welfare and may slow down technical progress. We used a data set covering 30 countries over a period of 8 years to empirically prove the existence of a change in investment behavior depending on whether or not the target level is achieved. A low margin per user may hamper achievement of the target level. As a result, maximum consumer surplus and welfare occur under imperfect competition and not perfect competition.

Keywords:

Competition, Investment, Investment incentives, Technical Progress, Regulation

JEL Codes: D21, D43, D92, L13, L51, L96, O12

1 Introduction

Information technologies are characterized by the regular exponential growth of data usage, as exemplified by Moore's law. The telecommunications sector is no exception, and shows an impressive increase in consumption, with annual growth rates often well into the double digits.

This is made possible by the sector's tremendous technological progress, as well as regular and ongoing investments by operators.

These investments are essential to allow consumers to benefit from technical progress.

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It is therefore crucial for policy makers and the competition authorities to ensure that investment incentives and capacities are sufficient for investments to continue.

In this paper, we will examine telecommunications companies' investments in wireless markets in 30 countries around the world from 2002 to 2010.

We will show empirically that in all studied countries, companies strive to achieve target investment levels based on market conditions (competition, standard of living, penetration rate, technological progress, etc.). However, only companies which generate adequate margins succeed. Companies with lower margins invest only what they can and find themselves threatened by the technology gap.

Target investment levels are the levels of investment which maximize expected corporate profits. They are closely related to the potential for technical progress: high potential provides more investment opportunities and makes investment more efficient, thus increasing the target level.

Investments in quality improvement, which represent a significant portion of telecommunications operators' investments, must be distinguished from investments in new activities or markets. The decision processes involved differ significantly.

Investments in new activities are expected to ultimately provide new revenues and profits. The decision to invest is based on the estimated Net Present Value and Return On Investment. The decision to invest in improving the quality of existing services, on the other hand, depends more on competition than on expected profits. Indeed, this paper shows that when the market is fully covered and symmetrical, investment in improving the quality does not increase profits.

Improving quality means improving network performance for users (bandwidth, availability, quality and ease of use, customer care, etc.) and leads to an increase in consumers' willingness to pay.

The operator which most improves its performance gains a competitive advantage and increases its profits. However, if all competitors improve their performances to the same extent, none of them creates a competitive advantage. In practice, competitive advantages are relatively weak because they are difficult to obtain and even more difficult to maintain over time. All operators can buy the same equipment and invest under similar conditions, meaning that this type of investment generally does not significantly increase corporate profits; however, these investments do dramatically increase consumer surplus and social welfare.

Competition based on quality improvement grows fiercer as the potential for technical progress increases. An increase in the potential for technical progress increases the profit margin required to achieve the target investment levels. It is impossible to achieve target investment levels if profit margins are too low, thus slowing technical progress at the expense of consumers and their welfare.

Our study revealed that this occurs not only in emerging countries but also in developed countries when price-based competition is so fierce that companies are unable to achieve their target investment levels. A Chow test shows that companies' investment behavior varies depending on whether or not they have the means to attain their target levels.

Competition plays a crucial role in investment behavior. More specifically, there are two types of competition, which have very different impacts: competition on pricing and competition on quality improvement. The former tends to decrease margins, while the latter tends to increase investments. As long as companies' margins remain sufficient to achieve their target investment levels, the competition is sustainable; otherwise it is too fierce and companies underinvest.

A trade-off seems to exist between the two types of competition. An increase in the potential for technical progress encourages competition based on quality improvement by increasing the target investment levels, implying a decrease in price-based competition. In a sense, these two types of competition are in competition with one another.

We will show that consumer surplus and welfare are maximized at investment levels which exceed the target. A trade-off should therefore be made in favor of competition based on quality improvement until the target levels are achieved, and in favor of competition based on pricing in other cases. Companies will not invest more once they have achieved their target levels.

Another key parameter which impacts investments in quality improvement is the user penetration rate. Investment increases consumers' willingness to pay, allowing consumers with lower willingness to pay to enter the market. This increases revenues and profits for all competitors, even without generating a competitive advantage. However, this phenomenon depends on the market's potential for growth. When a market is fully covered, it no longer offers any growth potential.

We will show that investments in quality improvement do not actually increase profits when the market is close to full coverage. A Granger test reveals that investment does not generate margins, except when the size of the market is increasing fast enough. On the other hand, margins always generate investments. Margins mainly depend on competition, market structure and standards of living, and have a major influence on target levels of investment.

Because investments in quality improvement do not have a major impact on margins, companies cannot rely on future additional margins to finance them, meaning that they must generate an adequate margin. This explains why corporate investment behavior varies when companies' margins are insufficient to attain target investment levels. Companies aim to reach their target levels, and try to come as close as possible when reaching their goal is impossible.

Our paper is organized as follows: Part 2 is a literature review on the relationship between competition and investment. Part 3 provides a theoretical framework which explains how investment incentives and target investment levels are determined in the specific and particularly relevant case of markets with full coverage. Part 4 describes the empirical model used, and Part 5 lays out our conclusion and discusses its policy implications.

2 Literature review

The literature on the relationship between competition and investment is quite rich, but mainly focuses on investments in Research and Development. These studies differ from ours, since R&D investment leads to uncertain outcomes while investments in quality improvement are much more predictable. The issues are, however, closely related and the findings are very similar. There are two conflicting traditions in the field (Loury, 1979). The first is the Schumpeterian Effect, which highlights competition's negative impact on innovation. Schumpeter emphasized that a monopoly gives entrepreneurs the greatest incentive to invest in innovation (Schumpeter, 1942). The second, the Escape Effect, highlights the positive impact of competition on innovation. In a competitive structure, companies are encouraged to innovate in order to escape from competition. Innovation provides a competitive advantage, thus restoring a portion of their monopoly rents. Adam Smith's "invisible

hand” supports the idea that monopolies should be restrained and competitive market structures promoted in order to foster innovation.

The trade-off between the Schumpeterian and Escape Effects raises the question of whether there is an optimal intermediate degree of competition located somewhere on the spectrum between monopoly and perfect competition. Several empirical and theoretical studies support this view, (Kaminen & Schwartz, 1975) (Dasgupta & Stiglitz, 1980), as well as the famous inverted U relationship between competition and innovation demonstrated by Aghion et al. (Aghion, Bloom, Blundell, Griffith, & Howitt, 2005).

The Escape Effect is true for relatively low levels of competition, but the Schumpeterian Effect prevails after a certain saturation point is reached.

The idea of a trade-off between competition and innovation has been extended to the trade-off between competition and investment (Friederiszick, Grajek, & Röller, 2008), as the concepts of innovation and investment are often closely linked. The inverted U relationship has also been observed between competition and investment (Kim, Kim, Gaston, Kim, & Lestage, 2010) or (Bouckaert, Van Dijk, & Verboven, 2010). The Escape and Schumpeterian Effects also apply to investments in quality improvement, but in a rather different way. The Escape Effect is more prevalent in this case, since investments in quality never lead to radical innovation and a competitive advantage is more difficult to obtain. Competition based on quality improvement drives companies to make regular investments, although these investments do not significantly increase their profits. However, it always increases both consumer surplus and social welfare. The Schumpeterian Effect also works differently in this case. Competition reduces margins, thus decreasing both the expected profits and investment capabilities.

The literature has consequences for regulatory authorities and policy makers, who must adjust their decisions depending on whether the Schumpeterian Effect or the Escape Effect prevails.

When the Escape Effect prevails, static regulation (Antitrust policies, entry promotion, increased price competition, reduced switching costs, etc.) will increase the intensity of competition, thus encouraging investment. When the Schumpeterian Effect prevails, on the other hand, dynamic regulation (regulatory vacancies, *laissez faire*, etc.) will decrease competition in order to increase investment. The debate surrounding the trade-off between static and dynamic regulations has changed over time.

Pakes et al. noted the positive impact of technological opportunities on R&D investments (Pakes & Schankerman, 1984). High levels of technical potential improve the effectiveness of investments, encouraging companies to invest more and requiring greater investment capacities. This shifts the balance between the Escape and Schumpeterian Effects towards the latter.

Pure static regulation has come under increasing criticism in recent years (Audretsch, Baumol, & Burke, 2001), (Valletti, 2003) and (Bauer, 2010). Its main drawback is the fact that it is best applied to situations with a very stable demand and market structure, at a time when the telecommunications sector is changing rapidly.

The need for significant investments in telecommunications networks such as the Next Generation Network has led regulatory authorities to increasingly take the issues of investment and dynamic efficiency into account. Bauer and Bohlin observed this shift in the USA (Bauer & Bohlin, 2008). Furthermore, Cambini and Jiang (Cambini & Jiang, 2009) note that:

“Nowadays, the urgency to spread broadband access calls for a large amount of capital expenditure. Therefore more and more regulatory concerns are attracted to the investment issue in the broadband market”

Dynamic regulation seeks to encourage investments in order to improve consumer appeal and surplus, as well as welfare. However, dynamic regulation is not a panacea for regulatory policies. (Salop, 1979), (Gilbert & Newbery, 1982) and (Sutton, 1991) refute this assumption and highlight the fact that dynamic regulation may reduce the intensity of competition and does not necessarily lead to improved consumer welfare.

3 Theoretical background

This section provides a theoretical framework for understanding the incentives to invest in quality improvement. In particular, it explains the origin of the target investment levels and the impact of the different parameters on these levels.

Our model is based on the spoke model described by (Chen & Riordan, 2007), a competition model with horizontal differentiation among companies.

The model highlights telecommunications operators’ incentives to invest. They invest in order to improve the quality of their offer and increase consumers’ willingness to pay. This boosts the total number of consumers who make purchases, thus expanding the market. Furthermore, the companies which most improve their quality gain a competitive advantage, although if all of them improve their quality to the same extent none of them gains a competitive advantage. Competition will, however, encourage them to invest anyway. This constitutes competition based on quality improvement. The amount that companies are willing to invest depends on their investments’ impact on consumer utility. The model shows that a certain amount of investment maximizes corporate profits. This is the target investment level. Companies invest this amount when they have the ability to do so; otherwise they invest as much as they can but are unable to reach their target and invest less than they would like to.

The model shows that the socially optimal level of investment is always higher than the financially optimal amount that companies seek to invest. Companies which can achieve their target levels of investment therefore come closest to the socially optimal level.

The model also reviews the ideal margin level, which maximizes consumer surplus and welfare.

We have chosen to study the relevant case of a fully covered market in order to analyze the role of competition based on quality improvement in investment incentives. The market size is normalized to 1. When the market is not fully covered, its potential for growth encourages investment. We wanted to set aside this factor in order to focus solely on the impact of competition on quality improvement.

The market is represented by a spoked wheel where consumers are uniformly distributed. Each company is located at the end of a spoke. The wheel’s diameter is normalized to 1; the length of each spoke is thus 1/2. Each consumer located within a spoke compares the utility of purchasing an offer from the company located at the end of the spoke and an offer from one of the other companies, which all have an equal probability of being chosen. Since all of the spokes converge at the centre of the wheel, the companies can be compared on a one-to-one basis. If there are N

companies, there will be $N(N-1)/2$ comparisons. Each company is involved in $(N-1)$ comparisons.

We assume that v_i and p_i are respectively the consumer's willingness to pay and the price of company i 's offer. We will focus on the comparison between companies i and j . The combined length of the two spokes is 1. A consumer located at a distance of x from company i is located at a distance of $(1-x)$ from company j . For the customer, the utility of purchasing company i and company j 's offers respectively is:

$$U_i = v_i - p_i - tx$$

$$U_j = v_j - p_j - t(1-x)$$

With t , the differentiation coefficient (transportation cost).

We consider the following two-stage game, which comprises an investment stage and a competition stage.

In the investment stage, each company decides on an investment level I per customer, which will improve the quality of its offer.

In the competition stage, companies compete on the basis of price.

The game is solved by backwards induction.

In order to simplify the situation, we assume that at the beginning of the game, the market is symmetrical which is not so far from actual markets².

All companies have the same market share and earn the same profit. In that case, $\forall i, j \quad v_i = v_j = v$ and $\pi_i = \pi_j = \pi = t/N$. Each company has an equal market share: $\sigma = 1/N$ customers.

The consumer hesitating between i and j is located at $x_{ij} = \frac{v_i - v_j + p_j - p_i + t}{2t}$

Company i 's market share is written:

$$\sigma_i = \frac{2}{N(N-1)} \sum_{j \neq i} x_{ij}$$

We assume that all companies incur the same marginal cost c . Company i 's profit is:

$$\pi_i = \sigma_i(p_i - c)$$

The first order condition allows us to determine p_i :

$$p_i = c + t + \frac{(N-1)v_i - \sum_{j \neq i} v_j}{(2N-1)} \quad (1)$$

and therefore:

$$\sigma_i = \frac{1}{N} + \frac{(N-1)v_i - \sum_{j \neq i} v_j}{(2N-1)Nt} \quad (2)$$

² The asymmetry index used in the empirical section, the variable IOA, shows that markets are generally relatively close to symmetrical. (See descriptive statistics in the appendix). The average IOA is under 15% and less than 10% of the markets observed have an asymmetry index above 30%.

3.1 Investment incentives

We assume that the investment I per customer at the investment stage increases willingness to pay by $V(I)$ during the competition stage. Function V characterizes the impact of investment on consumers' willingness to pay. We assume that function $V(I)$ is increasing, concave and tends toward a horizontal asymptote: increasing because the greater the investment, the greater its impact; concave because the marginal increase in investment is less and less efficient. According to the Weber Fechner law, consumers are sensitive to the logarithm of a stimulus (Reichl, Tuffin, & Schatz, 2010). It tends toward a horizontal asymptote because the impact of investment cannot be infinite. These conditions define the target amount that companies are encouraged to invest (F. Jeanjean, 2011) As the impact of the marginal investment decreases and tends toward zero (horizontal asymptote), there is a threshold above which the cost of investment is higher than the expected gains. This threshold is the target investment level, provided that the initial marginal investment is lower than expected gains.

Assume that company i decides to invest I_i and improves its consumers' willingness to pay from v to $v + V(I_i)$. In the competition stage, company i attempts to maximize Π_i , its profit minus the cost of the investments made during the previous stage, depending on the discount rate ρ :

$$\Pi_i = \frac{1}{Nt} \left(t + \frac{(N-1)V(I_i) - \sum_{i \neq j} V(I_j)}{2N-1} \right)^2 - \frac{1}{N} I_i (1 + \rho) \quad (3)$$

The level of investment which maximizes equation (3) is I^* . If all companies play an equal role on the market, they will all invest the same amount I^* .

The first order condition leads to:

$$\frac{dV(I^*)}{dI} = \frac{(1 + \rho)(2N - 1)}{2(N - 1)} \quad (4)$$

(See proof in appendix)

Let us denote T , the right side of equation (4). As we can see, T does not depend on the differentiation between companies, parameter t . It depends only on the discount rate ρ and the number of companies, N . For a given market, when ρ and N are fixed, T does not depend on the level of investment.

As V is increasing, concave and the marginal increase of V tends toward zero, dV/dI is positive, decreasing, and $\lim_{I \rightarrow +\infty} (dV/dI) = 0$. Therefore the higher the value of T , the lower the value of I^* . If $dV(0)/dI$ is higher than T , equation (4) has a solution, and companies are encouraged to invest I^* . However, if $dV(0)/dI$ is lower, equation (4)

has no solution and companies decide not to invest, as shown in the graph below (figure 1). T is thus the triggering threshold for investment.

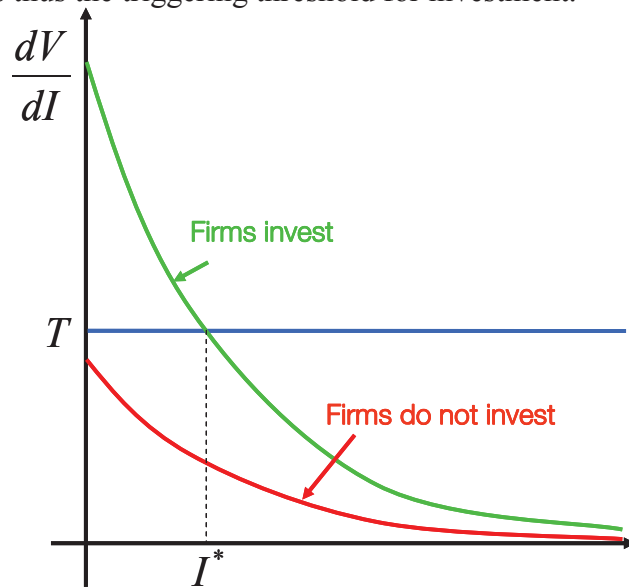


Figure 1: Threshold triggering of investment

The amount of investment I^* which maximizes corporate profits is obtained when the curve dV/dI crosses T . At this point, equation 4 is fulfilled. For lower levels of investment, dV/dI is higher than T , consumer utility increases faster than the corresponding cost of investment, and companies are encouraged to invest more. For higher levels of investment, where dV/dI is lower than T , consumer utility increases more slowly than the corresponding cost of investment so companies are encouraged to invest less.

The discount rate ρ tends to reduce investment because investment is riskier or the value of money is higher in the short run.

The number of companies N tends to increase investment. N strengthens competition, as the difference in quality between competitors, the competitive advantage, becomes more important. The variation in margin per user generated by a higher investment increases with N .

As the market is symmetrical, all companies invest the same amount, meaning that none of them gains a competitive advantage. They would therefore have been better off not investing but are driven to invest anyway by fear of competition. This is non price-based competition. This type of investment benefits consumers more than companies.

3.2 Budget constraints and effective investment levels

At the end of the game, given the assumption of a symmetrical market, all companies have invested the same amount, so the market remains symmetrical. The investments made have increased quality, but prices and margins remain stable. In a symmetrical market, equation (1) becomes $p_i = c + t$ and industry margin $\pi = t$ which does not depend on Investment.

In this case, companies cannot rely on futures profits to finance their investments; they must rely solely on self-investment. Indeed, investment does not increase profits and profits are fully mobilized for investment, thus there remains nothing to repay a loan. Companies try to invest target amount I^* . When their profits are sufficient to achieve I^* , they invest I^* ; otherwise they invest as much as possible but are unable to achieve their target investment levels.

Given the assumption of a symmetrical market, the margin (profit per customer) equals the transportation cost: $\pi_i/\sigma_i = t$

The relationship between investments and margins is as follows:

When the margin is low, i.e. $t < I^*$, companies do not make enough profits to invest I^* , so they invest $I = t$.

When investment capabilities are high enough, i.e. $t > I^*$, companies invest I^* .

The following graph (figure 2) illustrates the relationship

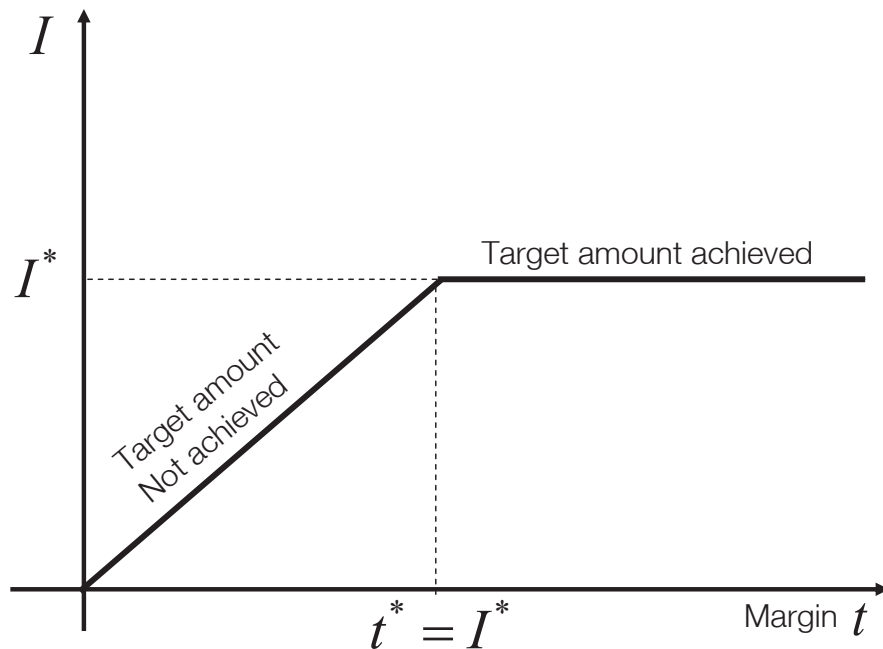


Figure 2: Investment according to the margin $I(t)$

The drop in investment for low margin is due to budgetary restrictions. This decrease in investment is empirically observed in the next section.

3.3 Socially optimal investment levels

Consumer surplus increases with investment. When the market is symmetrical, all companies benefit from the same willingness to pay $\forall i, j \in \{1, 2, \dots, N\}, v_i = v_j = v$

$cs = (v - c - \frac{5}{4}t)$ Investment increases willingness to pay by $V(I)$, thus

$$cs(I) = (v + V(I) - c - \frac{5}{4}t) \quad (5)$$

(See appendix)

and as a result $cs(I) - cs = V(I)$

Social Welfare, defined as the sum of consumer surplus and total profits generated on the market, is written as: $w(I) = cs(I) + \Pi(I)$

The market size is normalized to 1, so the profit generated on the market is $\Pi(I) = t - I(1 + \rho)$. The market's symmetry encourages all companies to invest the same amount and prevents them from winning a competitive advantage. Investment ultimately increases consumer surplus but decreases corporate profits. What level of investment I^{**} maximizes welfare?

Welfare is written as:

$$w(I) = (v + V(I) - c - \frac{t}{4}) - I(1 + \rho) \quad (6)$$

The first order condition leads to the following equation:

$$\frac{dV(I^{**})}{dI} = (1 + \rho) \quad (7)$$

A comparison of equations 4 and 7 shows that $dV(I^{**})/dI < dV(I^*)/dI$. As a result, $I^{**} > I^*$. The socially optimal level of investment is always greater than the investment level which maximizes corporate profits. As we saw in subsection 3.2, companies are never encouraged to exceed the target level, meaning that they always invest less than the socially optimal level I^{**} . They come closest to achieving I^{**} when they can afford to invest I^* .

3.4 Socially optimal margins

Equations (5) and (6) represent consumer surplus and welfare according to the margin t (figure 3).

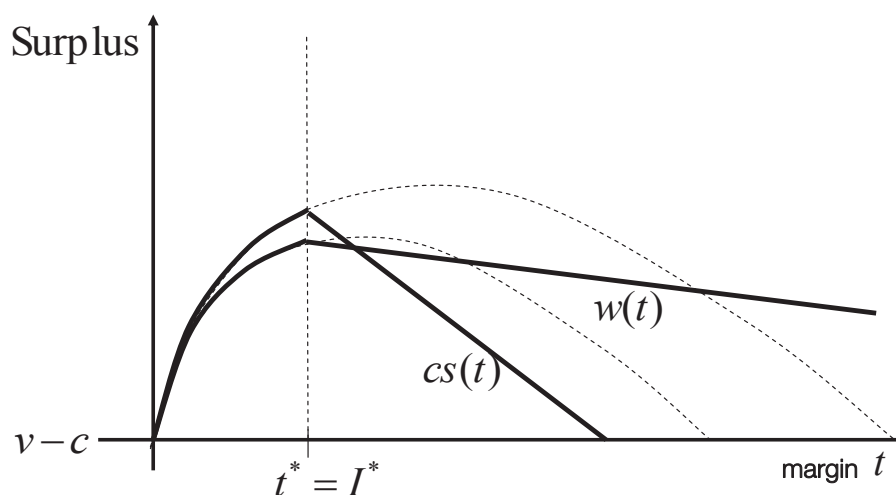


Figure 3: Optimal margin which maximizes consumer surplus and welfare³

³ The graph is based on the assumption that the impact of investment on consumers is high enough that $dV(I^*)/dI > 5/4 + \rho$. Consumer surplus and welfare increase as long as $t < t^*$

Derivatives of equations (5) and (6) provide variations of consumer surplus and welfare according to t :

$$\frac{dcs}{dt} = \frac{dV}{dI} \frac{dI}{dt} - \frac{5}{4} \quad \text{and} \quad \frac{dw}{dt} = \frac{dV}{dI} \frac{dI}{dt} - \frac{1}{4} - \frac{dI}{dt} (1 + \rho)$$

Figure 2 indicates that investment depends on whether the value of the margin is lower or higher than the target level. If $t < I^*$, then $I = t$ and $dI/dt = 1$. If $t \geq I^*$ then $I = I^*$ and $dI/dt = 0$.

If $t < I^*$, $\frac{dcs}{dt} = \frac{dV}{dI} - \frac{5}{4}$ and $\frac{dw}{dt} = \frac{dV}{dI} - \frac{5}{4} - \rho$, any margin growth is used to invest.

As long as the impact of investment on consumers is high enough, and so as long as the dynamic effects outweigh the static effects: ($dV/dI > 5/4$ for consumer surplus and $dV/dI > 5/4 + \rho$ for welfare), the margin's growth increases both consumer surplus and welfare.

If $t \geq I^*$ $dcs/dt = -5/4$ and $dw/dt = -1/4$, however, the margin's growth is no longer used to make investments. The dynamic effects disappear, leaving only static effects, so both consumer surplus and welfare decrease with the margin.

When the dynamic effects are high enough ($dV/dI > 5/4$ for consumer surplus and $dV/dI > 5/4 + \rho$ for welfare), the margin values which maximize consumer surplus or welfare are both strictly positive. The socially optimal margin value is therefore not equal to zero. The socially optimal situation is not perfect competition. A certain degree of margin t , which reduces market fluidity, can be socially efficient.

The greater the potential for technical progress, the higher the socially optimal margin value.

Moreover, if $N \leq 3 + 2\rho$, then $dV(I^*)/dI > 5/4 + \rho$, and consumer surplus and welfare are maximum for the same value $t = t^* = I^*$ (case of figure 3).

Remark: Investment mainly benefits the telecommunications sector and equipment suppliers. If we consider welfare without investment, equation (6) becomes:

$$w(I) = (v + V(I) - c - \frac{t}{4}). \quad \text{In that case, welfare is always maximum when } t = t^* = I^* .$$

Quality improvement based competition can be characterized by the target amount of investment I^* and price-based competition by the level of margin t or rather by $1/t$, the level of substitutability.

Maximum welfare occurs for $I^*/t = 1$ which means that the level of quality improvement based competition is inversely proportional to the level of price-based competition.

4 Empirical analysis

This section provides an empirical analysis of the relationship between investment and margin per user for in wireless markets in 30 countries between 2002 and 2010. It highlights the existence of a breaking point in the relationship between margin and investment. Companies' investment behavior in a country tends to change when their margins reach a certain threshold. Below the threshold, investment increases sharply with the margin, while the increase is slower above the threshold. The theoretical model in the previous section predicts this type of change in a symmetrical and fully covered market (figure 2). In that specific case, beyond the threshold (the target level), growth in investment is nil.

Section 3 address the problem in terms of the firms problem, however, because the market is assumed to be symmetrical, all firms play the same role. As a result the industry behavior is totally defined by a representative firm. In this section, the analysis is conducted at the industry level and the results could be compared at the theoretical results of section 3.

In markets which are not fully covered, investment may increase the number of consumers and profits. The observed growth of investment, although relatively low, therefore remains positive. The model also underscores the role of other factors including market structure, level of service adoption, level of technology and standard of living.

4.1 Data set

The data set used here is a panel data set for 30 countries (cf. list in appendix, which includes annual data by country from 2002 to 2010. The data set should comprise 270 observations, however 29 observations are unavailable. The data set therefore comprises 241 observations. The financial figures used (Revenue, Capex, Ebitda, HHI and the number of companies) are drawn from the Informa "World Cellular Information Service". The number of wireless users, the population and the level of technology come from the strategy analytics report "Broadband cellular user forecasts 2011-2016 (September 2011)"⁴, while the standard of living (GNI per Capita) is taken from the World Bank. A table of descriptive statistics is provided in the appendix.

The dependant variable in the linear regression model is the yearly Capex per user by country, *CAPU* in US \$. Capex per user is a proxy of investment.

There are two categories of explanatory variables: financial figures, which depend on the wireless market in the country, and country figures, which are based on the specificities of each country. A time trend is included, *YEAR*, which indicates the number of years counting from 2001, (the value of year in 2002 is 2, and in 2003 is 3, etc.), as is a squared time trend. Descriptive statistics are available in the appendix

These variables are presented as follows:

4.1.1 Financial figures:

These variables aim to evaluate the market's impact on investment incentives. First, the margin per user, *MAPU*, defined as annual Ebitda divided by the number of users.

⁴ This report provides not only forecast data but also data from 2002 to 2010.

Second, the number of companies on the market, N . Third, the asymmetry index , which measures the degree of asymmetry among companies present on the market: IOA . This index is calculated as follows: $IOA = \frac{N(HHI) - 1}{N - 1}$. IOA may range from 0 to 1. In a perfectly symmetrical market, $IOA=0$; IOA increases with market's asymmetry. HHI , the Herfindahl index, is expressed as a percentage. When the market is absolutely symmetrical, all companies have an equal market share: $HHI = 1/N$, thus $IOA=0$. When the market is absolutely asymmetrical, it tends towards a monopoly; HHI tends towards 1, so IOA tends towards 1 as well. Fourth, the potential for market growth, PMG . PMG depends on the penetration rate q , defined as the number of users divided by the total population of the country. Assuming that the demand function, which expresses the penetration rate according to price, is sigmoid shaped, which is a common assumption in telecommunications (Fildes and Kumar 2002) potential for market growth is close to its maximum at the middle of market coverage. When q is low or high, close to 0 or 1, the potential for market growth is low. $PMG = q(1-q)$. The potential for market growth increases with PMG , which seems more relevant than simply q . The strength of competition is given by $COMP$, which is defined by $1-L$, where L is the Lerner index. The Lerner index is calculated yearly by country; it is defined as Ebitda divided by total Revenue on the market.

4.1.2 Country-specific figures:

These variables aim to take into account the specific situation of each country. First, the density of population, $DPOP$, defined as the total population divided by the country's surface area. Density may have an impact on investment. Second, the standard of living, given by the Gross National Income per capita, $GNICAP$, expressed in PPP. Finally, the level of technical advances integrated in the network, $3GT$, defined as the proportion of subscriptions using 3G technologies as CDMA 2000, WCDMA or LTE.

The following table (Table 1) represents the descriptive statistics of the variables.

	<i>CAPU</i>	<i>MAPU</i>	<i>COMP</i>	<i>N</i>	<i>IOA</i>	<i>PMG</i>	<i>3G</i>	<i>DPOP</i>	<i>YEAR</i>	<i>GNICAP</i>
Mean	62,24	172,61	60,72%	5,94	14,50%	18,13%	14,88%	564	5,33	26579
Standard error	2,10	5,78	0,69%	0,60	0,69%	0,26%	1,29%	102	0,16	810
Median	60,99	173,55	61,33%	4,00	12,38%	17,20%	5,29%	108	5,00	29893
Standard deviation	32,58	89,79	10,76%	9,25	10,76%	3,97%	20,05%	1582	2,45	12575
Variance	1061,57	8061,65	1,16%	85,65	1,16%	0,16%	4,02%	2501646	6,01	158135179
Kurtosis coefficient (flattening)	3,12	-0,24	0,94	38,21	1,43	-1,16	2,58	9,41	-1,11	-0,41
Skewness	1,31	0,44	-0,36	6,05	1,27	0,29	1,67	3,35	-0,12	0,07
Minimum	5,32	12,92	23,76%	2	0,05%	9,35%	0,00%	2,65	1	4064
Maximum	211,11	466,51	93,43%	71	51,99%	25,00%	95,38%	6812,24	9	68547
Sum	15000	41599	146	1432	35	44	36	135976	1285	6405424
Observations	241	241	241	241	241	241	241	241	241	241

Table 1: Descriptive statistics

4.2 Econometric Model

We estimate first the determinants of the margin and we discuss the impact of investment on future margin. We have shown in section 3 that in a symmetrical and fully covered market, investment did not increase the margin. However, since markets are neither perfectly symmetrical nor fully covered, we will see to what extent investments actually affect margin.

4.2.1 Margin equation

We use a panel data regression OLS in order to estimate the coefficients of the following equation:

$$MAPU_{iy} = \alpha + \alpha_j X_{iy} + \alpha_k Y_{iy} + \varepsilon_{iy} \quad (8)$$

where X_{iy} represents the control variables and Y_{iy} the investment variables $X_{iy} \in \{COMP_{iy}, DPOP_{iy}, GNICAP_{iy}, N_{iy}, IOA_{iy}, YEAR_{iy}\}$, $Y_{iy} \in \{CAPU_{iy}, CAPU - 1_{iy}, CAPU - 1 * PMG_{iy}, CAPU - 1 * IOA_{iy}\}$ and ε_{iy} is the error term.

$CAPU-1$ is the Capex per user $CAPU$ lagged one year. $CAPU-1*PMG$ and $CAPU-1*IOA$ are the lagged values of $CAPU$ multiplied respectively by the Potential for market growth PMG and index of asymmetry IOA . These variables aim to assess the impact of the remoteness of assumption of symmetry and full coverage on the margin. The subscripts of the variables denote country i at year y . The results are presented in the following table (Table 2):

VARIABLES	MAPU (1)	MAPU (2)	MAPU (3)	MAPU (4)	MAPU (5)	MAPU (6)	MAPU (7)
COMP	-195.1*** (25.13)	-182.2*** (25.86)	-182.3*** (24.03)	-183.9*** (24.59)	-184.9*** (24.41)	-181.9*** (24.84)	-184.1*** (24.67)
DPOP	0.0755*** (0.0254)	0.0812*** (0.0255)	0.0716*** (0.0241)	0.0807*** (0.0239)	0.0748*** (0.0240)	0.0806*** (0.0242)	0.0804*** (0.0240)
GNICAP	0.00458*** (0.000873)	0.00489*** (0.000885)	0.00426*** (0.000832)	0.00455*** (0.000835)	0.00450*** (0.000829)	0.00461*** (0.000844)	0.00399*** (0.000871)
N	0.0148 (0.288)	-0.288 (0.276)	-0.153 (0.278)	-0.525* (0.267)	-0.581** (0.266)	-0.483* (0.272)	-0.656** (0.286)
YEAR	-0.0121 (1.220)	-2.364* (1.255)	-0.109 (1.162)	-2.684** (1.189)	-2.579** (1.181)	-2.171* (1.211)	-1.837 (1.215)
CAPU	0.0449 (0.0740)		0.223** (0.0913)		0.171* (0.0902)		
CAPU-1		0.0374 (0.0687)		0.277*** (0.0924)	0.253*** (0.0926)		
CAPU-1*PMG						1.127** (0.497)	
CAPU-1*IOA							1.216*** (0.428)
Constant	124.0*** (27.16)	121.6*** (27.59)	117.5*** (26.06)	120.5*** (26.29)	116.6*** (26.18)	119.3*** (26.66)	139.0*** (26.75)
Observations	241	211	238	208	208	208	208
R-squared	0.433	0.384	0.428	0.408	0.420	0.395	0.405
Number of Countries	30	30	30	30	30	30	30

Standard errors in parentheses

* p<0.01, ** p<0.05, * p<0.1

Table 2: Margin equation

The first specification is the regression on the full sample (241 observations). The second specification represents the same model with lagged $CAPU$, that is why we lose 30 observations (one per country). The results of the second specification are

very similar to the first. In this case, Investment seems to have no significant impact on margin. However, three observations show an abnormally high Capex. For those observations, Capex is significantly higher than margin. It is possible that these Capex do not only represent investments in improving quality or that these values are incorrect. Anyway, in the following columns, we removed these three values leaving 238 observations for CAPU and 208 for CAPU-1. In the third and the fourth specification, investment has a significant impact on margin. There is no significant difference between the coefficients estimated in these two specifications which suggest that an investment remains relatively steady over time. The fifth specification provides both CAPU and CAPU-1 in order to compare the respective impact of past year and current year investment on margin. As expected, although both CAPU and CAPU-1 are significant, the impact of past year is higher and more significant. Consequently, in the following model, we chose the lagged values of investment CAPU-1 rather than CAPU. In the sixth specification we replaced CAPU-1 by the product CAPU-1*PMG and in the seventh we replaced CAPU-1 by the product CAPU-1*IOA. These variables indicate respectively the impact of the Potential for Market Growth PMG and the asymmetry of the market on the relationship between investment and margin. These two variables have a positive and significant impact on margin. This means that PMG and IOA both increase the impact of investment on margin. This is consistent with section 3 and the hypothesis of market symmetry and full coverage. Under such hypothesis, PMG = IOA = 0, Investment has no impact on margin. Therefore, the impact we highlighted is caused by the fact that markets are neither fully covered nor symmetrical, even though they often approach close to symmetry and full coverage. PMG increases profits and thus encourages investment. Indeed, when PMG is high, investment in quality improvement encourages customers who were not yet in the market to enter. This increases the market size and thus profits. Asymmetry of market also encourages investment because asymmetry means there are leader firms, and leader firms can expect their investment to provide them a competitive advantage and increase their profits.

The coefficients of control variables are robust to the different specifications. As expected, competition COMP and the number of firms N have a negative impact on margin. The density of the population DPOP and the GNI per capita have a positive one. The time trend YEAR, indicates a decline of margin over time.

4.2.2 Investment equation

The investment equation emphasizes the difference in behavior between companies according to their margins. In order to do so, we will compare two hypotheses: The first hypothesis, H_0 supposes there is no change in firms' behavior according to their margin. The corresponding equation is as follow:

$$CAPU_{iy} = \beta_0 + \beta_1 MAPU_{iy} + \varepsilon_{iy} \quad (9)$$

The Capex per user CAPU is explained by the margin per user MAPU. ε is the error term.

The alternative hypothesis, H_a supposes there is a break in firms' behavior. Before the break, for the low values of margin, Capex per user follows the equation (9) and after the break, Capex per users follows the following equation:

$$CAPU_{iy} = \beta'_0 + \beta'_1 MAPU_{iy} + \beta'_2 MAPU * PMG_{iy} + \varepsilon_{iy} \quad (10)$$

Where $\beta'_0 = \beta_0 + \Delta CONSTANT$, $\beta'_1 = \beta_1 + \Delta MAPU$; and $\beta'_2 = \Delta MAPU * PMG$

We will make a Chow test to choose the most likely hypothesis. We will first test the model with all the 241 observations then we will remove the three abnormal observations like in margin equation.

We will also test the model for $\beta_0 = 0$ which suggests there is no investment when there is no margin.

The results are presented in the following table (table3):

VARIABLES	CAPU (1)	CAPU (2)	CAPU (3)	CAPU (4)	CAPU (5)
MAPU	0.253** (0.108)	0.502*** (0.0366)	0.255*** (0.0868)	0.478*** (0.0296)	0.478*** (0.0308)
Δ Constant	31.30*** (11.61)	52.89*** (7.599)	24.46** (9.506)	43.96*** (6.364)	38.89*** (6.521)
Δ MAPU	-0.357*** (0.124)	-0.606*** (0.0713)	-0.303*** (0.100)	-0.526*** (0.0586)	-0.331*** (0.0415)
Δ MAPU*PMG	1.151*** (0.271)	1.151*** (0.274)	1.016*** (0.221)	1.016*** (0.224)	
Constant	21.59** (8.848)		19.50*** (7.138)		
Observations	241	241	238	238	238
R-squared	0.327	0.852	0.438	0.892	0.883
Chow test	8.46	27.9	8.9	30.27	32.42
Prob (H ₀)	0.00002	0.00000	0.00001	0.00000	0.00000

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table3: Investment equation

Specifications (1) and (2) use all the 241 observations. Specifications (3), (4) and (5) removed the three abnormal observations.

Specifications (1) and (3) have a coefficient $\beta_0 \neq 0$, specifications (2), (4) and (5) have a coefficient $\beta_0 = 0$. Those specifications reflect the fact that there should be no investment when there is no margin⁵. The specification (5) have the coefficient $\beta'_2 = \Delta MAPU * PMG = 0$ in order to compare the impact of the potential for market growth between specification (4) and (5).

Removal of abnormal observations do not change significantly the results, however, it improves the accuracy of the model.

The Chow test indicates that in all specifications, the hypothesis H₀ is highly unlikely. This means that the alternative hypothesis H_a is confirmed: There is actually a structural change. Under a certain threshold of margin, Capex per user CAPU is proportional to the margin per user CAPU and follows the equation (9). Beyond the

⁵ This is theoretically exact when the market is symmetrical and fully covered because in that case investment does not provide an increase in profits (see section3).

threshold, CAPU follows the equation (10). The margin threshold is chosen for the value of MAPU that maximizes the fisher's statistic of the chow test. This occurs for a value of MAPU=117 \$/user/year.

Equation (10) does not depend on the initial specification of the coefficient β_0 . We can notice that $\beta'_0 = \beta_0 + \Delta CONSTANT$ and $\beta'_1 = \beta_1 + \Delta MAPU$ have exactly the same values in specification (1) and (2) and in specification (3) and (4).

The structural change in investment behavior according to the margin is consistent with the theoretical framework of section 3.

For low margin values (under the threshold), the target amount of investment is not achieved, therefore an increase in margin entails a proportional increase in investment to approach the target amount.

For high values of margin (above the threshold), the target amount is achieved and an increase in margin does not necessary lead to a higher investment. The value of $\beta'_1 = \beta_1 + \Delta MAPU$ in specifications (2), where $\beta'_1 = 0.505 - 0.606 = -0.104$ and in specification (4), where $\beta'_1 = 0.478 - 0.526 = -0.048$, is very low (and negative), barely significant in specification (2) and not significant in specification (4). Only the specification (5) indicates a positive and significant coefficient $\beta'_1 = 0.478 - 0.331 = 0.147$ but this is just because we do not have taken into account the variable $MAPU * PMG$. In specifications (2) and (4), the coefficient of this variable, β'_2 , is positive and significant. This variable, indeed, captures all the impact of the variation of the margin. This means that, beyond the threshold, the impact of margin on investment is positive only if the Potential for market growth, PMG, is nonzero. As a result, when the market is fully covered, the margin has no impact on investment, as theoretically stated in section 3. However, when the potential for market growth is high, investment increases the market size and future profits, as shown in the margin equation. Thereby, an increase in margin leads to an increase in investment.

The figure below (figure.4) illustrates the relationship between margin and investment.

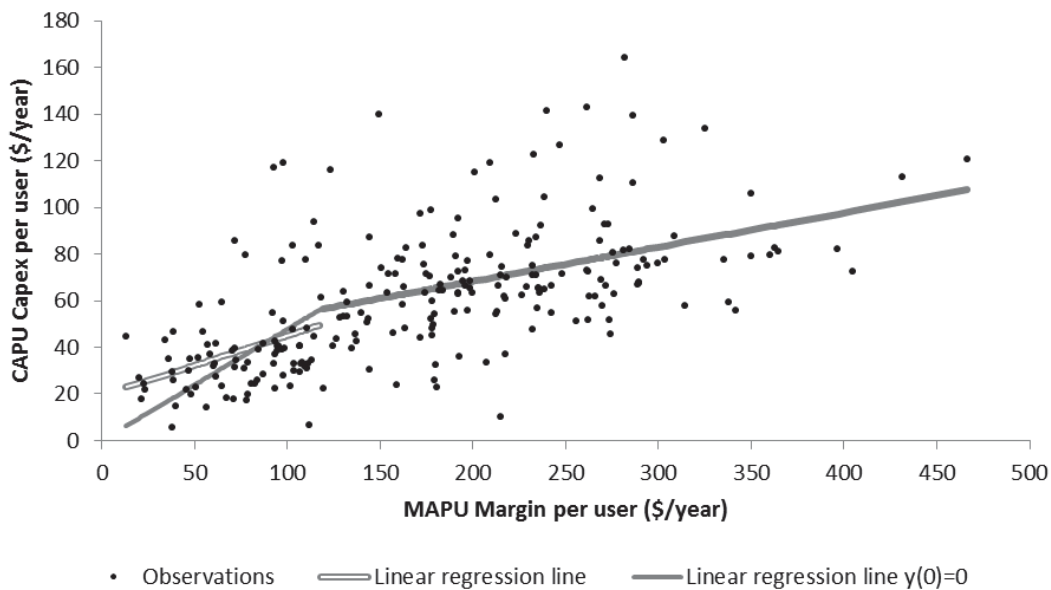


Figure.4: Relationship between Investment and margin

The linear regression lines on Figure 4, calculated when the 3 abnormal observations are removed, are quite similar to the theoretical Figure 2. Especially the “y (0) = 0” line where $\beta_0 = 0$. The break between low margin and high margin values appears clearly from both sides of the margin threshold (MAPU=117 \$/year). The main difference is the slope of the line due to the potential for market growth. It is noteworthy that when $\beta_0 = 0$ (y (0) =0 line), the two half-lines are continuous at the breaking point. This is not the case when $\beta_0 \neq 0$. Thus the hypothesis $\beta_0 = 0$ is consistent with the trend beyond the threshold. The fact that markets are neither fully covered nor perfectly symmetrical could explain the constant.

Investment behavior is different from either sides of the breaking threshold. Before the breaking threshold, margin is too low to achieve the target amount of investment. Thereby, in this case, an increase in margin results in a proportional increase in investment in order to approach the target amount. Beyond the breaking threshold, the target amount is achieved. An increase in margin does not result in an increase in investment if the market is not fully covered. When the market is fully covered, the target amount is achieved and the investment is no more linked to the margin as indicated by equation 4 in the theoretical framework. When the market is not fully covered, target amount depends on the margin. An increase in investment allows an increase in market size and profits, and therefore, margin is reinvested proportionally to the potential for market growth.

4.2.3 Impact of competition on investment

Considering that beyond the margin threshold the target amount is achieved, investment does not exceed this target amount. As a result, we consider that, in such case, CAPU equals the target amount. We will now test the impact of the other variables: (COMP, N and 3G+) on the target amount. Beyond the threshold MAPU>117 \$/year,

$$CAPU_{iy} = \beta_0 + \beta X_{iy} + \varepsilon_{iy} \quad (11)$$

With X, the vector of variables $X = \{MAPU, MAPU * PMG, COMP, N, 3G+\}$, and β the coefficients to be estimated. The results are presented in the following table (Table.4)

VARIABLES	CAPU (1)	CAPU (2)	CAPU (3)	CAPU (4)
COMP	58.16*** (21.45)	39.43** (17.36)	49.15*** (9.826)	35.18*** (8.036)
N	2.833*** (0.714)	2.760*** (0.574)	2.758*** (0.694)	2.724*** (0.558)
3G+	26.65*** (9.698)	33.62*** (7.829)	27.88*** (9.319)	34.21*** (7.515)
MAPU	-0.0177 (0.0659)	0.0129 (0.0532)	-0.0332 (0.0571)	0.00564 (0.0461)
MAPU*PMG	0.844*** (0.299)	0.776*** (0.240)	0.872*** (0.292)	0.789*** (0.235)
Constant	-7.950 (16.81)	-3.743 (13.53)		
Observations	158	156	158	156
R-squared	0.357	0.477	0.914	0.941

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table.4: Target amount of investment

Specifications (1) and (3) use all the 241 observations, specifications (2) and (3) removed the three abnormal observations. Specifications (1) and (2) use the constant term while specifications (3) and (4) do not.

Coefficients of competition *COMP* and number of firms *N* are positive and significant in all the specifications in table 4.

Competition has an ambiguous impact on investment. On the one hand, table 4 indicates that competition tends to increase; however, on the other hand, table 2 highlights that competition decreases margin.

The overall impact of competition on target amount seems to be positive provided the potential for market growth is not too high, because the variable *MAPU*, as in equation 10, is not significant. Although variable *MAPU*PMG* is positive and significant, its impact becomes negligible when market approach the full coverage.

However, when competition is fierce enough to reduce the margin below the threshold, then the target amount is no more achieved. In this case, margin is pushed below the threshold where investment is proportional to the margin. As a result, investment decreases.

In other words, competition has a positive impact on investment as long as the target amount can be reached; otherwise it has a negative impact.

4.2.4 Discussion

As we discussed in subsection 3.3, the target investment level is lower than the socially optimal level of investment, but is the highest amount that companies are encouraged to invest. Non-achievement of the target level thus means underinvestment and a decrease in consumer surplus and social welfare. A low margin may cause non-achievement of the target investment level. This could explain the inverted U relationship between investment and competition. As we have seen, competition and the number of companies have a positive impact on investment when the margin is sufficient to achieve the target investment level. However, they also have a negative impact on the margin. If this negative impact is strong enough to decrease the margin to a point below the level which makes it possible to achieve the target investment level, the overall impact may be negative. Otherwise the overall impact remains positive.

5 Conclusion and policy implications

Competition based on quality improvement leads to a target investment level which companies strive to achieve in order to maximize their profits. This target level is lower than the socially optimal level, meaning that the target level is, in social terms, the best level of investment that companies are encouraged to make. However, companies need to have adequate margins to achieve their target amounts. A lack of resources causes non-achievement of the target level and entails a decrease in technical progress, consumer surplus and welfare.

The potential for technical progress increases investment's impact on quality. The target level is thus even higher than the potential for technical progress. This potential is particularly high for information technologies and telecommunications, meaning

that the target investment level is particularly high and difficult to achieve. There are many examples where the target level is not achieved, not only in emerging countries where standards of living are low, but also in developed countries when price-based competition is too fierce.

There is a trade-off between competition based on quality improvement, which represents the dynamic side of competition, and competition based on pricing, which represents the static side of competition. These two types of competition can be seen as competitors. Welfare is maximized when the target investment level is exactly achieved. For a given potential for technical progress providing a given target investment level and thus a given level of dynamic competition, the static side of competition should be adjusted in order to allow achievement of the target level.

Regulatory and competition authorities in the sector should avoid underinvestment by ensuring that companies are able to achieve their target levels.

In terms of market tools, competition and entry have a positive impact on investment but only when companies can achieve their target levels, otherwise they may have a negative impact.

Appendix

List of countries:

Argentina 2004-2010; Australia 2005-2010; Austria 2002-2010; Belgium 2003-2010; Brazil 2002-2010; Canada 2002-2010; China 2005-2010; Colombia 2005-2010; Egypt 2006-2010; France 2003-2010; Germany 2002-2010; Hong-Kong 2002-2010; Hungary 2002-2010; Italy 2002-2010; Japan 2004-2010; Korea 2002-2010; Mexico 2003-2010; Netherland 2003-2010; Norway 2002-2010; Poland 2002-2010; Portugal 2002-2010; Russia 2002-2010; Singapore 2003-2010; South Africa 2002-2010; Spain 2004-2010; Sweden 2002-2010; Switzerland 2003-2008; Turkey 2003-2010; UK 2002-2010; USA 2002-2010.

Correlation Matrix:

Correlation matrix	<i>CAPU</i>	<i>MAPU</i>	<i>COMP</i>	<i>NF</i>	<i>IOA</i>	<i>PMG</i>	<i>3GT</i>	<i>DPOP</i>	<i>YEAR</i>	<i>GNICAP</i>
<i>CAPU</i>	1.000									
<i>MAPU</i>	0.505	1.000								
<i>COMP</i>	0.003	-0.314	1.000							
<i>NF</i>	0.119	-0.166	-0.087	1.000						
<i>IOA</i>	-0.068	-0.192	-0.155	0.190	1.000					
<i>PMG</i>	-0.114	-0.307	-0.027	0.096	0.416	1.000				
<i>3GT</i>	0.324	0.363	0.142	-0.119	-0.139	-0.443	1.000			
<i>DPOP</i>	-0.021	-0.038	0.138	-0.050	-0.211	-0.352	0.119	1.000		
<i>YEAR</i>	-0.084	0.075	0.033	-0.153	-0.021	-0.311	0.609	-0.002	1.000	
<i>GNICAP</i>	0.469	0.783	0.069	-0.148	-0.376	-0.457	0.447	0.227	0.136	1.000

Proof of equation (4):

$$\frac{d\Pi_i}{dI_i} = \frac{2}{Nt} \frac{(N-1)}{2N-1} \frac{dV}{dI_i} \left(t + \frac{(N-1)V(I_i) - \sum_{i \neq j} V(I_j)}{2N-1} \right) - \frac{1}{N} (1 + \rho)$$

If the market is symmetrical, $I_i = I_j = I$; in that case, $(N-1)V(I_i) = \sum_{i \neq j} V(I_j)$ and

$$\text{therefore: } \frac{d\Pi_i}{dI_i} = \frac{2}{N} \frac{(N-1)}{2N-1} \frac{dV(I)}{dI_i} - \frac{1}{N}(1+\rho)$$

The first order condition $\frac{d\Pi_i}{dI_i} = \frac{d\Pi_i}{dI} = 0$ leads to

$$\frac{dV(I^*)}{dI} = \frac{(1+\rho)(2N-1)}{2(N-1)} \text{ equation (4)}$$

Proof of equation (5) and (6):

There are N spokes and $\frac{N(N-1)}{2}$ different i,j pairs. There are q/N consumers on

each spoke or $2q/N$ customer for each pair. Each company appears in $(N-1)$ pairs.

Let us denote cs_{ij} the consumer surplus of the pair i,j . Total Consumer surplus is:

$$cs = \frac{N(N-1)}{2} \frac{2}{N} \frac{1}{(N-1)} cs_{ij} = cs_{ij}$$

$$cs_{ij} = \int_0^{x_{ij}} U_i dx + \int_{x_{ij}}^1 U_j dx$$

When market is symmetrical, $v_i = v_j = v$; $x_{ij} = 1/2$

$$cs = cs_{ij} q = \left(\int_0^{1/2} (v - c - t - tx) dx + \int_{1/2}^1 (v - c - 2t + tx) dx \right) = (v - c - \frac{5}{4}t)$$

Welfare is the sum of consumer surplus and industry profits.

In a symmetrical market, industry profits are $qt - I(1+\rho)$. Welfare is written:

$$w = (v - c - \frac{1}{4}t) - I(1+\rho)$$

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Is there a level of competition intensity that maximizes investment in the mobile telecommunications industry?*

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Preliminary version, comments are welcome

Abstract

This paper empirically assesses the causal impact of competition on investment in new technologies using firm level data from the mobile telecommunications industry. It finds an inverted-U relationship between the intensity of competition and investment. The investment maximizing intensity of competition stands at 63 percent plus or minus 6 percentage points at the 5% confidence level. This means that the maximal level of investment is reached when the operating profit represents 37 percent of total revenue. This result is robust across regions of World, notably Asia-Pacific, Western Europe and Africa. It is also robust to investment in the network quality. Moreover, it finds that the threat of entry reduces the incentive to invest in the mobile network and can explain 4 percentage points of the investment maximizing intensity of competition. Finally, this paper also shows that unlike the extensive investment, intensive investment; that is the ratio of the extensive investment over revenue, has a U-shaped relationship with the intensity of competition. It provides a simple theoretical model to show that these results can partly be explained by the size of innovation in the mobile telecommunications industry. The larger the size of innovation, the lower is the investment maximizing intensity of competition.

Keywords: Competition, Investment, Mobile Telecommunications.

JEL Classification: D21, D22, L13, L40.

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1 Introduction

The relationship between competition and investment is the topic of a large economic literature. Although the debate has been lively for many decades, no clear-cut conclusion has been reached so far. There are mainly two opposite views about the direction of the relation. The Schumpeterian view highlights that large firms in low concentrated markets are more likely to invest, and the school of Harvard's view highlights the virtues of competition that stimulates investment to escape competition. One of the significant contributions to this debate is the findings by Aghion, Bloom, Blundell, Griffith, and Howitt (2005) of an inverted-U relationship between competition and investment in R&D. While these findings raise a caution about the relevance of perfect competition as a policy objective, they do not identify the level of competition which maximizes investment, as this level may depend on each industry.

The goal of this paper is to assess empirically whether there is a level of competition intensity that maximizes investment in infrastructures and network quality within the mobile telecommunications industry. It takes advantage of the availability of firm level data on mobile network operators worldwide to identify the causal impact of the intensity of competition on investment. The intensity of competition is measured at the firm level as 1-Lerner index and investment is the quarterly expenditures in tangible and durable assets. The identification strategy stems from the cross-firms and cross-country differences in the intensity of competition due to the date of entry into the market and the number of frequency bands released by regulators.

It turns out that there is an inverted-U relationship between competition intensity and investment. That is, investment is maximal for an intermediate level of competition intensity between monopoly and perfect competition. The intermediate level of competition intensity that maximizes investment is found at 63 percent. This means that the maximal level of extensive investment is reached when the operating profit of a firm represents 37 percent of its revenue. Below this level, more competition decreases investment. The inverted-U is valid for different regions of the World, with an investment maximizing intensity of competition reached at 65 percent for Asia-Pacific, 66 percent for Western Europe, and 69 percent for Africa. It is also valid for investment in the network quality. Here the quality is measured by the download speed of the mobile network. The intensity of competition which maximizes investment in network quality is found at 71 percent.

Moreover, our results shows that a part of the downward sloping part of the rela-

tionship between the intensity of competition and investment stems from the threat of entry, measured by the number of planned entries into the market. More specifically, the investment maximizing intensity of competition is 4 percentage points higher when we control for the number of planned entries into the market. The point estimate of this latter variable is negative and significant, implying that the threat of entry into the market reduces the incentive for investment in the mobile network infrastructure. Finally, we also find that unlike the extensive investment, the intensive investment; that is the ratio of investment over revenue, has a U-shaped relationship with the intensity of competition. This is because the revenue of the mobile network operators is maximized at the investment maximizing intensity of competition.

Nonetheless, this empirical evidence cannot be generalized to other sectors. Actually, the mobile telecommunications industry is characterized, like the whole information technologies sector, by a very high rate of technological progress, more than 20% for more than a century according to (Koh and Magee, 2006). This high rate of technological progress implies that the size of innovation is large in the mobile telecommunications industry. To highlight the role of the size of innovation in driving the shape of the relationship, we propose a theoretical model in which investment in a new technology generates a stream of monopoly profit for the investing firm over a certain period. However, this period is reduced by competition. Technological progress shifts downward the marginal cost of production. Provided that the size of innovation is large enough, the model yields a non-monotonous relationship, particularly an inverted-U, between competition and investment, consistently with the empirical findings for the mobile industry. In addition, the size of innovation reduces the investment maximizing intensity of competition. More generally, we show that the inversion of the curve is more likely to occur under high technological progress as observed in the mobile telecommunications industry.

The rest of the paper is organized as follows. Section 2 provides a summary of the related literature, section 3 describes the industry, the dataset and the variables, section 4 presents the empirical evidence and section 5 provides a theoretical framework that gives the insight of the inverted-U shaped curve for a highly innovative industry. The final section discusses the results and provides some concluding remarks.

2 Related Literature

Most of the papers dealing with the relationship between competition and investment focus on investment in RD (innovation). This feature of the literature differs from this paper which rather focuses on investment in quality improving technologies and infrastructures. However, as emphasized by Mathis and (Mathis and Sand-Zantman, 2014), once we abstract from property rights issues, there is no difference between investment in RD and in other types of assets. Therefore, this literature review shall mainly rely on the findings from the literature on the impact of competition on innovation.

Actually, as reviewed by (De Bondt and Vandekerckhove, 2012), the relationship between competition and investment is a long standing debate owing to the critical role of investment for economic growth. Two conflicting views reside at the core of this debate. On the one hand, the Schumpeterian view pioneered by Schumpeter (1942) points out the role of firm size, financial constraints and more specifically the incentive of the monopoly to invest more than a firm in a competitive market. This latter is driven by the efficiency effect as epitomized by the paper of Gilbert and Newbery (1982). On the other hand, the Arrow's view developed by Arrow (1962) emphasizes that the monopolist has less incentive to innovate due to what Tirole (1988) terms the replacement effect.

Several theoretical and empirical papers have been proposed to settle this debate. From the abundant theoretical literature, it turns out that the relationship between competition and investment can be of any type (Schmutzler, 2013). It actually depends on the theoretical parameterization of competition, the mode of competition and the nature of investment. This conclusion is strongly supported by the multitude and somehow contradictory empirical findings. For instance, using data of British firms, Blundell, Griffith, and Van Reenen (1999) found that larger firms innovate more; while firms in more concentrated markets innovate less. Likewise, Kraft (1989) found a negative relationship between the number of competitors and the percentage of sales attributable to new products, whereas Nickell (1996) identified a positive relationship between competition and innovation for British firms. In his paper, competition is measured by the number of competitors and the Lerner index, and innovation is measured by productivity and productivity growth of British firms.

In this unsettled debate, the paper by Aghion, Bloom, Blundell, Griffith, and Howitt (2005) provided both a theoretical and empirical evidence of an inverted-U relationship between competition and innovation. In their paper, the measure of competition

is based on the Lerner index and innovation is measured by the citations weighted patents counts of British firms between 1968 and 1997. The underlying mechanism of the inverted-U stems from the reconciliation between the escape-competition effect, corresponding to the Arrow's view, and the Schumpeterian effect whereby laggards firms have no incentive to invest due to a lower incremental profit from catching up with the leader. The Arrow's effect plays out at lower level of competition; whereas the Schumpeterian effect dominates above a certain level of competition; yielding an inverted-U relationship between competition and investment. The central force driving the inverted-U relationship is the technological gap between firms within each industry. These findings have been confirmed by several subsequent empirical papers ; though they emphasize their limitation in terms of causal identification.¹

Another issue investigated in the literature is the impact of the threat of entry on innovation by the incumbent firms like in Aghion, Blundell, Griffith, Howitt, and Prantl (2009). This paper shows that the threat of entry raises the incumbent's investment in innovation in those industries which are at the technological frontier. In industries lagging behind on the contrary, entry threat reduces investment in innovation.

Currently, there are two important issues that emerge from the literature. First, the lack of robustness in the theoretical results requires a focus on specific industries to identify the actual level of competition which maximizes investment. Second, the interaction between competition and the technological gap across firms play an important role in determining the impact of competition on investment. Both of these issues pose a great deal of challenges to the empirical identification of the nature of the relationship between competition and investment. To the best of our knowledge, there is so far no empirical paper tackling these two issues, probably due to the lack of the required data.

Indeed, most of the cross-industries studies are plagued with the unobserved difference in the presence of basic scientific knowledge (technological opportunities) across industries (Kamien and Schwartz, 1975). To the extent that technological opportunities drive both investment and competition, the empirical estimation of the relationship between competition and investment is biased by the difference in technological opportunities across industries. In addition, the need to focus on specific industries requires panel data on firms from a given industries across several countries. Although many firm level databases have been assembled very recently, they are still hardly accessible to researchers. When they are, the issues of unobserved

¹See the special issue of the Journal of Industry, Competition and Trade for a list of papers

efficiency and collusion, as well as the reverse causality running from investment to competition require additional information to implement a robust identification strategy.

In this study, we take advantage of the availability of firm level data on mobile network operators (MNO) and the specific role of spectrum policy in determining the intensity of competition to identify the causal impact of competition on investment. The empirical evidence is supported by a simple theoretical model that yields the inverted-U and suggests the size of innovation as one of the drivers of the inverted-U relationship.

3 Background, Dataset and Variables

This section presents the key features that make the mobile telecommunications industry suitable for the identification of the impact of competition on investment. It also presents the available information and the main variables that will be used for the estimation.

3.1 Industry background: The role of spectrum policy and technological progress

There are mainly two features that make the mobile telecommunications industry suitable for identifying the causal impact of competition on investment. First, spectrum policy strongly determines the number of firms and the technology that can be adopted within the market. As a consequence, it affects the intensity of competition in the mobile telecommunications market.

Indeed, electromagnetic spectrum is a key input for the provision of mobile telecommunications services. However, due to their properties in terms of coverage and propagation, the range of spectrum bands that can be used for communications purposes is limited. In addition, there is a risk of interference when similar or neighboring frequency bands are used for different communication purposes. As a result, the electromagnetic spectrum is managed by the government.²

²At the global scale, the World Radio-communication Conference (WRC) allocates the range of frequency to each region of the World. Thereafter, each country in a given region sets up a government agency which assigns the allocated frequency range to radio-navigation, maritime mobile, broadcasting and land mobile telecommunications.

So often, the governments release additional frequency bands according to their own assessment of the intensity of competition.³ Each frequency band is split into several spectrum licenses according to the number of network operators that the government is willing to accommodate in the market. In Europe for instance, the 2100 MHz frequency band was split into four spectrum licenses in some markets with initially three operators in order to allow the entry of a fourth operator. Unlike the number of spectrum licenses, the number of frequency bands allocated by the government does not depend on the firms' behavior. It rather directly affects the intensity of competition and the number of firms in the market. As its allocation depends on the assessment of competition by the government, pro-competitive governments are much more likely to release more frequency bands into the mobile telecommunication market at an earlier date. The release of the frequency bands lowers the legal barriers to entry into the industry.

Another reason why the governments may decide to grant additional frequency bands is to respond to the demand for larger bandwidth as new applications appear and require faster data transmission. This is currently the case in most of the developing countries where an increasing traffic over the internet is generated on mobile devices (Pepper, 2013). Frequency bands allocated under these circumstances can generate more competition in the market. As the demand for larger bandwidth is driven by technological progress, which can be viewed as exogenous at a country level, the number of frequency bands is an exogenous shifter of competition in the mobile market.

It turns out that the intensity of competition in the mobile telecommunications industry is partly driven by the allocation of frequency bands by the governments because of their own assessment of competition and the rate of technological progress. This feature makes the number of frequency bands allocated before a given year a good instrumental variable for the intensity of competition in the mobile telecommunication market.⁴ In addition to the number of frequency bands, the spectrum management policy determines exogenously the exact year of entry of a firm into the market: network operators decide upon their entry into the market and the year of entry is determined by the government through the process of granting the spectrum license.

The second feature of the mobile telecommunications industry is the significant rate

³As of December 2012 at the global scale, the following frequency bands have been assigned to mobile network operators: 1500, 2100, 800, 1600, 1700, 1900, 2500, 2600, 1800, 2300, 3400, 3500, 410, 450, 700 and 850 MHz.

⁴The validity of the instrumental variable is presented in the result section.

of technological progress which drives regular investment in the adoption of new technologies (Koh and Magee, 2006). Each year, equipment providers innovate and release new technologies of mobile telecommunications on the market. The new technology can be a radical change in the provision of telecommunications services or a mere improvement in the transmission of traffic over the network. Radical innovations commonly referred to as a new generations of network, are characterized by a shift in the speed or the protocol of data transmission. So far, there have been four overlapping generations of mobile telecommunications networks (Analog, 2G, 3G and 4G). The overall outcome is a continuous progression of performances.

One consequence of this technological progress is that mobile network operators need to invest regularly in order to upgrade the quality of their network and keep in the race for technology adoption. Another consequence stems from the fact that the new technology is not available in every region for historical reasons owing to their initial level of development. Therefore, a comparison between these regions can provide an insight into the role of technological progress in determining the impact of competition on investment in new technologies.

3.2 Description of the dataset

We build a new dataset by aggregating information from several sources. The first source is the World Cellular Information Services (WCIS) database provided by *Ovum*. This database provides quarterly accounting information on mobile network operators worldwide. This information includes firms' revenue, profit, investment, and their purchase of frequency licenses.

This information is complemented by data on the fixed access lines market share for those mobile networks operators that also operate a fixed network. In order to account for difference across markets in terms of fixed network penetration and regulation, the dataset also include data on household penetration of fixed telephony lines and the share of unbundled local loop access lines. Data on the fixed network were retrieved from the World Broadband Information Service database managed by *Ovum*.

Additional information on the year of entry, merger or exit as well as the year of future entries were also added to the database from the Wireless Intelligence online database. We were also able to obtain data on the characteristics of the mobile networks of each MNOs including the date of launch, the download and upload

speed, as well as the list of mobile virtual network operators that it hosts.

Finally we also use the World Development Indicator online database managed by the World Bank to include data on the population density and the size of the population between 15 and 64 years old (working-age population). These data will be useful to control for differences in the cost of network deployment and the size of the markets which are critical for the investment in the mobile telecommunications industry.

The final dataset is cleaned from negative profits and investment as well as extreme values. Under the assumption that the distribution of the intensity of competition should be normal, we define a confidence interval as the sample median intensity of competition plus or minus twice the sample standard deviation. Then observations outside this confidence interval are deemed extreme values. In the end, we obtain an unbalanced panel of 240 firms from 119 countries observed from 2000 to 2014. As a result the main estimation sample contains 4695 observations.

3.3 Description of the Variables

The summary statistics of the main variables are presented in the table 1 in appendix. From these variables, we build the investment both at firm and market levels using the firm's capital expenditures (CAPEX). The CAPEX includes the expenditures in the acquisition of tangible (fixed) assets, the expenditures in the maintenance of the existing tangible assets with a useful lifetime that extends beyond the taxable year, and the expenditures for the purchase of spectrum licenses. As we focus on investment in new technologies, only the first component of the CAPEX, related to the acquisition of tangible asset, is interesting for the estimation. However, we do not observe the expenditures in the maintenance of the existing assets or the expenditures in the purchase of spectrum licenses. One could assign an arbitrary share of the CAPEX to the maintenance expenditures in order to get rid of this component. Under the assumption that this share is the same for all firms, the econometric estimation of the impact of competition on investment would be scaled up by this percentage. In addition, if we use the logarithm of the investment in the regression, the constant share of the CAPEX dedicated to the maintenance shall only affects the constant of the econometric model. Regarding the expenditures in the purchase of spectrum licenses, we could exclude from the sample those observations which correspond to the purchase of license or include into the regression a dummy variable capturing the effect of the purchase of licenses on the CAPEX. In

the following, we use the logarithm of the CAPEX as a measure of investment and include dummy variables capturing the effect of the purchase of licenses.⁵

Regarding the intensity of competition, it is built at the firm level based on the Lerner index of monopoly power. Its computation requires information on prices and marginal cost which are not available. Under the assumption of constant marginal cost of production, the ratio between a firm's operating profit and its total revenue is a valid measure of the Lerner index of monopoly power. According to the methodology and definition guide accompanying the WCIS database, the operating profit is measured by the earnings before interest, tax, depreciation and amortization (EBITDA). It is the difference between total revenues and operating expenditures, excluding portions arising through tax, interest payment, depreciation and amortization of assets. The total revenue is the sum of revenue generated through the provision of wireless communications services during a year and the revenue generated from the sales of mobile devices or other equipment sold by the operator during the year. The revenue from the provision of wireless communications services includes revenue from voice and data services over the mobile network, roaming charges, revenue from international direct dialing and interconnection revenue.⁶

If $Comp_i$ denotes the intensity of competition experienced by the firm i , the following equation provides the formula for computing the intensity of competition:

$$Comp_i = 1 - \frac{Ebitda_i}{Revenue_i}$$

In line with the discussion on the role of spectrum policy and technological progress in determining the intensity of competition in the mobile telecommunications industry, we build the number of frequency bands allocated to mobile communications services before a given year for all the 119 countries in our sample. Here we focus on the number of frequency bands but not the number of spectrum licenses to avoid correlation with the number of firms within the market. Actually, the number of licenses is as endogenous as the number of firms within the market; whereas for a given number of spectrum licenses, firms in countries that released more frequency bands should be expected to experience higher intensity of competition. This ad-

⁵We obtain similar results when we exclude from the sample, observations corresponding to the purchase of licenses. However, the instruments are less strong due to the fall in the sample size.

⁶Actually, the service revenue is a better measurement of the revenue as it only includes revenue from the provision of retail access to the mobile network. However, based on data from firms for which we have both total and service revenue, we found that the revenue from the sales of mobile devices and equipment accounts for less than 1 percent of the total revenue.

ditional intensity of competition is exogenous with respect to investment as it is generally driven by government seeking more revenue or the exogenous rate of technological progress in the mobile industry. The number of frequency bands allocated before a given year is a cumulated variable. When new frequency bands are released for mobile communications in a country, there are added up to the number of frequency bands released before that year to make up the variable. It actually characterizes the extent of the regulatory barriers to entry into the mobile telecommunications industry. The higher the number of frequency bands released before a given year, the lower the barrier to entry into the industry.

To ensure comparability across markets regarding the joint determinants of investment in new mobile network technologies and the intensity of competition, we define the logarithm of the size of the working age population and the population density as proxies for the market size and the cost of network deployment respectively. We also build a dummy variable characterizing country with local loop unbundling regulation when there is a fixed network, and a set of regional dummy variables to capture regions fixed effects such as the difference in the standards of living or the willingness to pay for mobile communications services across markets. Similarly at the firm level, we build dummy variables characterizing respectively an MNO which is also the incumbent fixed network operator, an MNO which hosts an MVNO, and an MNO which has purchased spectrum license during a given quarter.

4 Empirical Evidence

4.1 Descriptive statistics and Non-parametric estimation

Figure 2 in appendix presents the scatter plot of the relationship between the intensity of competition and investment. This figure exhibits an inverted-U relationship between the intensity of competition and the logarithm of investment; as evidenced by the quadratic fit from the data. The inverted-U observed from this figure results from the parametric assumption about a quadratic relationship between the intensity of competition and investment.

In order to identify the actual relationship in the data without making any parametric assumption, we proceed by estimating the non-parametric relationship based on a local polynomial smoothing and a locally weighted scatter plot smoothing. The results of these estimation are presented in figures 3 and 4 respectively. In

both estimations, we partial-out the effect of the size of the market; that is we use the residuals plus the constant from the regressions of investment and competition on the size of the working-age population. It turns out that there is indeed an inverted-U relationship between the intensity of competition and the investment in new technologies.

The descriptive statistics provided by figures 2, 3 and 4 provide some insights into the potential impact of the intensity of competition on investment. However, they are not sufficient to draw any causal impact of competition on investment. They are actually plagued with issues related to omitted variables biases and reverse causality. Figures 5 and 6 in appendix provide evidence about the exogenous drivers of the intensity of competition that will be used to identify its causal impact on investment. The first figure presents a positive relationship between the number of frequency bands released and the intensity of competition within a market. The second figure shows that firms that enter the market later face higher intensity of competition on average. Altogether, these figures show that the regulation of entry and access to spectrum drive the intensity of competition experienced by MNOs.

4.2 Econometric models and identification strategies

In order to estimate the causal impact of the intensity of competition on investment, we adopt a two-stage structural approach based on reduced-form models. In the first stage, competition is modeled as a linear function of the regulatory variables identified in the background section. Then, in a second stage, investment is expressed as a function of competition. The coefficients of the resulting models have been estimated by implementing an instrumental variable approach based on the Generalized Method of Moment (GMM) (Hansen, 1982). Typically, the intensity of competition and its square are deemed endogenous and instrumented by the cumulated number of frequency bands and the year of entry into the market. All estimations correct for arbitrary heteroskedasticity and autocorrelation using the Bartet Kernel of bandwidth 2. We implement the weak instruments test using the instrumental variables Stata routine proposed by Baum, Schaffer, and Stillman (2007). The Kelibergen-Paap Wald rank F-statistics are compared to the critical values tabulated by Stock and Yogo (2002) to test the weakness of the instruments. The details of the modeling are presented as follow:

Across similar markets and firms, the intensity of competition is determined by the cumulated number of frequency bands released and the year of entry allowed by

the regulator. The cumulated number of frequency bands acts as a proxy for the barrier to entry into the mobile telecommunications market. The larger the number of cumulated frequency bands, the lower is the barrier to entry and the fiercer is the competition within the market. Similarly, firms that enter later into the market face more competitors, and therefore experience higher intensity of competition. More formally, the intensity of competition is linearly related to these exogenous competition shifters as:

$$Comp_{iq} = \alpha_0 + \alpha_1 freq_{iq} + \alpha_2 entry_i + \alpha X_q + \varepsilon_{iq} \quad (1a)$$

$$Comp_{iq}^2 = \beta_0 + \beta_1 freq_{iq} + \beta_2 entry_i + \beta X_q + \epsilon_{iq} \quad (1b)$$

These two equations determine the exogenous change in competition and represent the first-stage of the estimation of the impact of the intensity of competition on investment in new technologies. $Comp_{iq}$ is the intensity of competition experienced by firm i during the quarter q . $freq_{iq}$ is the cumulated number of frequency bands released in the market of firm i before the quarter q (included). $entry_{iq}$ is the year of entry of firm i into the market. Finally, X_q is a vector of control variables to ensure similarities across markets and firms. It includes the logarithm of the working-age population, the logarithm of the population density, four dummies characterizing markets with local loop unbundling, incumbent fixed network operators, firms hosting an MVNOs and the purchase of spectrum license. The vector X_q also includes a quarterly trend and regional fixed effects.

The second stage of the estimation considers various outcomes to measure the investment in new technologies, namely the extensive investment, the extensive investment in network quality and the intensive investment. Given the results of the non-parametric estimation, we postulate a quadratic relationship between the intensity of competition and the investment.

The following equation estimates the impact of the intensity of competition on the extensive investment:

$$lninv_{iq} = \gamma_0 + \gamma_1 Comp_{iq} + \gamma_2 Comp_{iq}^2 + \gamma X_q + \mu_{iq} \quad (2)$$

Where $lninv_{iq}$ is the logarithm of investment of firm i during quarter q , and μ_{iq} are the residuals of model.

The impact of the intensity of competition on investment in new technologies is estimated through the coefficients γ_1 and γ_2 . If the inverted-U relationship observed from the descriptive statistics is valid, these coefficients should be statistically significant and respectively positive and negative. In this case, the investment maximizing intensity of competition (IMIC) is estimated as:

$$IMIC = -\frac{\gamma_1}{2\gamma_2}$$

The confidence interval of the investment maximizing intensity of competition is estimated using the delta method.⁷ An estimation algorithm is developed in Stata by Hole (2007).

We investigate the heterogeneous impact of competition on investment by estimating equation (2) on the sub-samples of regional observations. In particular, the estimations are based on the sub-samples of observations from Asia-Pacific, Western Europe and Africa. In the other regions, there were not sufficient observations to make the statistical inference, or the power of the instruments is not strong enough. The following equations have been estimated to examine the heterogeneous effects of competition on investment.

$$\ln inv_{iq} = \gamma_0 + \gamma_1 Comp_{iq} + \gamma_2 Comp_{iq}^2 + \gamma X'_q + \mu_{iq} \quad (3a)$$

$$\ln inv_{iq} = \gamma_0 + \gamma_1 Comp_{iq} + \gamma_2 Comp_{iq}^2 + \gamma X'_q + \mu_{iq} \quad (3b)$$

$$\ln inv_{iq} = \gamma_0 + \gamma_1 Comp_{iq} + \gamma_2 Comp_{iq}^2 + \gamma X'_q + \mu_{iq} \quad (3c)$$

Equations (3a), (3b) and (3c) have been estimated on the sub-sample of observations from Asia-Pacific, Western-Europe and Africa respectively. The main difference between these equations and the equation 2 is the set of controls X'_q which no longer includes regional dummies.

To disentangle between investment in the extension of the network and the investment in upgrading the quality of the network through the adoption of new technologies, we also estimate the model (2) above but replace the logarithm of investment by the logarithm of the predicted investment in new technologies. This latter results from the predicted values of the linear regression of the capital expenditures

⁷Typically, the delta method linearizes an estimator using the Taylor expansion around its mean in order to compute its variance. See Oehlert (1992) for details.

on the maximum download speed allowed by the mobile networks of each network operator.⁸ If $lninvtech_{iq}$ the predicted investment in new technologies, the model then writes:

$$lninvtech_{iq} = \gamma_0 + \gamma_1 Comp_{iq} + \gamma_2 Comp_{iq}^2 + \gamma X_q + \mu_{iq} \quad (4)$$

One of the hypotheses emphasized in the literature to explain the downward sloping part of the inverted-U is the negative impact of the threat of entry on investment. In order to test this hypothesis, we estimate the following model:

$$lninv_{iq} = \gamma_0 + \gamma_1 Comp_{iq} + \gamma_2 Comp_{iq}^2 + \lambda E[\xi_{iq}/Comp_{iq}] + \gamma X_q + \mu_{iq} \quad (5)$$

$E[\xi_{iq}/Comp_{iq}]$ is the threat of entry given the current intensity of competition. In the econometric estimation, we use the number of entries planned, as of the last quarter of observation (Q1 of 2014), as a proxy for the threat of entry.

On top of looking at the extensive investment, one can also be interested as in (Vives, 2008) in identifying the impact of the intensity of competition on the intensive investment; that is the ratio of investment over revenue. The following equation presents the model to be estimated for that purpose:

$$\frac{capex_{iq}}{revenue_{iq}} = \delta_0 + \delta_1 Comp_{iq} + \delta_2 Comp_{iq}^2 + \delta X_q + \mu_{iq} \quad (6)$$

4.3 Results

The results of the estimation of the models (1a) and (1b) are presented in the first two columns of table 3. As suggested by the descriptive statistics, they confirm that the regulation affects the intensity of competition experienced by firms in the market. More specifically, the release of an additional frequency bands is predicted to increase the intensity of competition by 0.1 percentage point. Likewise, entering into the market a year later raises the intensity of competition experienced by a firm by 0.4 percentage point. These effects are statistically significant at 1% level.

The effect of this change in competition, as predicted by regulation, on the investment is estimated from model (2). The results of this estimation are presented in

⁸The download speed is nil when the best available network is 2G.

the first column of table 4. The sign and significance of the point estimates of the competition variables indicate that there is an inverted-U relationship between competition and investment in the mobile telecommunications industry. More precisely, as long as the intensity of competition is below 63 percent, an increase in the intensity of competition raises investment. Above this level, any further increase in the intensity of competition decreases investment. For instance, 1 percentage point increase in the intensity of competition raises investment by 7.2 percent at the first quartile of the intensity of competition (53%); but decreases investment by 6.7 percent at the third quartile of the intensity of competition (72%). The 95 percent level confidence interval of the investment maximizing intensity of competition (*IMIC*) lies between 57 and 69 percent.

The heterogeneous impact of the intensity of competition on investment is estimated from models (3a), (3b) and (3c). These models are used to estimate the impact of the intensity of competition on investment respectively in Asia-Pacific, Western Europe and Africa. The results are presented in the corresponding columns of table 4. They show that the inverted-U relationship between the intensity of competition and investment still holds in these three regions. However, there are some differences with respect to the *IMIC* and the slope of inverted-U curves.

Indeed, not only is the *IMIC* higher in these regions than in the whole World; but also it is higher in those regions which are still extending their network coverage. This is the case for instance in Africa, where the penetration rates of both the 2G and 3G network are still very low at 63 and 9 percent respectively (See figures 7 and 8). Likewise, the *IMIC* is slightly higher in Western Europe where the coverage of the 3G network is under way. These results suggest that the relationship between the intensity of competition and investment tends to be monotonously increasing in absence of technological progress. In other words, the rate of technological progress is potentially one of the drivers of the *IMIC* : the lower the rate, the higher the *IMIC*. This statement will be further investigated in a theoretical model in next section.

In addition, on the one hand, at the first quartile of the intensity of competition, a further increase by 1 percentage point raises investment by 17.8 percent in Asia-Pacific, 6.2 percent in Western Europe and 7.1 percent in Africa. On the other hand, at the third quartile of the intensity of competition, the effect of the same increase in competition decreases investment by 10 percent in Asia-Pacific, 2.7 percent in Western Europe and 1.5 percent in Africa. Thus, the slope of the inverted-U curve is steeper in Asia-Pacific than in the other two regions.

As expected, the capital expenditures is on average 12 percent higher when a firm purchases frequency licenses during a quarter (column (2) of table 4). While this effect extracts the effect of the purchase of licenses from the estimated impact of the intensity of competition on investment, it does not help disentangle between the effects on the investment in network extension from the effect on the investment in upgrading the quality of the network through the adoption of new technologies. The estimation results of the model (4) presented in the corresponding column of table 4 provide an insight into the impact of the intensity of competition on the investment in network quality. They show that there is also an inverted-U relationship between the investment in the quality of the network and the intensity of competition. However, the level of the *IMIC* is 8 percentage higher compared with the level obtained with the overall investment in both the infrastructure and the quality of the network. With a probability of 95 percent, the *IMIC* of the investment in the network quality is comprised between 66 and 76 percent; with a point estimate at 71 percent. This result suggests that investment in network extension falls at lower level of the intensity of competition compared to investment in network quality.

The impact of the threat of entry on investment is estimated from model (5) and the results are presented in the corresponding column of table 4. It turns out that the threat of entry, as measured by the number of planned entries, has a negative impact on investment. That is, the higher the number of planned entries, the lower the current level investment. In terms of magnitude, the planning of an additional entry into the market lowers investment by 4 percent on average. One consequence of this effect is that the slope of the inverted-U curve is underestimated below the *IMIC* and overestimated above the *IMIC*. For instance, a one percentage point increase in the intensity of competition raises investment by 13.8 percent at the first quartile but decreases investment by 5.2 percent at the third quartile. Compared to the prediction from the model (2), the estimated impact was underestimated (7.2 percent) at the first quartile and overestimated (6.7 percent) at the third quartile. More interestingly, the *IMIC* turns out to be 4 percentage points higher when we control for the effect of the threat of entry. This means that the downward sloping part of the inverted-U curve is partly driven by the threat of entry into the market. These results also hold for the investment in network quality. Using the framework provided by Aghion, Blundell, Griffith, Howitt, and Prantl (2009), we can explain this result by the fact that entry in the mobile telecommunications industry is made by technologically advanced firms. However in the meantime, the incumbent firms mostly still rely on the old technology, reducing their incremental

rent from investment in the new technologies.

Regarding the impact of the intensity of competition on the intensive investment, the results of the estimation of the model (6) are presented in the last column of table 4. Contrary to the impact of the intensity of competition on the extensive investment, we find a U-shaped relationship between the intensity of competition and investment. Though the intensive investment minimizing intensity of competition is slightly higher than the *IMIC*, the confidence interval is fully included in the confidence interval of the *IMIC*. Actually, the U-shaped stems from the fact that firm's revenue is maximized at the similar level as the extensive investment.⁹ As a result, the intensive investment, as the ratio of the extensive investment over revenue, is minimized at similar intensity of competition. The similarity between the relationship between competition and investment and the relationship between competition and revenue is due to the strong and positive correlation between investment and revenue. However, we do not know whether this correlation stems from a causal impact of investment on revenue and particularly how investment affects prices and the quantity of output supplied by firms. The answer to this question has implications for the social welfare effect of the investment.

The set of controls provide some descriptive statistics that characterizes investment in the mobile telecommunications networks. The size of the market as measured by the logarithm of the working age population is positively correlated with both the extensive and the intensive investment. Interestingly, it does not affect the investment in the network quality. The cost of network deployment as proxied by the logarithm of population density is positively correlated with investment. The higher is the population density, the lower is the cost of network deployment and the lower is the capital expenditures (investment). However, the sign of this correlation depends on the regions. For instance, it is rather negative in Western Europe; that is investment is lower in Western Europe countries with lower density.

Local loop unbundling has no effect on the total investment; but negatively affects investment in the quality of the mobile network. This latter effect is contradictory of the findings by Nardotto, Valletti, and Verboven (2012) of the effect of LLU on the quality of the fixed broadband in the UK. Actually, countries without LLU regulation are mostly those in which the fixed network is less developed. Thus the deployment of mobile network with higher download speed is more necessary in these countries. This is potentially the reason why investment in mobile network quality

⁹The estimation results of the impact of the intensity of competition on revenue are available upon request.

is lower in countries with LLU regulation.

The incumbent fixed network operators, on average invest more than the other MNOs, particularly in Asia-Pacific and in Western Europe. The result is still valid for the investment in the quality of the mobile network in Asia-Pacific and in Western Europe. The increase in the point estimate of the dummy variable characterizing FNO from 0.17 to 0.36 and its significance in model (5), suggests that the incumbent FNO's investment in mobile network is much more negatively affected by the threat of entry into the market. Furthermore, the incumbent FNO has lower intensive investment than the other firms mainly due to economies of scale.

The point estimate of the dummy variable characterizing Mobile network operators hosting virtual operators (MVNOs) is positive, meaning that they invest more than the other MNOs which do not host any virtual operators. However, this effect is no longer significant when we control for the threat of entry in model (5) following a fall in the point estimate from 0.25 to 0.13; the standard error being roughly the same. Therefore, the omission of the effect of the threat of entry overestimates the effect hosting an MVNO. In other words, MNOs that host MVNOs are less affected by the threat of entry compared to the other firms.

Finally, the point estimates of the quarterly trend variable suggest that over the period of this study, both extensive and intensive investment have been declining particularly in Asia-Pacific and in Western Europe, due to the increasing network coverage. On the contrary, extensive investment has been increasing so far in Africa, as a result of lower penetration of mobile network. Interestingly, investment in mobile network quality has been increasing at the global scale.

5 A theoretical model to explain the role of the size of innovation in driving the inverted-U shaped

In this section, we present a simple theoretical model to show the role of the potential for technological progress in driving the inverted U shaped relationship between competition and investment. This potential for technical progress is not a parameter of the econometric model that we have tested because our dataset only consider the mobile market where all firms have roughly access to the same technologies. As a result, there is not enough difference between firms or countries to test it as one of the underlying mechanism of the inverted-U. However, technological progress is

particularly high in mobile telecommunication sector. Koh and Magee (2006) found a 20 to 30 percent rate of technological progress for information technologies for more than a century. This is far above most of other sectors like energy where technological progress is close to 6 percent, and far above the rate of global productivity growth often under 5 percent. This is probably one of the reasons why the relationship between competition and investment is inverted U-shaped in mobile telecommunication industry.

In the literature, the main model rationalizing the inverted-U is the one provided by Aghion, Bloom, Blundell, Griffith, and Howitt (2005) (ABBGH). This model does not help explaining our empirical evidence as it is derived from an endogenous growth model. It is therefore a general equilibrium model in which the main feature driving the inverted-U is the technological gap between firms within the industries. In addition, when the technology is normalized and available to all firms within an industry, there is hardly a technological gap between them.

This model encloses both the escape-competition and the Schumpeterian effects like in the ABBGH's model. However, while the modeling of the escape competition effect is alike, the Schumpeterian effect, which decreases the incentive to invest with the intensity of competition, is modeled as a reduction in the duration over which a first mover enjoys its investment. This is not the same as in the ABBGH model, whereby the Schumpeterian effect is driven by the technological gap. By doing so, we are able to emphasize the technological progress or the size of innovation as the main driver of the inverted-U relationship within an industry.

5.1 Settings of the model

Consider a symmetric Bertrand duopoly with differentiated goods, produced at constant marginal cost c . The differentiation parameter $\theta \in [0, 1]$ stands for the intensity of competition. When $\theta = 0$ the goods are independent and each firm enjoys a monopoly over its product. When $\theta = 1$ goods are perfect substitutes, in which case the Bertrand competition yields the perfect competition outcome. Typically, an increase in θ implies a rise in competition.

We consider an infinite horizon over which innovation occurs once. This horizon is split into three periods during which firms first invest and then compete in the product market.

Period 0: Symmetric market

During this period there is no innovation and both firms incur the marginal cost \bar{c} and earn the duopoly profit $\pi^d(\bar{c}; \theta)$.

Period 1: Innovation and the first mover's investment

At the beginning of period 1, an exogenous innovation occurs; providing a new technology which is available to both firms. The cost of this technology is decreasing over time and investment in the new technology reduces the marginal cost of production from \bar{c} to \underline{c} , with $\bar{c} > \underline{c}$.

Given the innovation, one of the firms invests in the new technology; this is the first-mover. Then, they both compete in price to supply the differentiated good until the end of this period.

During this period, the reduced form of the profit of the first mover writes: $\pi^1(\underline{c}; \theta)$ and the profit of the second firm writes $\pi^1(\bar{c}; \theta)$. As such, the intensity of competition is not affected by the investment in the new technology.

Period 2: The follower's investment

The second firm, the follower, invests in the new technology at the beginning of period 2. As a result, both firms now incur the marginal cost \underline{c} and earn the duopoly profit $\pi^d(\underline{c}; \theta)$.

The lag between periods 1 and 2 represents the reaction time of the follower to the investment of the leader. This duration is denoted T and assumed to be exogenous. We assume that the more the products are substitutes, the quicker the reaction of the follower; that is, T is a decreasing function of θ : $T'(\theta) < 0$. In particular, T tends to infinity when θ tends to zero.

Note that the settings of the model accord well with the investment and competition in the mobile telecommunications industry.

Now that the settings of the model are in place, our goal is to show how the potential for technological progress, measured by the impact of the innovation on marginal cost of production and denoted $\tau = \bar{c} - \underline{c}$, affects the relationship between investment and the intensity of competition. More specifically, we first determine the nature of the relationship between the intensity of competition and investment by relying on the incentive to invest in the new technology. This incentive is characterized by the additional flow of profit generated by investment over the whole period. Then, we study how the relationship is affected by the potential for technological progress τ .

Let's f and g denote this instantaneous and constant additional flow of profit over the first and second periods respectively:¹⁰

$$f(\theta) = \pi^1(\underline{c}, \theta) - \pi^d(\bar{c}, \theta) \text{ and } g(\theta) = \pi^d(\underline{c}, \theta) - \pi^d(\bar{c}, \theta)$$

$f(\theta)$ and $g(\theta)$ are respectively increasing and decreasing function of θ .

The total incremental flow of profit generated by investment by the first mover writes:

$$V(\theta) = \int_0^T e^{-rt} f(\theta) dt + \int_T^\infty e^{-rt} g(\theta) dt$$

This is equivalent to:

$$V(\theta) = \frac{1}{r} [\phi(\theta) f(\theta) + (1 - \phi(\theta)) g(\theta)]$$

With r , the discount rate and $\phi(\theta) = 1 - e^{-rT(\theta)}$.

Although we do not know the explicit expression of $V(\theta)$, we are able to derive the shape of its curve by studying the sign of its derivative at the extreme of the intensity of competition. This derivative writes:

$$\frac{\partial V}{\partial \theta} = \frac{1}{r} \left[\frac{\partial \phi}{\partial \theta} (f(\theta) - g(\theta)) + (1 - \phi(\theta)) \frac{\partial g}{\partial \theta} + \phi(\theta) \frac{\partial f}{\partial \theta} \right] \quad (7)$$

5.2 The inverted-U and the role of the potential for technological progress

Given that $T(\theta)$ is decreasing, so is the derivative of $\phi(\theta)$: $\frac{\partial \phi}{\partial \theta} < 0$. In addition, $f(\theta) - g(\theta) \geq 0$ because the efficient duopolist's profit is higher than the profit of the symmetric duopoly. Therefore, the first term within the bracket is negative; that is $\frac{\partial \phi}{\partial \theta} (f(\theta) - g(\theta)) \leq 0$.

Moreover, given that $f'(\theta) \geq 0$, $g'(\theta) \leq 0$ and $0 \leq \phi(\theta) \leq 1$, we have that $(1 - \phi(\theta)) \frac{\partial g}{\partial \theta} \leq 0$ and $\phi(\theta) \frac{\partial f}{\partial \theta} \geq 0$.

¹⁰The expression of the instantaneous profit over the second period stems from the fact that the duration $T(\theta)$ is exogenously determined by the intensity of competition. Should the timing of investment chosen by firm, then $g(\theta) = \pi^d(\underline{c}, \theta) - \pi^1(\underline{c}, \theta)$.

The sign of the derivative of $V(\theta)$ at the extreme of the intensity of competition turns out as follow;

■ When $\theta = 0$, the products are independent and both firms are monopolists in each product's market. In this case, $f(0) = g(0)$ and $\phi(0) = 1$. As a result, $\frac{\partial V}{\partial \theta} = \frac{1}{r} \frac{\partial f}{\partial \theta} > 0$. The derivative of the incentive to invest is positive when the market is monopolistic.

■ When $\theta = 1$, the positive term in the brackets of equation (3) is lower than the negative terms and $\frac{dV}{d\theta} < 0$, only if $\phi(1)$ is sufficiently small. This condition means that the duration of the first mover's advantage is sufficiently small under perfect competition. Under this condition, the derivative of the incentive to invest is negative at the perfect competition.

It turns out from these two results that $V(\theta)$ is locally increasing at $\theta = 0$ and locally decreasing at $\theta = 1$, when $\phi(1)$ is sufficiently small. Therefore, there can be a value θ^* in the interval $[0,1]$ that maximizes $V(\theta)$ and therefore an inverted-U relationship between competition and investment can arise. Otherwise, if $\phi(1)$ is large, the positive term can be higher than the negative ones and $\frac{\partial V}{\partial \theta} > 0$. In that case, investment is maximized under perfect competition.

A first note from this result is that the duration of the first mover's advantage under perfect competition determine whether or not relationship between competition and investment is inverted-U. Indeed, this duration is a decreasing function of the potential for technological progress τ . Hence, the potential for technological progress decreases the incentive to invest because of a lower duration of the first mover advantage under high intensity of competition. This effect is similar to the Schumpeterian effect. On top of this effect, we can observe that the difference $f(\theta) - g(\theta)$ represents the magnitude of the first mover advantage. It is an increasing function of the potential for technological progress τ . This is the escape-competition effect.

The Schumpeterian effect tends to reduce the positive term of equation (3); whereas the escape-competition effect tends to raise the negative ones. As a result, the larger the potential for technological progress, the more likely is the inverted-U. This is precisely because the first mover enjoys higher rent from investing; but over a smaller period.

5.3 An illustration with the Singh and Vives' demand function

The inverse demand function of firm i writes: $p_i = 1 - \frac{1}{1+\theta}q_i - \frac{\theta}{1+\theta}q_j$, where $0 \leq \theta \leq 1$ (See(Singh and Vives, 1984)). If c_i and c_j denote respectively the constant marginal cost of production of firm i and j , the Nash-equilibrium of the Bertrand competition with differentiated products yields:

$$p_i(\theta) = \frac{(2 - \theta^2) + 2 * c_i - \theta(1 - c_j)}{(2 - \theta)(2 + \theta)}$$

$$\pi_i(\theta) = \frac{[(2 - \theta^2)(1 - c_i) - \theta(1 - c_j)]^2}{(4 - \theta^2)^2(1 - \theta)}$$

Before investment in the new technology, the market is symmetric and both firms incur the marginal cost \bar{c} and earn the profit:

$$\pi^d(\bar{c}, \theta) = \frac{(1 - \theta)(1 - \bar{c})^2}{(2 - \theta)^2}$$

The first-mover invest in the new technology and decreases its cost from \bar{c} to \underline{c} and earns the asymmetric profit which writes:

$$\pi_i^1(\underline{c}, \theta) = \frac{[(2 - \theta^2)(1 - \underline{c}) - \theta(1 - \bar{c})]^2}{(4 - \theta^2)^2(1 - \theta)}$$

At date T, the follower reacts and the market becomes symmetrical again. Then, each firm incurs the cost \underline{c} and earns the symmetric profit:

$$\pi^d(\bar{c}, \theta) = \frac{(1 - \theta)(1 - \underline{c})^2}{(2 - \theta)^2}$$

The instantaneous profits before and after the reaction of the follower writes:

$$f(\theta) = \frac{(2(1 - \bar{c})\tau + \tau^2)(2 - \theta^2)^2 - 2\theta(2 - \theta^2)(1 - \bar{c})\tau}{(4 - \theta^2)^2(1 - \theta)}$$

$$g(\theta) = \frac{(1 - \theta)(2(1 - \bar{c})\tau + \tau^2)}{(2 - \theta)^2}$$

We choose an arbitrary duration of the $\phi(\theta) = 1 - \lambda\theta$, with $0 \leq \lambda \leq 1$. This function is decreasing in the intensity of competition θ and yields the required properties for the reaction time $T(\theta)$.¹¹

The graphical illustration of the relationship between competition and investment based on this model is presented below:

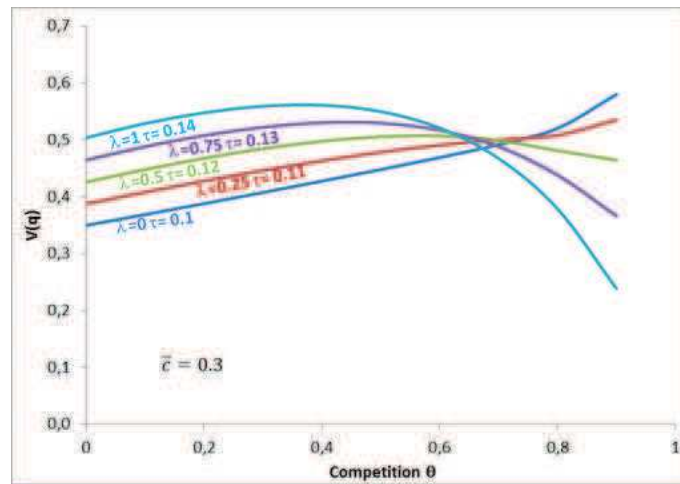


Figure 1: Competition and investment using Singh and Vives' demand function

¹¹Theoretically, $\phi(\theta) = 1 - e^{-rT(\theta)}$. Thus, the corresponding reaction time is $T(\theta) = -\frac{\ln(\lambda\theta)}{r}$ and it is decreasing in the intensity of competition.

6 Conclusion

In this paper, we use firm level data and an instrumental variable estimation strategy to identify the causal impact of the intensity of competition on investment in the mobile telecommunications industry. We find an inverted-U relationship between competition intensity and investment. The investment maximizing intensity of competition stands at 63 percent. This result is qualitatively robust across regions of the World, for investment in network quality and the threat of entry.

To explain this result, we derive a simple model that embeds both the escape competition effect and the Schumpeterian effect. Provided that the size of innovation is large enough, this model yields an inverted-U relationship between competition intensity and investment, consistently with the empirical findings. That is, at low level of competition intensity, the escape competition effect dominates over the Schumpeterian effect. However, above certain intermediate level of competition, the escape competition effect is overtaken by the Schumpeterian because of the smaller duration over which any first mover enjoys the monopoly rent generated by investment.

One of the key features of this model is the fact that the inversion of the curve depends on the size of innovation, measured by the impact of investment in new technologies on the marginal cost of production. The model implies that the investment maximizing intensity of competition is higher in industries with smaller size of innovation. Therefore, the significance of technological progress in the mobile telecommunications industry, as found in the literature, can partly explain the inverted-U. Otherwise, an increasing relationship would be more likely to emerge.

These results suggest that policymakers need to consider the profit margin, the ratio of the EBITDA over revenue, of the mobile network operators before allowing an entry or a merger in the industry. When the profit margin is below the investment maximizing profit margin, then a merger is more desirable than an additional entry. On the contrary, when the profit margin is above its "optimal level", an additional entry may generate more investment incentive than a merger. In the mobile network industry, regulators often plan a new entry several years in advance as a disciplining device for the incumbent mobile network operators. Our results show that this strategy lowers the investment of the incumbent operators.

These policy implications raise the questions of whether there is an investment maximizing number of mobile network operators. For further research, we would like to understand how the market structure affects the investment incentives and

how it depends on the asymmetry between the firms. Given the dynamic feature of the mobile industry, a study of the impact of entry and merger on pricing and investment over several years would provide an additional insight into the impact of competition in this industry. Finally, a complementary view to the main question is to study how cooperation in investment such as network sharing interplays with the effect of the number of firms and more generally market dynamics.

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A Appendix

A.1 Summary and Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Revenue	4695	957.4	2241.3	2.5	24808.0
Fixed market share (%) [*]	1683	29.2	25.2	0.0	100.0
Profit (Ebitda)	4695	354.2	937.2	0.1	10841.8
Investment (Capex)	4695	153.4	458.8	1.0	6705.9
Market size ^{**}	841	39.6	116.6	0.4	990.5
Population density	841	283.0	1039.8	2.4	7589.1
Percentage of LLU lines ^{***}	763	1.9	5.2	0.0	37.0

Revenue, Profit and Investment are in millions constant dollars of the first quarter of 2014.
^(*) Applies to mobile operators that also operate a fixed network.
^(**) Market size is measured by the size of the population between 15 and 64 years old, reported in millions.
^(***) Applies to countries with a Local loop unbundling regulation.

Table 1: Summary Statistics

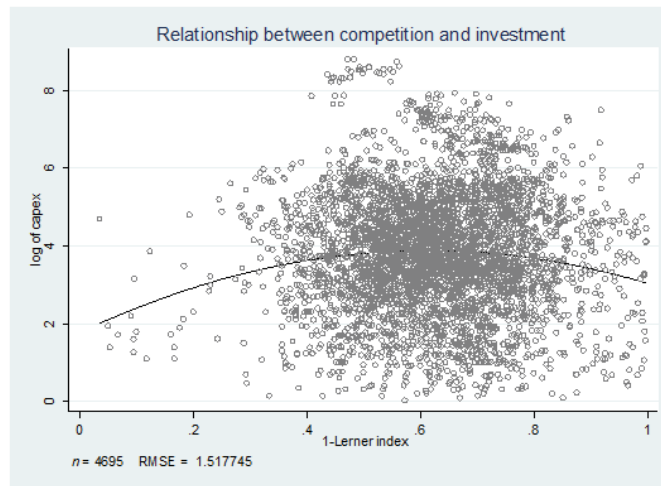


Figure 2: Relationship between competition and investment

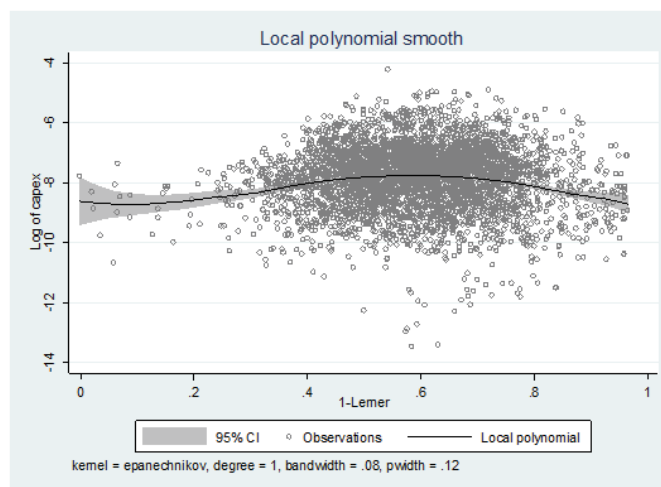


Figure 3: Local polynomial smoothing

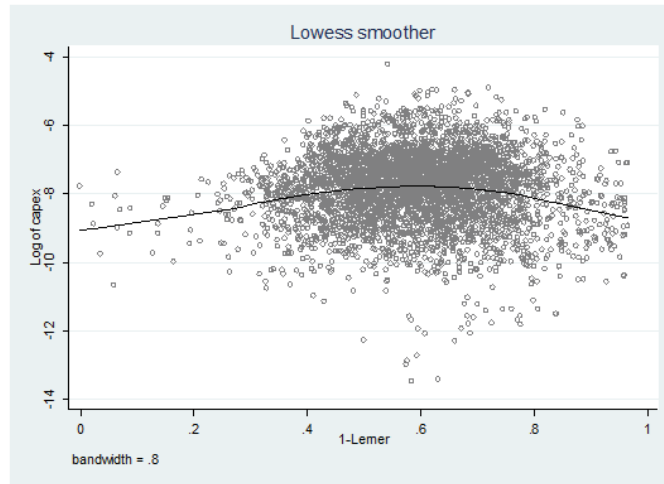


Figure 4: Locally weighted scatterplot smoothing

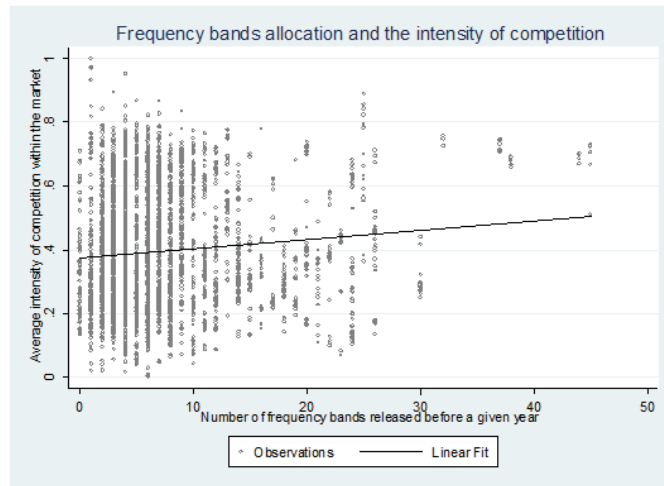


Figure 5: Relationship between the number of frequency bands released and the intensity of competition

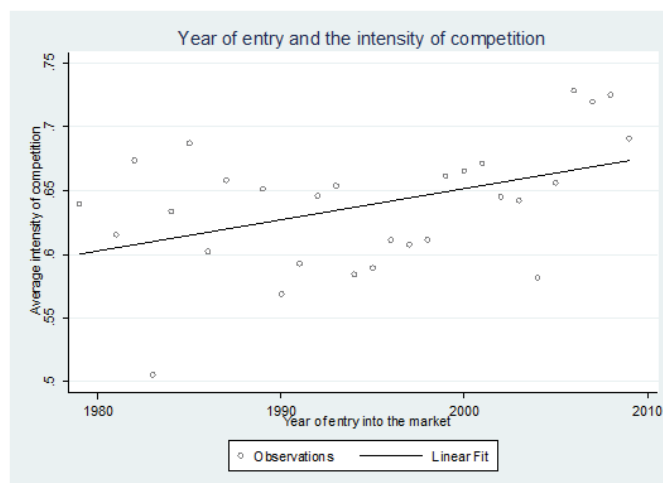


Figure 6: Relationship between the year of entry and the intensity of competition

A.2 Characteristics of the Regions

Regions	Countries
Africa 32 countries 711 observations	Algeria, Cameroon, Congo, Cote d'Ivoire, Democratic Republic of Congo, Egypt, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Tunisia, Uganda, Zambia, Zimbabwe
Americas 10 countries 321 observations	Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay, Venezuela
Asia Pacific 16 countries 862 observations	Australia, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, New Zealand, North Korea, Pakistan, Philippines, Singapore, Thailand
Eastern Europe 27 countries 1130 observations	Albania, Armenia, Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kirghizstan, Kosovo, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovak Republic, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
Western Europe 18 countries 1245 observations	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom
Middle East 10 countries 236 observations	Afghanistan, Bahrain, Iran, Iraq, Jordan, Kuwait, Palestine, Saudi Arabia, Syria, Yemen
USA/Canada	Canada, USA

Table 2: List of countries within the regions

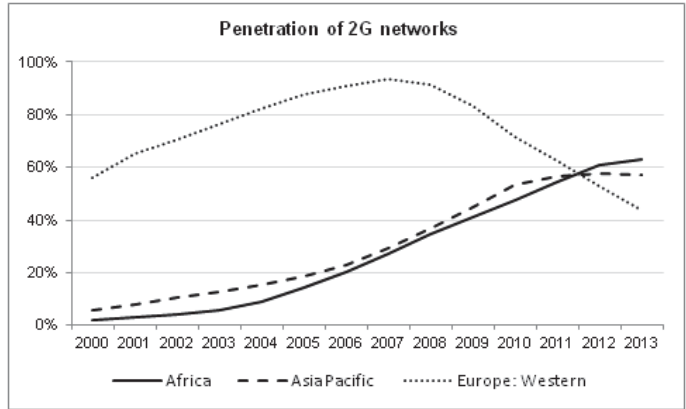


Figure 7: Penetration rate of 2G mobile networks

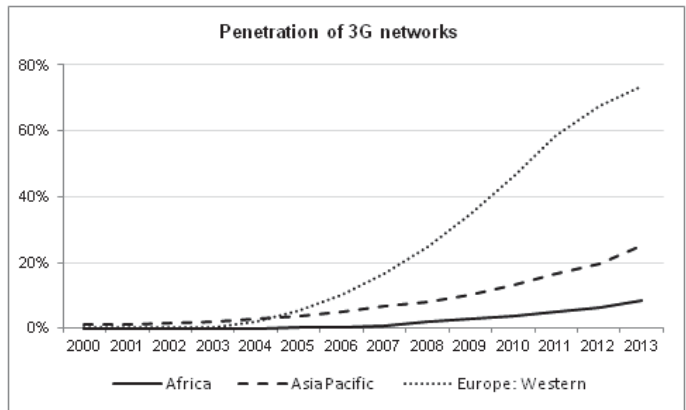


Figure 8: Penetration rate of 3G mobile networks

A.3 Econometric estimation results

	(1-Lerner)	(1-Lerner) ²
	(1a)	(1b)
# frequency bands before a given year	0.001*** (0.000)	0.001*** (0.000)
Launching year	0.004*** (0.001)	0.007*** (0.001)
Incumbent FNO	-0.042*** (0.006)	-0.052*** (0.007)
Log of working age pop.	-0.013*** (0.002)	-0.015*** (0.003)
Log of pop. density	0.005** (0.002)	0.006** (0.003)
LLU regulation	0.036*** (0.007)	0.041*** (0.009)
Hosting MVNO	0.021*** (0.005)	0.022*** (0.007)
Purchase a license	-0.016*** (0.006)	-0.021*** (0.008)
Quarter	0.000 (0.000)	0.000 (0.000)
Region fixed effects	v	v
Constant	-7.933*** (1.117)	-12.871*** (1.423)
Observations	4,695	4,695
R-squared	0.172	0.169
F-statistics	48.22	45.76

Significance at 1% (***), 5% (**) and 10% (*). Standard errors in parentheses are robust to arbitrary heteroskedasticity and autocorrelation. The Bartlett kernel with a bandwidth of 2 is used to correct for arbitrary autocorrelation. Specifications (1a) and (1b) represent the first stage of the main estimation of the impact of competition on investment.

Table 3: The impact of regulation on the intensity of competition and the number of firms

	Logarithm of investment						Investment
	(2)	(3a)	(3b)	(3c)	(4)	(5)	/revenue
Competition (1-Lerner)	46.51*** (13.55)	95.40*** (18.05)	31.17* (18.47)	31.03*** (11.21)	2.64*** (0.62)	67.22*** (13.82)	-41.88*** (8.84)
Squared competition	-37.01*** (9.20)	-73.20*** (13.18)	-23.56* (12.98)	-22.59*** (7.89)	-1.86*** (0.41)	-50.36*** (9.68)	31.68*** (6.20)
# of entries planned as of Q1 2014						-0.04** (0.02)	
Log of working age pop.	0.81*** (0.03)	0.95*** (0.29)	0.75*** (0.05)	0.77*** (0.07)	-0.003 (0.002)	0.87*** (0.04)	0.07*** (0.02)
Log of pop. density	-0.06** (0.03)	-0.19*** (0.07)	0.07** (0.03)	0.02 (0.09)	-0.006*** (0.002)	-0.08*** (0.03)	0.02 (0.02)
LLU regulation	0.21 (0.13)	-0.05 (1.32)	0.11 (0.07)		-0.016** (0.007)	-0.00 (0.13)	0.10 (0.09)
Incumbent FNO	0.17 (0.13)	1.11*** (0.41)	0.25** (0.13)	-0.11 (0.16)	0.014 (0.009)	0.36** (0.14)	-0.18** (0.09)
Hosting MVNO	0.25** (0.10)	0.38 (0.45)	-0.10* (0.05)	0.09 (0.25)	-0.012* (0.007)	0.13 (0.11)	0.08 (0.07)
Purchase a license	0.12* (0.07)	0.69* (0.42)	0.06 (0.09)	0.32 (0.21)	0.012* (0.006)	0.18** (0.09)	0.04 (0.06)
Quarter	-0.00 (0.00)	-0.04*** (0.01)	-0.01* (0.00)	0.02*** (0.01)	0.003*** (0.000)	-0.00 (0.00)	-0.01*** (0.00)
Region fixed effects	√				√	√	√
Constant	-23.70*** (4.96)	-39.73*** (10.72)	-18.36*** (7.10)	-20.08*** (3.46)	2.819*** (0.224)	-31.87*** (4.93)	10.53*** (3.12)
Observations	4,695	862	1,245	711	3,979	4,695	4,695
Investment maximizing intensity of competition (IMIC):							
Lower bound	0.57	0.54	0.60	0.58	0.66	0.64	0.63
Mean	0.63	0.65	0.66	0.69	0.71	0.67	0.66
Upper bound	0.69	0.76	0.73	0.79	0.76	0.70	0.69
Under-identification test (H0: the instruments do not significantly affect the intensity of competition)							
LM statistic	22.25	7.76	7.31	10.67	61.61	24.88	22.25
Weak instruments test (H0: instruments are weak)							
Wald F statistic	12.89	3.71	3.04	5.85	38.72	12.78	12.89

Significance at 1% (***), 5% (**) and 10% (*). Standard errors in parentheses are robust to arbitrary heteroskedasticity and autocorrelation. The Bartlett kernel with a bandwidth of 2 is used to correct for arbitrary autocorrelation. The confidence interval of the investment maximizing intensity of competition is obtained by computing the standard error based on the delta method. The Lagrange Multiplier (LM) statistics for under-identification is to be compared to the critical value of a Chi2 with two degrees of freedom at 5% significance level (0.103). The Weak identification test's Wald F statistics is to be compared to Stock & Yogo (2005)'s critical values: 7.03; 4.58 or 3.95 for a maximal size of 10%, 15% or 20% respectively.

Table 4: The impact of competition intensity on investment in new technologies

3. Conclusion générale

Les modèles macroéconomiques soulignent l'importance de l'investissement sur la croissance. L'investissement permet d'une part de fournir l'effort de recherche permettant le progrès technique et d'autre part d'incorporer le progrès technique dans l'économie, c'est-à-dire de transformer les connaissances en information utile.

L'investissement a d'autant plus d'impact sur la croissance que le progrès technique est fort, et le progrès technique est d'autant plus fort que l'effort de recherche est conséquent et que les connaissances sont développées. Dans les technologies de l'information en général et dans les télécoms en particulier, l'effort de recherche nécessite plutôt moins de dépenses d'énergie et de matériel que dans d'autres secteurs ce qui peut expliquer pourquoi le progrès technique y est si dynamique.

Ce dynamisme rend la question des incitations à investir dans les infrastructures de télécommunication particulièrement sensible, et cela ne touche pas seulement le secteur des télécommunications mais l'ensemble de l'économie car les infrastructures de télécommunication stimulent la croissance.

La régulation sectorielle et les règles de la concurrence ont une influence importante sur les incitations à investir, leur adaptation adéquate à des contextes changeants peut donc avoir un impact conséquent sur la croissance.

Par exemple, le fait de favoriser les technologies anciennes basées sur la paire de cuivre, comme le xDSL, par le biais des marchés de gros, se fait au détriment des technologies nouvelles comme la fibre optique. Cela ralentit les investissements dans les nouvelles technologies et donc l'incorporation du progrès technique dans l'économie ce qui peut nuire, en fin de compte, au surplus des consommateurs et au bien-être social.

Ces régulations, mises en place dans un contexte d'ouverture à la concurrence de monopoles ne sont plus adaptées au renouvellement des infrastructures.

Les politiques de la concurrence jouent aussi un rôle majeur dans les incitations à investir. La relation entre concurrence et investissement résulte essentiellement de la combinaison de deux effets contraires : Un effet croissant, dit effet d'échappement à la concurrence et un effet décroissant, dit effet Schumpétérien. L'effet croissant pousse les firmes à investir d'autant plus que la concurrence est intense afin d'obtenir un avantage compétitif et atténuer les effets de la concurrence. L'effet décroissant incite les firmes à réduire leurs investissements lorsque la concurrence devient plus intense car la baisse des marges tend à rendre les investissements moins rentables. Ces deux effets se combinent de manières différentes suivant les secteurs. Le progrès technique joue un rôle prépondérant dans cette combinaison car il tend à renforcer l'effet Schumpétérien et à atténuer l'effet d'échappement.

Lorsque le progrès technique est faible, l'effet d'échappement domine et la relation entre concurrence et investissement est croissante. Lorsque le progrès technique est suffisamment fort, la relation est en U inversé, d'abord croissante, puis décroissante au-delà d'un certain niveau de concurrence pour lequel l'investissement est maximum. C'est le cas de la téléphonie mobile, comme nous l'avons montré empiriquement et il est très probable que ce soit aussi le cas dans le fixe et dans les technologies de l'information en général étant donné le dynamisme du progrès technique.

Connaissant cette relation en U inversé, il est important que les règles de la concurrence en tiennent compte et permettent au marché de se placer le plus près possible du niveau de concurrence qui maximise l'investissement afin de favoriser l'incorporation du progrès technique dans l'économie, de maximiser le surplus des consommateurs et le bien-être social.

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VU et PERMIS D'IMPRIMER



A Montpellier, le

Le Président de l'Université de Montpellier

Philippe Augé

Résumé

Les incitations à investir dans les réseaux de télécommunications

Cette thèse présente 4 articles de recherche qui étudient les relations entre la structure de marché, la concurrence, la régulation et les investissements dans les réseaux de télécommunications. Les réseaux de télécommunications nécessitent des investissements réguliers et importants. Ces investissements sont essentiels pour incorporer le progrès technique dans le réseau et ont une influence importante sur la croissance et l'emploi. C'est pourquoi la question des incitations à investir revêt une importance particulière. Le premier article étudie les relations entre la régulation (tarif de la charge d'accès au réseau cuivre, taux d'accès cuivre vendu en gros) et les taux de pénétration des différentes technologies (cuivre, fibre optique et câble). Il montre qu'une régulation trop favorable au cuivre, diminue les incitations à investir et peut donc ralentir le développement des autres technologies et en particulier les technologies de nouvelle génération. Le deuxième article étudie la relation entre les investissements dans la téléphonie mobile et les prix moyens du trafic (en mégaoctet). Il montre que le développement du trafic est lié aux investissements et au progrès technique. Un investissement régulier produit une croissance exponentielle du trafic. Il montre aussi que la baisse des prix unitaires du mégaoctet est principalement due à la croissance du trafic et donc aux investissements. Le troisième étudie la relation entre la marge et l'investissement des opérateurs de téléphonie mobile. Il met en évidence une rupture de comportement des opérateurs en fonction de leur niveau de marge. Il montre aussi qu'il existe un niveau d'investissement qui maximise le profit. Ce niveau d'investissement dépend de la structure du marché et de la demande des consommateurs. Lorsque la marge des opérateurs est suffisante, le niveau d'investissement maximisant le profit est atteint, dans le cas contraire, l'investissement est plus faible ce qui ralentit l'incorporation du progrès technique dans le réseau, la croissance du trafic et finalement la baisse des prix de mégaoctet au détriment des consommateurs. Le quatrième étudie empiriquement de manière précise la relation entre le taux de marge et l'investissement dans la téléphonie mobile. Il met en évidence une relation en U inversé. L'investissement maximum est atteint pour un taux de marge de 37,2%. Un modèle théorique complète cette étude et montre que le progrès technique, c'est-à-dire la réponse à l'investissement en terme d'utilité pour les consommateurs, joue un rôle important dans la forme de la relation entre marge et investissement. Lorsque le progrès technique est faible, la relation est monotone et décroissante. La probabilité d'avoir une relation en U inversé augmente avec le progrès technique et lorsque la relation est en U inversé, le sommet de la courbe se déplace vers des niveaux de marge plus élevés.

Mot clés : Investissement, Concurrence, Régulation, Structure de Marché, Incitations, Oligopole.

Abstract

Incentives to invest in telecommunications networks

This thesis presents four research papers studying the relationship between market structure, competition, regulation and investment in telecommunications networks. Telecommunications networks require regular and substantial investments. These investments are essential to incorporate the technical progress in the network and have a large impact on growth and employment. This is why the issue of investment incentives is especially important. The first paper examines the relationship between regulation (price of the access charge to legacy network, copper wholesale access share) and penetration of different technologies (copper, optical fiber and cable). It shows that a regulation which is too favorable to copper, decreases incentives to invest in other technologies and may slow down their development, especially the new generation technologies. The second paper examines the relationship between investment in mobile telephony and the average prices of the traffic (in megabytes). It shows that traffic growth depends on investments and technical progress. Regular investment yields an exponential growth of traffic. It also shows that the fall in average prices of the megabyte is mainly due to traffic growth and therefore investment. The third paper examines the relationship between margin and investment of mobile telephony operators. It shows a break in operators behavior based on their level of profit margin. It also shows that there is a level of investment that maximizes profit. This level of investment depends on the structure of the market and consumers' demand. When the margin of the operator is sufficient, the level of investment to maximize profit is reached, otherwise, the investment is lower which slows down the incorporation of technical progress in the network, traffic growth and ultimately the fall in megabyte prices to the detriment of consumers. The fourth paper empirically examines precisely the relationship between the rate of margin (margin/revenues) and investment in mobile telephony. It highlights an inverted U-shaped relationship. The maximum investment is achieved for a 37.2% rate of margin. A theoretical model complements this study and shows that technical progress, that is to say, the response to the investment in terms of usefulness to consumers, plays an important role in shaping the relationship between the rate of margin and investment. When technical progress is weak, the relationship is monotonic and decreasing. The likelihood of having an inverted U relationship increases with technological progress and when the relationship is inverted U, the peak of the curve shifts to higher rates of margin.

Key words : Investment, Competition, Regulation, Market structure, Incentives, Oligopoly

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