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Impact of Japanese GLO launch on Philip Morris International stock prices

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Affidavit:

Hereby, I declare that I have compiled the master's thesis „Impact of Japanese GLO launch on Philip Morris International stock prices" on my own and all of the used literature and other sources are properly marked and stated in the enclosed list.

In Prague, January 18th, 2018

Abstract:

The thesis deals with newly expanding segment of tobacco industry – "heat-not-burn" products in context of the current tobacco market and regulations. Heated tobacco products promise up to 90% risk reduction in using nicotine thanks to heating tobacco instead of burning it. The first product of this kind, iQOS by Philip Morris International (PMI), found a potentially strong rival in GLO launched by British American Tobacco, which impacted the Philip Morris International's prices significantly since the day of the GLO launch announcement for Japanese market. The thesis aims to quantify the financial impact the shareholders of PMI suffered purely because of this by using "event study" methodology to detect abnormal losses.

Abstrakt:

Diplomová práce se zaobírá nově rostoucím segmentem bezdýmných tabákových výrobků v kontextu současného tabákového trhu a regulací. Bezdýmné tabákové výrobky slibují až 90% snížení rizika při užívání nikotinu díky zahřívání tabáku namísto spalování. První výrobek tohoto druhu, iQOS od společnosti Philip Morris International (PMI) našel slibného protivníka ve výrobku GLO od společnosti British American Tobacco a tento fakt významně ovlivnil ceny akcií Philip Morris International ode dne oznámení uvedení GLO na japonský trh. Práce si klade za cíl kvantifikovat finanční dopad na akcionáře PMI čistě z titulu tohoto oznámení za použití "event study" metodologie na určení abnormálních ztrát.

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INTRODUCTION

The tobacco market is undoubtedly one of the most regulated industries out there and for good reasons - addictiveness of nicotine in tobacco products and harmfulness of combustion byproducts. This has twofold implications – on one hand, significant regulations in form of restricted promotion and sales, modifications of the products that would make them attractive to e.g. underage individuals, non-smokers and others (such as fruity flavors, smaller affordable packages etc.). On the other hand, the tobacco industry represents a significant source of excise tax income for public budgets worldwide since the demand elasticity is low thanks to addictive nature of the products.

Because of the regulations, the market has been steadily declining and it has become increasingly more difficult for tobacco companies to promote their products. Actions such as the introduction of a new revision of Tobacco Products Directive (TPD) in the EU, mandatory plain packaging in various markets (most notably in Australia) and continuously increasing excise taxes imposed upon cigarettes (with more and more emphasis on cheaper fine-cut tobacco and other alternatives too), the manufacturers have started investing heavily in research & development in search of a way to stay in business.

The way of adapting the tobacco companies took is introduction of „heat-not-burn" products that heat tobacco instead of burning it at half the temperature of classic combustion, while producing nicotine-infused vapor. The products are marketed as reduced-risk alternatives to smoking, yet promising an effect similar to classic cigarettes (unlike e-cigarettes that deliver lower dose of nicotine) and up to 90% reduction of harmful substances. These claims are being challenged since most of the studies on the smokeless tobacco products come from the manufacturers themselves and currently the U.S. Food & Drug Administration is conducting and investigation supposed to allow or ban launch of one of the products in the U.S. market.

The main products stirring the tobacco market are iQOS (Philip Morris International), GLO (British American Tobacco) and Ploom TECH (Japan Tobacco International). Even though these are not the first prototypes of such products ever, their introduction has started shift of a relatively minor niche (and sort of experimental) area into a segment in its own right, with the Japanese market serving as the primary "battleground".

The successful series of Japanese city tests of iQOS in 2014 led to a nationwide release in fall 2015 and within the next two years, the HEETS brand (tobacco sticks for iQOS) has achieved approximately 12% market share in Japan. Ploom TECH launched in Japan (in a single city) at the beginning of 2016 but struggled heavily both with supply chain issues and quality of the product and still has not managed to make the product available in the entire Japanese market up to now. However, British American Tobacco announced their launch of GLO in Japan on November 8th 2016 and within a matter of days, the Philip Morris International stock prices slumped by approximately 10%.

This dramatic decline in price motivated the main question for the thesis asking if the slump of PMI's stock prices was caused by the announcement of a competitor's product or any other known shock news interfered, and how much this event cost the Philip Morris stockholders. It is explained via logic taken from analytic approach of event study which strives for estimation of normal shock-free returns in order to quantify excessive losses induced by the shock event. Choosing of a suitable model for ex-post extrapolation of normal returns is part of the solution to the problem.

The first „Conventional Tobacco Market" chapter introduces the environment of the tobacco industry through its main players, describes their recent development and main portfolio points for conventional cigarettes and e-cigarettes. The second chapter „Heat-not-burn Tobacco Products" digs into particular tobacco heating devices, their convenience, launching to market and current status. Additionally, it also hints a new direction of smokeless products that is taking off (TEEPS) and briefly explores controversy of claims about reduced risk. The third chapter outlines the current situation in the tobacco industry regulation and taxation (especially in Japan and the EU) and trends and prospects for regulations that are about to come into force in foreseeable future. The fourth „Methodology" chapter provides an overview of event study logic, approaches it takes and various models that can be used for estimations. The final chapter „Practical Part" aims to choose the appropriate model/models for normal returns estimation and use those for quantification of losses that the Philip Morris International's stockholders suffered because of the announcement of the competitor's product GLO.

1 CONVENTIONAL TOBACCO MARKET OVERVIEW

To understand why a tobacco company stock prices respond to an announcement of competitor's announcement of an electronic device (especially when electronic cigarettes have been around for quite some time), one must first comprehend the context of the situation. With the ever-tightening regulations placed upon tobacco industry all over the world, tobacco companies are looking for ways to stay relevant in business and to bring value to their owners. Out-of-the-box thinking has led both bigger and smaller tobacco companies (or even start-ups) to idea of heating tobacco at temperature below point of burning to reduce health-damaging compounds. It is necessary to state that heat-not-burn products are by no means less addictive than conventional cigarettes and are aimed at target audience of legally adult smokers who would probably not quit smoking or switch to a less harmful alternative otherwise.

Even though Japan as the targeted market is rather small-sized/medium-sized, it has proven to be first choice of the tobacco companies when testing the new kind of so-called "heat-not-burn" products. These devices heat tobacco[1] instead burning it to produce nicotine-laced vapor instead of smoke.

A certain emphasis will be put on the U.S. market as well even though any major heat-not-burn device has not been launched there yet but the ongoing filings with the U.S. Food & Drug Administration (FDA) look promising.

Even though there have been many smaller companies coming up with alternative devices, marketing resources and brand awareness plays its role in switching to heat-not-burn products – therefore bigger tobacco companies have the upper hand in mass promotion in this area and are more likely to have a big-scale impact. Because of this, this thesis is mostly focusing on the game-changing devices that are likely to establish the new segment from something niche to a bit more wide-spread. For the sake of context, an overview of current development in the tobacco industry is necessary – especially regarding Philip Morris International Inc. (iQOS), British American Tobacco Inc. (GLO) and Japan Tobacco International Inc. (Ploom TECH), the regulations being

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[1] Either bigger pieces of leaves, crushed mass or granulated tobacco in form of cigarette-like sticks, capsules or loosely inserted tobacco

tightened (e.g. already implemented or impending cigarette plain packs or ban of capsules and menthol) or specifics of the Japanese market.

1.1 Tobacco Market Overview

The current global tobacco market is pretty much concentrated between a few key players and it is easy to tell why. Tight regulations, controversial nature of the industry and necessary economies of scale are not easy to deal with and in some countries, the tobacco companies operating there are still at least partly owned by the state (e.g. China, Japan).
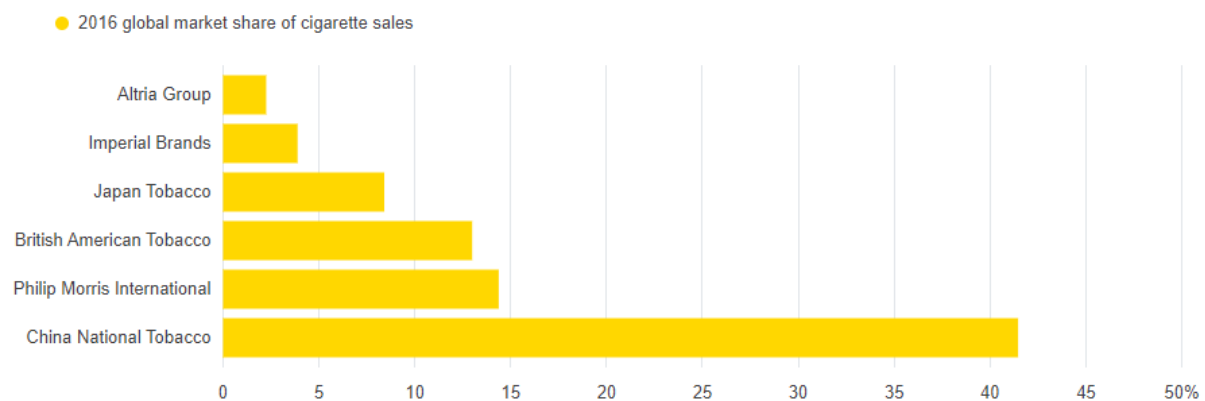
Figure 1: Portion on world CIG sales (source: Euromonitor International)

Figure 1 summarizes the biggest tobacco companies worldwide by their 2016's cigarette sales. The no.1 tobacco company by far is China National Tobacco that makes up more than 40% of the globally sold cigarette volume. The Chinese giant is fully owned by the state and serves as a corporate body belonging to the State Tobacco Monopoly Administration which owns the tobacco monopoly. Small local manufacturers or foreign brands or are not completely forbidden but they are heavily regulated. In case of foreign brands, those are mostly made locally in China and represent roughly 2-3% of the Chinese market.

The rest of global tobacco market is a bit less concentrated – Philip Morris International is the biggest privately-owned tobacco company in the world with approximately 14% of global sales in 2016, closely followed by British American Tobacco with 13%. However, the BAT's number reflects the company's recent merger with Reynolds American Inc.[2], formerly the 2nd biggest tobacco company in the U.S. market. Behind those lags Japan Tobacco International, with the

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[2] Fully approved and completed in July 2017

Japanese government still owning around a third of the company. The last two companies included are Imperial Brands Plc. and Altria Group Inc., the previous mother company of Philip Morris International operating in the U.S. market.

The latest marking point of the industry, apart from the ongoing shifting to tobacco-heating devices, have been regulations that most strongly encouraged cigarette plain packaging. Plain packaging requires olive-colored boxes with standardized font regardless of the brand or the company, with no pictures allowed. Typically, the restriction is combined with no-display policy and the packages are taken out. This policy is recommended e.g. by the EU Tobacco Product Directive (or its latest version approved in 2013) or already implemented by e.g. Australian government. Regarding the former, some of the EU markets have already gone for plain packs under TPD (such as United Kingdom or France), others have it planned by the end of the decade or are waiting for reviews of impact in other markets. As for the latter, plain packs were announced in 2011 and came into force at the end of 2012 making Australia the first country in the world implementing this policy. The policy[3] has resulted in a controversial lawsuit[4] when Philip Morris Asia Ltd. sued Australian government for alleged violation of intellectual property rights regarding cigarette brands goodwill and breaching a bilateral business contract by implementing plain packaging. Philip Morris ultimately lost the lawsuit in 2015 when the Permanent Court of Arbitration (based in Singapore) declined further proceedings ending the challenge. In May 2015, British American Tobacco, Imperial Brands and Japan Tobacco International joined PMI in a new lawsuit against the UK government for the very same reason.

1.2 Philip Morris International Inc.

Philip Morris International is the manufacturer of well-known tobacco brands such as Marlboro, L&M, Chesterfield or Parliament. Its roots can be tracked back to a London tobacconist Philip Morris who opened his store on the Bond Street in 1847. The company covers basically all of the world markets outside of the U.S. market, where its previous mother company Altria Group Inc. operates. The operational headquarters of the company is located in Lausanne, Switzerland, yet separate markets are usually separate legal entities. The company was separated from Altria in

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[3] Enforced via Commonwealth restriction
[4] Financial Times; for full **citation** please see Sources – item [8]

2008 supposedly to divide strategies to conform with the U.S. tobacco regulations and with those in other markets.

Lately, the company has been trying to pioneer the heat-not-burn product segment since 2014 when its first product called iQOS was launched in Japan and since then it has been released in more than 25 markets. The company states that this is the beginning of „smoke-free future".

Apart from heated tobacco, PMI also operates in area of classic e-cigarettes. In 2014, it acquired the Nicocigs, a leading British e-cig company (with their products Nicocig and Vivid) and in 2013 PMI obtained approval from Altria to market their e-cigarettes branded Solaris in Spain and Israel.

As well as that, PMI is launching a new e-cigarette platform called MESH which is supposed to operate on principle of metallic tiny-holed mesh heating the pre-filled and pre-filled nicotine e-liquid.

PMI Cigarette Shipment Volume by Region (million units)	Fourth-Quarter			Full-Year		
	2016	2015	Change	2016	2015	Change
European Union	45,193	47,210	(4.3)%	193,586	194,589	(0.5)%
EEMA	67,763	69,271	(2.2)%	271,393	279,411	(2.9)%
Asia	63,815	68,183	(6.4)%	260,029	281,350	(7.6)%
Latin America & Canada	23,794	25,105	(5.2)%	87,938	91,920	(4.3)%
Total PMI	200,565	209,769	(4.4)%	812,946	847,270	(4.1)%

Table 1:PMI cigarette shipments by region (source: Philip Morris 2016 result report)

One more fact worth stating is importance of the Japanese market for PMI since the company has chosen to launch iQOS there first. *Table 1* shows that the Asia region which includes Japan makes up around 32% of the company's worldwide volume for 2016 and around 33% for 2015. Apparently, in 2015 Asia region was the biggest one for PMI in terms of shipments, making it understandable that one of the iQOS testing markets would be placed there. The Asia region was beaten by EEMA[5] in 2016. Although all of the regions declined in 2016, Asia declined the most (by 7.6%) which was mostly driven by switching of Japanese legal adult smokers from cigarettes to iQOS (or more precisely HEETS sticks) and by Philippines where new excise taxation on

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[5] EEMA = Eastern Europe, Middle East and Africa

cigarettes was imposed and it drove decline in classic cigarette consumption and likely increased illicit trade.

	Total Market vol. (billion units)		PMI Domestic Market Share	
Key Market	**2016**	**2015**	**2016**	**2015**
Indonesia	315.6	320.0	33.4%	34.3%
Japan	**173.8**	**182.3**	**24.9%**	**25.3%**
Korea	73.6	67.3	21.0%	21.2%
Philippines	79.3	90.2	71.3%	73.4%

Table 2: Asia region - total market volumes and PMI domestic market shares (source: based on PMI 2016 financial report)

All in all, looking at the 2015 numbers, it is logical that the Japanese market was chosen as a testing market – it was the second biggest market in Asia region by 2015 shipping volume with a reasonable PMI market share of almost 25%, high purchasing power of the smoker population (compared to other markets), relatively favorable regulation (as explained later on) and reputation of the country for being enthusiastic about innovative products. Another motive might have been to get ahead of the domestic tobacco giant Japan Tobacco in their own market.

1.3 British American Tobacco Inc.

British American Tobacco is a tobacco company headquartered in London, UK that manufactures cigarette brands such as Lucky Strike, Kent or Pall Mall. Until recently, it was the biggest European tobacco company before the Philip Morris spin-off.

In 2016, the company announced intentions to acquire the rest of the shares of Reynolds American Inc. to get access to the U.S. market (it had previously already owned a 42% stake in RAI). The merger was approved by the RAI's board of directors and officially confirmed in January 2017, with completion in July 2017. As shown above, this made BAT the biggest rival of PMI and Altria and it is easy to guess the reason for this merger - gaining access to a vast potential market for GLO since rival PMI with iQOS already had access to the U.S. market via Altria. This

was also openly admitted by the BAT's CEO Nicandro Durante[6] as well as stating that the U.S. market is the most profitable one except for China. This fact surely comes in handy in a slowly-shrinking industry that needs monetary fuel for technologic transformation.

BAT is even more active in area of e-cigarettes than Philip Morris, with its VYPE range of vaping products (started in 2013) and acquisition of CHIC group in Poland, gaining also their Research & Development centers. An interesting fact is that in 2015, BAT launched iFuse which is already halfway to a heated-tobacco product – producing heated nicotine-liquid vapor and subsequently sending it via tobacco section[7].

Regarding the likely explanation of why BAT started aiming GLO at the Japanese market just like their rival PMI, unfortunately detailed numbers on cigarette shipments on regional or market levels are nowhere to be found in the company's annual reports or other statements. As well as that, the company groups regions in a different way compared to PMI, often states results together for cigarettes and cigarette equivalents (calculated from fine-cut tobacco products) and does not state its national shares in the markets. However, it is not far-fetched to conclude that the successful performance of iQOS and other positive aspects of this particular market (mentioned before) were a factor in decision-making about the market for GLO launch and PMI technically tested suitability of the market first. Also, it is far harder to fight competition like this once it has been established in the market for too long, so BAT took a quick approach in entering the market and using favorable pricing of their product compared to iQOS.

1.4 Japan Tobacco International Inc.

Japan Tobacco International Inc. (with headquarters in Geneva, Switzerland) is an international division of Japan Tobacco Inc. (headquarters in Tokyo, Japan). 33.35% of Japan Tobacco Inc. is owned by the Government of Japan and it controls around 66% of the domestic market. JT manufactures and sells cigarette brands such as Camel, Winston or Mevius.

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[6] CNBC, for full **citation** please see Sources – item [7]
[7] As explained later on, infusing hot vapor with nicotine via running it through tobacco is typical for Ploom TECH by JTI

JTI was the most delayed out of the big players[8] with their development of a heat-not-burn device, initially only buying a stake in a start-up aiming at this segment, later buying patents and know-how from the company to quickly develop their own device (Ploom TECH). The device was launched in March 2016 in Japan and suffered significant prolonged supply chain delays to a point where it is still not launched nationwide in the country at the beginning of 2018.

As for electronic cigarettes, JTI's main e-cig brand is Logic which is sold in 9 markets all over the world and claims to be the no.1 in the U.S., United Kingdom and France.

1.5 Imperial Brands Plc.

Imperial Brands[9] is a British tobacco company headquartered in Bristol, United Kingdom, where it was founded in 1901 by merger of 13 smaller tobacconists. It manufactures brands such as Davidoff, West or Golden Virginia and even though it is not a top cigarette tobacco company, it beats its competitors in categories such as fine-cut tobacco or more niche cigars.

Imperial Brands does not seem to catch up on its competitors in heat-not-burn category so far and their official website statement on it says the following:

"Heated tobacco is a smaller NGP category but one that is growing, most notably in Japan. We do not sell these products but continue to monitor their development. We have developed options in heated tobacco which can be deployed should the category start showing broader signs of significant and sustainable growth.

Unlike EVPs, heated tobacco products contain tobacco and in our view should therefore be regulated and taxed as conventional tobacco products."[10]

This statement, especially the part about regulation, makes it evident that Imperial Brands is not likely to come up with their own device belonging to the category soon, otherwise they would not be requiring the regulation.

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[8] If Imperial Brands are omitted since their heat-not-burn development is nowhere close to mass production of a prototype

[9] Sometimes incorrectly called Imperial Tobacco

[10] Next Generation Products. Imperial Brands Plc. [online]. 2017 [cit. 2018-01-10]. Available from: http://www.imperialbrandsplc.com/About-us/next-generation-products.html

1.6 Altria Group Inc.

Altria Group is one of the top tobacco companies worldwide and the biggest one in the U.S.[11] founded in 1985, but only named this way in 2003 - its previous name was Philip Morris Companies Inc. It is headquartered in Henrico County, Virginia and it is a mother company of e.g. Philip Morris USA, John Middleton Inc. or U.S. Smokeless Tobacco Company Inc. Until 2008, Philip Morris International Inc. belonged under Altria Group, but since the group started acquiring stake in different industries[12], it was considered suitable to reflect it in the company name re-branding.

The company's portfolio is different from the European offerings[13], but it keeps brands famous worldwide such Marlboro, L&M, Virginia Slims or Benson & Hedges[14]. The company belongs to both most famous market indices - S&P 500 and Dow Jones Industrial average.

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[11] Given that Reynolds American operating is considered as operating in the U.S. (a separate British American Tobacco subsidiary after recent acquisition), not the whole BAT

[12] Such as SABMiller plc. (brewery) or Kraft (food)

[13] Although this is true with almost every market, reflecting requirements of LAS and traditionally popular formats and brands in a particular country

[14] Although Benson & Hedges is manufactured and sold by various tobacco companies depending on particular market

2 „HEAT-NOT-BURN" TOBACCO PRODUCTS

The „heat-not-burn" tobacco products have become a novelty of past months that are commonly confused with classic electronic cigarettes. They deliver a certain dose of nicotine without burning tobacco and thanks to heating and additive substances produce nicotine-infused vapor instead of smoke use thanks to technologies varying by company. The manufacturers claim that these products reduce harmful substances produced by combustion by up to 90%, but most of the studies conducted by now come directly from the tobacco companies and more independent studies need to come (for instance, these claims are currently being investigated by the U.S. Food & Drug Administration in the process allowing/declining request to launch iQOS in the U.S. market filed by Philip Morris).

To be able to tell the difference between „heat-not-burn" products and classic e-cigarettes, first it is necessary to define what an electronic cigarette actually stands for, e.g. with of the following definition currently published by the U.S. Food & Drug Administration (FDA):

"Vapes, vaporizers, vape pens, hookah pens, electronic cigarettes (e-cigarettes or ecigs), and e-pipes are some of the many terms used to describe electronic nicotine delivery systems (ENDS). These products use a liquid "e-liquid" that may contain nicotine, as well as varying compositions of flavorings, propylene glycol, vegetable glycerin, and other ingredients. The liquid is heated into an aerosol that the user inhales. "[15]

Of course, this definition is by no means all-inclusive, but it reflects the fact that up to now the major way to deliver nicotine to legal adult smokers (from now on mentioned via abbreviation "LAS") without burning has been vaping nicotine-infused liquid[16]. The key word here is "liquid" and it hints that these products do not typically use tobacco leaves like classic cigarettes or fine-cut tobacco[17].

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[15] Vaporizers, E-Cigarettes, and other Electronic Nicotine Delivery Systems (ENDS). U.S. Food & Drug Administration [online]. Silver Spring: U.S. Department of Health and Human Services, 2017, 12/20/2017 [cit. 2018-01-04]. Available from:
https://www.fda.gov/TobaccoProducts/Labeling/ProductsIngredientsComponents/ucm456610.htm

[16] Another minor way is e.g. chewing tobacco called „snuss", popular in Sweden and historically used in the U.S.; this way, nicotine is much more swiftly absorbed to bloodstream and causes more visible teeth and gum discoloration

[17] Fine-cut tobacco is sold as a packaged mass intended to be rolled of stuffed into cigarette filter tubes by LAS themselves

This fact is heavily promoted in the current wave of "heat-not-burn" products to distinguish them from e-cigs. Phrases such as "taste of real tobacco" are often used to emphasize the fact that tobacco sticks for devices such as iQOS (made by Philip Morris International Inc.), GLO (a product of British American Tobacco Inc.) or Ploom TECH(manufactured by Japan Tobacco International Inc.) use actual tobacco leaves instead of liquid.

Another two experience-related factors supposed to distinguish „heat-not-burn" products are taste and nicotine delivery. These products, unlike electronic cigarettes, provide so-called „throat-hit" that is subjectively often considered a part of smoking experience missing in e-cigs.

As for the nicotine delivery, the study conducted by the *Nicotine & Tobacco Research*[18] and published in June 2017 concluded that nicotine content in heat-not-burn products is indeed closer to conventional cigarettes than with e-cigs:

„The levels of nicotine to the aerosol were similar for regular and menthol HnB products (1.40 ± 0.16 and 1.38 ± 0.11 mg/12 puffs respectively) and did not change significantly with prolonged puff duration. The tobacco cigarette delivered the highest level of nicotine (1.99 ± 0.20 mg/cigarette), with levels being higher than HnB and ECs under Health Canada Intense regime.

*The HnB product delivers nicotine to the aerosol at levels higher than ECs but lower than a tobacco cigarette when tested using Health Canada Intense puffing regime. No change in HnB nicotine delivery was observed at prolonged puff duration with the same puff volume, unlike **ECs which deliver more nicotine with longer puff duration.**"*

This is a strong argument in why heat-not-burn products have created a market in its own right from LAS point of view – their nicotine delivery is quicker, higher and more similar to conventional smoking compared to their e-cig counterparts where length of puffing is a factor in immediately achieved nicotine dose. This is expected to make conversion of conventional LAS more likely and more stable and thus presents a more perspective alternative to smoking.

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[18] FARSALINOS, Konstantinos E., Nikoletta YANNOVITS, Theoni SARRI, Vassilis VOUDRIS and Konstantinos POULAS. Nicotine Delivery to the Aerosol of a Heat-Not-Burn Tobacco Product: Comparison With a Tobacco Cigarette and E-Cigarettes. Nicotine & Tobacco Research [online]. 2017, 16 June 2017, 138 [cit. 2018-01-05]. Available from: https://academic.oup.com/ntr/advance-article-abstract/doi/10.1093/ntr/ntx138/3868870?redirectedFrom=fulltext

The Japanese market (that this thesis focuses on particularly) is a bit more specific since national regulations restrict usage of e-liquid. Because of this, classic e-cigs are not a segment in Japan and the LAS switching to heat-not-burn products are also those that would opt for electronic cigarette if those were available. This is one of the reasons why Japan is a no.1 testing market for these products but it can also cause bias estimating potential of the device in other markets.

The following text in this chapter will elaborate on the three above-mentioned heat-not-burn devices – iQOS, GLO and Ploom TECH.

2.1 iQOS

iQOS is a heat-not-burn device developed, manufactured and sold by Philip Morris International Inc. and its name is an acronym for „I-Quit-Original-Smoking". It works on principle of outer heating of short cigarette-like sticks called Heets[19] filled by specially cut tobacco[20], which are impaled upon a heating blade (hinted in *Figure 1* since yellow color represents heat) placed in a so-called holder (the holder resembles a thick pen).

Figure 2: iQOS holder with a Heets stick - a half-transparent illustration (Source: pmi.com)

Except for the holder, the device includes also a charging box which serves for both charging and protection of the holder on the go. The whole device is battery-powered and the holder requires charging after every stick. The process of using begins with removing the holder from the charger box, sticking a tobacco Heets stick onto the blade, then a button push which starts heating the tobacco up to approximate temperature of 350°C (as compared to 700°C-900°C

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[19] Other version of name depending on a particular market is „Heatsticks", sometimes with addition of suffix „by Marlboro"

[20] If tobacco in convetional cigarettes resembles sawdust, the Heets tobacco resembles a rolled rug stuffed inside a cigarette tip

produced during burning classic cigarettes). After approximately ten seconds, the stick is ready for aerosol puffing delivering nicotine. The puffing ends either after 12-13 puffs or after 5.5 minutes of heating and subsequently requires approximately 3 minutes of charging.

The properties explained above are the key to a more widespread conversion of conventional LAS to heat-not-burn devices with reduced risk – their convenience and resemblance to a classic ritual of smoking are the battlefield for the „Big Tobacco" companies. It's obvious that a better, more user-friendly and reliable device will win the fight in long run. Therefore, these qualities can help estimate if the shock of a competitor's product announcement is likely to be temporary or long-term – and thus e.g. add a simple common sense support to the development of stock prices after the GLO announcement shock.

Figure 3: HEETS sticks for iQOS (source: thevape.guide)

A profound question might present itself – flammability of Heets (thus straying from original intended way of using). The Heets cannot be burnt thanks to a special foil and therefore cannot be classified as conventional cigarettes.

2.1.1 iQOS – Launch in Japan and Italy (2014)

iQOS was first launched in November 2014 in two testing markets - Japan and Italy. For the sake of this pilot, only two testing grounds were chosen – Nagoya and Milan.
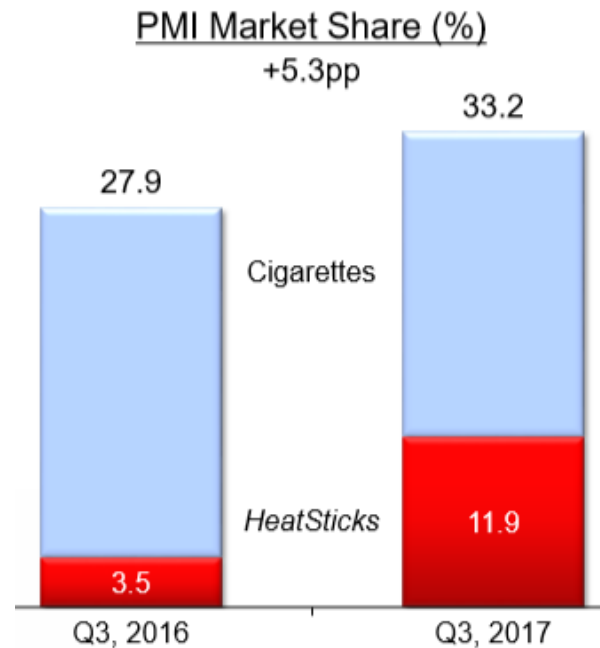
Figure 4: Share of Market YTD of PMI in Japan – last quarterly results (PMI 2017 Q3 results; emphasis on HeatSticks)

The success in the Japanese market led to a nationwide roll-out in September 2015 followed by a quick take-off of market share up to 3.5% of the whole market[21] for HeatSticks at the end of 2016 Q3. According to the 2017 Q3 report published by PMI[22], within a year, the famously novelty-crazed Japanese market accepted iQOS to a point where the whole brand acquired 11.9% market share YTD[23] in total (+8.4p.p.within a year) and This makes HeatSticks a no.2 brand in the entire Japanese market and no.1 in Philip Morris Japanese portfolio. Expectedly, iQOS excels especially in urban areas such as Tokyo or Sendai.

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[21] This share of market represents share on all tobacco products sold, not just cigarettes (thus including also classic electronic cigarettes, fine-cut tobacco and others)

[22] Philip Morris International - 2017 Third-Quarter Results; for full citation please see Sources – item [3]

[23] YTD market share is calculated as (total volume of item sold since January)/ (total marketvolume sold since January) and is typically stable than monthly market shares

On the other hand, Italian market took a bit more conservative attitude towards iQOS and Philip Morris stated in its Annual Report 2014 that production constraints and delivery delays played their part in the process. In the same report, the company announced the start of construction of a factory close to Bologna (Italy) to tackle the manufacturing and delivery issues.

Conservativity of Italian LAS might have been joined by another inconvenient contributing factor – the sales of devices were launched directly to customers (i.e. it was possible to buy the device at a point of sale) without the necessary "guided trial" process. Guided trial of the product is supervised by a trained employee of PMI and it is supposed provide the right information for usage and maintenance of the device to prevent users from careless manipulation leading to damage (e.g. breaking the blade). Unfortunately, this initially was not performed in Italian market but that situation definitely served as a valuable lesson for penetration of other EU markets.

2.1.2 iQOS – launch in other markets

Figure 5: Map of markets with iQOS launched in key cities (source: pmi.com)

Presence of iQOS worldwide is summed up in the map in *Figure 5* and it represents countries where iQOS is launched at least in key cities. A successful launch does not necessarily mean success itself and a heavy factor in it is regulatory environment of a particular country. While strict tobacco regulations in Hungary prevent market penetration altogether for now, e.g. launch in the

Netherlands hit an obstacle in form of a restriction dictating that for LAS to actually try iQOS, they have to buy the device first, which is, of course, bound to slow down acceptance by customers.

Lately, launch of iQOS could have been seen in Czech republic and Slovakia. The launch occurred in May/June in Czech republic and in August/September 2017 in Slovakia. First, there was a classic city test as in previous markets, hitting the biggest urban areas. Learning from the mistakes in Italy, the launch at first took form of exclusive sales by so-called iQOS partners who conducted guided trials with interested LAS and provided them with an option to borrow the whole kit for two weeks before making the decision to purchase.

With relatively friendly regulatory environment in these countries, lessons from previous launches and solid base of premium/medium price segment LAS, hopes were set high.

2.2 GLO

GLO is a heat-not-burn device developed and manufactured by British American Tobacco Inc. It is a second-to-market product of this kind and it also works on principle of vaporized nicotine delivery achieved by heating actual tobacco (not a liquid). Unlike iQOS, its heating process is not run via blade stuck in the middle of a tobacco stick. Instead, a thin tobacco stick[24] is inserted into a holder/charger approximately of size of a cigarette box and it is heated externally to produce the vapor. The tobacco sticks are marketed as "Neostiks" with branding of Kent[25].

Figure 6: Neostik by Kent inserted to GLO device (source: bat.com)

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[24] Resembling a superslim cigarette
[25] Analogically to HeatSticks by Marlboro

Since the stick remains in the holder/charger for the whole time of using, the process does not require separate charging of a removable holder like it does with iQOS and the only pause between using 2 sticks is approximately 15-20 seconds that a stick takes to pre-heat. This represents greater convenience compared to iQOS. The device is supposed to heat tobacco at temperature around 240°C compared to combustion of conventional cigarettes that produce heat from 700°C to 900°C (depending on intensity of puffing). The Neostiks are priced in a similar way as Heets and are expected to source from premium cigarette segment as well.

The shortcoming of GLO is its design which is a bit less practical and elegant compared to iQOS. Another possible problem (especially in terms of regulation) is flammability of the tobacco sticks – British American Tobacco Inc. has yet to provide a proof that Neostiks cannot be used as conventional cigarette if lighted. This fact might disqualify Neostiks regarding more beneficial regulatory conditions that are usually negotiated for tobacco products that do not burn.

2.2.1 GLO – Launch in Japan (2016)

On November 8th 2016, GLO was announced to be launched in Japanese market with retail availability in December, with the launch taking place in a top chain of convenience stores in Sendai. Six months later, British American Tobacco boasted a 8% market share of GLO in its regular Half-Year Report to 30 June 2017, but the "market" still meant just the city of Sendai. The nationwide launch was announced for October 2017. Since British American Tobacco only issues reports twice a year, the latest results are yet to come in February 2018 to see preliminary results of the nationwide roll-out.

2.2.2 GLO – Launch in other markets

GLO went on to launch in Vancouver, Canada in May 2017, announcing launch in Russia in October 2017[26] and launch in Romania in December 2017. Most of those will have their first results published in the upcoming Annual Report 2017 so it is too early to judge how GLO is doing e.g. compared to its major rival iQOS. Another factor to be taken into account once the results come is its significant delay when coming to market and shortening of the city test periods, which might lead to worse decisions.

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[26] Also extending manufacturing for GLO and Neostiks by a factory close to Saint Petersburg

2.3 Ploom TECH

The third heat-not-burn device coming from a "Big Tobacco" player is Ploom TECH by Japan Tobacco International Inc. The previous two rival devices used tobacco sticks that at least loosely resembled conventional cigarettes, yet Ploom TECH operates by heating capsules filled by granulated tobacco which belong under the Mevius cigarette brand popular in Japan. The capsule is inserted into a holder resembling a pen in the same end where a user inhales from. The holder does not bear much similarity to iQOS since it is long and thin. Another difference is that the device, unlike iQOS and GLO, is not heating the tobacco directly, rather it produces vapor which goes through the tobacco capsule inserted into the device and this way it is infused with nicotine. This slightly resembles technology of BAT's iFuse[27].

Ploom TECH was launched for a city test in March 2016 in Fukuoka, Japan and nationwide through a specialized e-shop. In its Annual Report 2016 it boasts no tobacco smoke smell and no direct tobacco heating. It is highly subjective but online reviews of Ploom TECH from various sources state this as a slight shortcoming since the taste is even softer compared to iQOS and GLO.

Apparently, the heat-not-burn products are primarily intended for LAS who have not yet been convinced by electronic cigarettes[28] and seek taste that and effect that emulated their traditional ritual a bit more. This is in part caused by speed of puffing since Ploom generates vapor that is only subsequently being tobacco-infused. Logically, the slower the puff, the more nicotine-dense the vapor and the more dense the taste. This is, to a certain extent, offset by convenience of Ploom device that causes no delay by pre-heating tobacco (since it does not), the very moment it is switched on it delivers.

2.3.1 Ploom before acquisition by Japan Tobacco International

Ploom TECH is not the same item as the original Ploom products, which was originally developed by a start-up company founded by Stanford graduates Monsees and Bowen in 2005. The product design and concept were developed without any prior specific tobacco expertise and

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[27] As mentioned before, iFuse heated nicotine e-liquid like a classic electronic cigarette and then rushed the vapor through a tobacco section

[28] An exception is target market that does not have access to e-cigs because of regulations and for part of those LAS soft flavor is not a problem

their original product Ploom modelOne was originally butane-powered which made it seem inferior to ubiquitous battery-powered electronic cigarettes.

In 2011, after many failed negotiations with potential investors and venture capital funds[29], Japan Tobacco International stepped into the game as a minor shareholder and a strategic partner. At the time, Ploom modelOne had been in the market for a year but it struggled with its design similarity to electronic cigarettes and quadruple price in comparison[30].

In 2012, Ploom released a device called Pax which was already battery-powered but operated using loose tobacco (not capsules or sticks) which became a hit in a a market that was rather niche at the time. Pax was followed by Ploom modelTwo which already looked quite hi-tech and operated on capsules similar in looks to those intended for coffee machines.

Later, Japan Tobacco International acquired patent and know-how from the Ploom designers and developed a different product themselves – Ploom TECH that is currently on the market.

2.3.2 Ploom TECH – Launch in Japan and Switzerland

Even though Ploom TECH was announced to be launched already at the beginning of 2016 and it was delivered to the market shortly afterwards (although to just one city and an e-shop, as mentioned above), it has been struggling with supply chain issues regarding a nationwide launch. Sales of the device in Ploom flagship stores were planned for and started in July 2017. At the end of July, Japan Tobacco International announced a nationwide launch of Ploom TECH in Switzerland. Also, full coverage of key urban areas is planned for first half of 2018.

In July 2017, JTI's executive vice-president Hideki Miyazaki openly admitted failure in the way JTI handled the market penetration in its early stages:

„It's a pity we fell behind when IQOS and [BAT's] Glo appeared.[31] "

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[29] There were some minor investments prior to JTI stepping in, but this one is the most significant, bringing in tobacco know-how and massive marketing equity around the world
[30] 10 USD vs. 40 USD
[31] Financial Times, for full **citation** please see Sources item [6]

Since the company has not announced launch in any other market since Switzerland, it is being questioned if the manufacturing and supply-chain issues have been resolved or if the response to the product is not as good as expected.

An interesting fact is that even though announcement of GLO in Japanese market caused a significant drop in stock prices of iQOS manufacturer (Philip Morris International) in November 2016, the announcement of the same kind regarding Ploom TECH in spring 2016 caused little to no reaction. A likely explanation is that previously niche market of heated tobacco needed to gain momentum to be taken seriously by capital markets for such an announcement to cause a shock. One of the first proofs of the segment growing were quarterly reports by PMI documenting performance of iQOS – and those were yet to come at the time.

2.4 iQOS, GLO and Ploom TECH – Price comparison in Japan

A crucial factor with any product (apart from user-friendliness and convenience) is pricing. Especially in the tobacco industry with ever-increasing prices of the products, price is often a significant factor in consumers' decision. Since currently available heat-not-burn products require initial investment in the heating device (apart from tobacco sticks themselves), this might be an obstacle in conversion of LAS from cigarettes to smokeless tobacco products. Because of these reasons, it is necessary to compare prices of the currently available devices. Since these prices fluctuate across various markets, it is useful to have a look at least at the Japanese pricing that surely played a role in the GLO announcement shock.

iQOS, the first product to the market, is priced at 9,980 JPY (90.4 USD). The second-to-the-market GLO that arrived almost 2 years later tried to use price in its favor being sold for 8,000 JPY (72.4 USD), which likely convinced some consumers who had not purchased iQOS by then. Ploom TECH, significantly late to the party regarding nationwide release, is priced at 4,000 JPY (36.2 USD) which might be its main advantage over competitors. However, the companies strive for offering discounted starter packs in various forms such as a discount on the device upon registration to an online consumer system, including a free bundle with the device or providing discounts after finishing an online guide.

2.5 Heat-not-burn products coming in future

All prototypes of new products have certain bugs and provoke further development and enhancements. The heat-not-burn products described earlier in this chapter have some inconvenient qualities in common – necessity of charging the device (either the charging/heating box or a holder after every stick) and initial investment in buying the device to be able to heat the sticks. As well as that, regular cleaning is required to keep it functional and without altering the taste since bits of tobacco stuck close to the source of heat in device could add smokey flavor to vapor.

One of the announced products of next generation promising to solve these issues is called TEEPS. The product is being developed and tested by Philip Morris International and its release date is unknown for now. TEEPS will be more similar to conventional cigarettes and will not require a charging device or a holder to function.

TEEPS are likely to be sold and usable as conventional cigarettes and they operate based on pressed-carbon heat source at the tip of a TEEPS. This tip is ignited and subsequently heats a patented tobacco plug, which leads to heating the tobacco in the stick instead of burning it[32]. Similarly to other products, TEEPS produces nicotine-laced vapor which is then inhaled by the user.

Figure 7: iQOS and HEETS vs. TEEPS comparison (source: www.americabu.com/iqos)

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[32]The whole technology is patented under name "HeatControl Technology"

As for the PMI's competitors British American Tobacco and Japan International Tobacco, no, new tobacco-heating platforms have been announced. BAT mentions its product iFuse in this category (mentioned before – similar to combination of technologies of an electronic cigarette and Ploom TECH) but this product is only available in Romania for now. JTI has no new announcements, which is expected give the company is currently busy catching up on their competitors with Ploom TECH.

2.6 Heat-not-burn products – controversy

Heat-not-burn products are alleged to reduce harmful substances created by burning tobacco by up to 90%. As mentioned elsewhere in this thesis, further independent research on this matter is necessary.

However, these substances are not the only way in which smoking and nicotine affect body - cigarette smoking also affects cardiovascular system by elevating heart rate and blood pressure (up to 20 minutes after smoking), as well as limiting cardiopulmonary[33] blood vessels in their ability to transport oxygen. The latter is caused by elevated blood pressure between lungs and heart combined with lower ability of the vessels to dilate and displacement of part of oxygen by inhaled carbon dioxide. The possible results involve decreased ability to perform physical activities, hypertension, risk of a heart-attack and stroke and other consequences. The study conducted by American Heart Association[34] investigated ability of the vessels to dilated under increased blood pressure in rats, at first while inhaling cigarette smoke and then iQOS vapor. The found results showed that ten 15-second exposures to classic cigarette smoke over span of 5 minutes led to 57% decrease in vessel expandability, whereas the same amount of exposure to iQOS-produced vapor led to very similar 58% decrease. The other set of experiments consisted of ten 5-second exposures (over 5 minutes) and the decrease with cigarette smoke was 62% and with iQOS vapor 60%. The tests were not conducted for other smokeless tobacco products yet.

These results justify health warnings still being placed on heat-not-burn products and even though they possibly carry reduced risk compared to conventional cigarette combustion, the health

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[33] Cardiopulmonary = involving cardiovascular and respiratory systems
[34] American Heart Association (2017), for full **citation** please see Sources – item [31]

risk is not absent and these products are by no means intended for anyone outside current legal adult smokers who would not quit smoking otherwise.

Further results are expected to be published after filing for iQOS U.S. market launch approval, which is likely to come in February 2018.

3 TOBACCO PRODUCT REGULATIONS

An extra explanation of types of tobacco regulation all over the world is necessary since it seems to be the primary motivation the tobacco companies get to move to heat-not-burn products. This is indicated by repeated lawsuits as a response to national regulations (especially when plain packs and alleged loss of intellectual property is involved) and them getting declined.

The next logical step is shifting nature of the industry in a way that is not as much regulated or harmful and the heat-not-burn segment is a perfect response for that, especially for LAS who do not fancy electronic cigarettes or consider them too mild. Yet the regulations that are protecting the population and limiting profitability of the industry still seem to remain the major trigger of these expensive innovations, especially when they get modified over time to include new tobacco products (many countries have already started regulating electronic cigarettes). As well as that, the chapter is partly dedicated to taxation of tobacco products (namely cigarettes) since it represents another kind of regulation of the industry directly impacting profits of the companies. Emphasis is placed upon the Japanese market and the EU legislation since these are the markets where the smokeless products have been placed lately (Japan as a primary choice, then EU market).

Since these new products mostly do not fall under the existing regulation (or the regulations are too mild being created some time prior to it) and their taxation needs legislative adjustment, it is only matter of time until the new heat-not-burn products get under stricter restrictions too to serve as they were intended – an option for LAS who would not quit conventional smoking otherwise. This will also be influenced by increasing number of independent studies of mid-term and long-term impact of their usage and a heated debate if "less risky" should go together with "less regulated".

3.1 Tobacco regulation – Japan

The tobacco regulation in Japan is pretty different from other parts of the world. Text warning is required to cover at least 30% of both the front and the back part of a box and if wording on the package includes statements such as „mild", „ultra-light" or „low tar", an extra warning must be added to clarify that the product is no less harmless than classic cigarettes.

However, basically no other laws restrict promotion of cigarette brands all over the country. The industry is largely self-regulated[35] and operates upon official recommendations for tobacco companies not to advertise „excessively". Indoor smoking in public places is not prohibited by law but once again – recommendations are provided for employers and business owners to create a pleasant environment without excessive smoke. There are a few exceptions on a regional level - bans are placed upon outdoor smoking in crowded public places in a few prefectures. Chiyoda, a wealthy ward of Tokyo and center of business and government institutions was the first one to apply such rules in 2002[36]. However, special smoking areas usually follow such bans.

Regarding taxation (even though it is not purely regulation in its own right), national consumption tax is imposed but various regions have the right to impose their own additional taxes, determining a more precise final % that tax takes off a cigarette box revenue is a lengthy process. Since revenues from tobacco products are a common choice to aid government budgets, recently there have been voices to raise the imposed national tax on cigarettes. In October 2017, a newly formed Japanese government (led by prime minister Shinzo Abe who is in charge of Liberal Democratic Party) declared intentions to spend more public resources on matters of child care and also education, which is supposed to be financed by announced consumption tax increase from current 8% to 10%. However, as the government intends to keep lower tax on necessary basic goods, the difference is planned to be offset by increased tax on tobacco products and probably financial transactions[37]. This creates further incentive to promote heat-not-burn products, but the big success of iQOS, GLO or Ploom TECH in Japan is motivating creators of tax legislation to turn attention to this area as well.

Cigarettes sold in the Japanese market are nationally taxed per piece at 12.24 JPY (approximately 0.1 USD[38]) which makes it approximately 245 JPY (2.22 USD) for a standard 20-cigarette box. The selling prices of cigarettes range approximately from 430-460 JPY (3.9 USD to 4.2 USD) which makes the national tax around 50% of the price[39]. Since heat-not-burn devices contain less tobacco (and thus less normal-cigarette equivalents), they can be taxed by a

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[35] Meaning it voluntarily avoids certain business or marketing practices deems unsuitable without legal requirements to do so
[36] BBC NEWS World Edition, for full citation please see Sources – item [22]
[37] The Japan Times News; for full citation please see Sources – item [23]
[38] The mid-market exchange rate used is 1 JPY = 0.00905529 USD from (January 15th, 2018)
[39] Regionally imposed taxes would need to be added for a complete picture

significantly lower sum (according to Henmi and Ishibashi, Nikkei authors[40]) of 34 to 192 JPY (0.3 USD to 1.7 USD) depending on the actual tobacco content. With this lower taxing, heat-not-burn sticks or cartridges are sold at very similar prices as conventional cigarettes and generate higher marginal contributions for the manufacturing companies. This is naturally an incentive for arising new regulations to prevent lost tax income for public budgets as legal adult smokers switch to smokeless tobacco alternative.

E-cigarettes are banned in the country as long as they contain nicotine-laced liquid. Only nicotine-free variants are freely sold, which might seem slightly odd given the benevolent tobacco regulations. Officially, this is because of toxic substances such as formaldehyde or acetaldehyde are released in doses ten-times higher compared to conventional cigarettes. A more realistic reason seems to be that e-cigarettes pose a rival segment for classic tobacco, in which a great stake is held directly by the Japanese government[41]. However, shipping of nicotine e-cigarettes to Japan from other countries is not prohibited (even though extra custom fees apply). This reason contributes to explanation of why Japan is such a popular battleground for heated tobacco – apart from the Japanese being enthusiastic consumers of novelty electronics, the tobacco regulations are not a big obstacle and there is no competing alternative, such as nicotine e-cigarettes, therefore testing results are bound to look better in financial reports than in other potential markets.

3.2 Tobacco regulation – EU

Regulation of tobacco products in the European Union falls under the Tobacco Product Directive (2001/37/EC)[42]. The latest version of the TPD was proposed in December 2012 and the content of new restrictions was approved by most of the EU member states in December 2013. Poland (supported by Romania) challenged ban on highly popular menthol cigarettes[43] before the Court of Justice of the European Union, but their claims have been dismissed in May 2016 when the court confirmed lawfulness of the menthol ban.

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[40] For full **citation** please see Sources – item [24]
[41] The previously mentioned 33% stake of the Japanese government in Japan Tobacco Inc., which controls 66% of the domestic market
[42] „directive" meaning that the member states are obliged to comply with the norm by implementing their own legislation by the set deadline
[43] Expected to become effective as of May 2020

In February 2014, the TPD got a formal approval by the European Parliament and came into force in May of the same year. Since this, the member states had two years to incorporate the directive into their legislations and fixed deadlines for phase-outs of certain product categories have been set.

Figure 8: Design of a cigarette pack after the TPD (source: ec.europa.eu)

The TPD dictates several major changes in both kinds of tobacco products that will be banned entirely and packaging and presentation of the allowed products. The most prominent change that has already taken place in most of the markets is obligatory pictorial warning as an addition to previously mandatory text warning taking up 30% of the box. The combination of a warning picture and text is newly required to take up at least 65% of top of the box both on its front and back.

Another change is prohibiting production of cigarettes or fine-cut tobacco flavored by menthol or other flavors covering taste of tobacco, for product categories with at least 3% market share as of 2020[44]. TCNO labelling[45] was replaced by 'Tobacco smoke contains over 70 substances known to cause cancer.' information since numeric TCNO created a misleading impression that LAS could choose a less harmful cigarette. Also, the only acceptable option for cigarettes will be a cuboid-shaped box of at least 20 sticks and no information on it referring to „less smell", „fresh

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[44] This restriction was already implemented e.g. in the Czech market when popular blueberry capsules went out of production in fall 2016

[45] tar, nicotine and carbon monoxide

taste" or anything similar is permissible. One more brand-new requirement concerning conventional cigarettes is the necessity to report ingredients and substances in all the products placed on the EU market via a standardized electronic form.

Figure 9: Cigarette plain packaging in the UK (source: scottishgrocer.co.uk)

Apart from the newly-approved restrictions, there have been national promotion and usage regulations varying across markets with some signs in common – promotion of tobacco brands anywhere where the age of a person cannot be checked upon entrance (apart from promotion in close proximity of points of sale – i.e. in immediate surroundings of tobacconist shops).

Plain packaging is not required by the TPD, just recommended, but some European governments have taken initiative and passed the law voluntarily – apart from previously mentioned United Kingdom (where the policy resulted in a lawsuit), the policy is currently in practice in France, Ireland and Hungary. In Ireland, plain packs went to market in fall 2017, yet simultaneous sales of already manufactured cigarettes in original packs is still permitted until fall 2018. Hungary made the policy effective since August 2016, but mandatory plain packs only apply to newly registered cigarette launches and as of May 2019, plain packs are obligatory for the whole market. The law for plain packs was also passed in Slovenia in July 2017 and its transition period for manufacturers and retailers ends a year later.

The TPD also newly aims to regulate electronic cigarettes with nicotine liquid, setting maximum values of nicotine concentration and maximum volume of liquid cartridges. As well as that, packaging of an e-cig is now required have a health warning and list of ingredients. One of

the most proactive countries in enforcing all kinds of tobacco regulation is Hungary, which in 2015 announced ban on using electronic cigarettes in all public places where the traditional ban on conventional cigarettes applies combined with the e-cigs only being allowed to be sold at special specialized tobacconists – regardless of the fact if e-cigs in question contain nicotine-laced liquid or not[46]. This fact makes it the regulation stricter than required by the EU directives. The ban came into force in May 2016. This makes an example of a market where heat-not burn products may have particularly hard time succeeding as opposed to other markets where networks of restaurant, bars and public places friendly to heat-not-burn products have started to be built.

Legislation regarding excise tax on tobacco products in the EU is aiming towards harmonization across countries[47] and, evidently, the member states are getting close. Current tax burden on an average cigarette pack across the states is around 75%-80% (according to the data collected by the European Commission in 2016) and it is highest in Ireland (approximately 85%) and lowest in Luxembourg (below 70%), as visible from *Figure 10*.
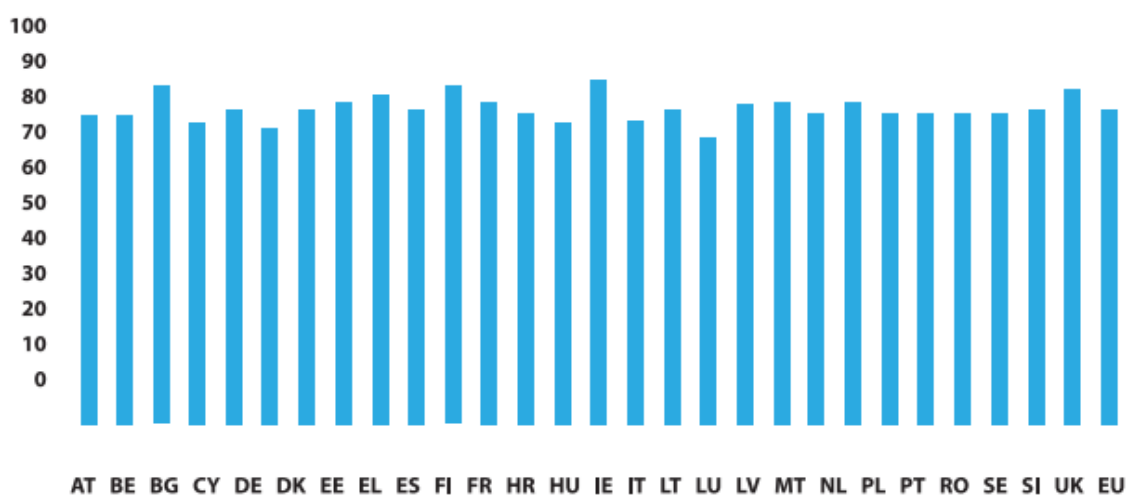
Figure 10: Tax burden on cigarette revenues (% of weighted average price) in the EU member states (source: European Comission)

The tax structure is seemingly a bit more complicated compared to Japan, yet thanks to efforts to unify it across countries, it might become more comprehensible than region-varying Japanese taxation. It consists of classic value-added tax (VAT) calculated as certain percent

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[46] FTCT, WHO Framework Convention on Tobacco Control (2016), for full citation please see Sources – item [26]
[47] The EU strives for harmonization of taxes in general, not just of tobacco tax

surcharge to package price without VAT, and of excise tax[48] created by combination of specific and ad valorem component. The specific component stipulates a fixed amount of tax per cigarette (e.g. 1.5 CZK per cigarette) which is multiplied by number of cigarettes in a box. This does not necessarily mean times 20 since packages containing more than 20 cigarettes (but instead up to 30 or 40) are traditionally popular in some EU markets such as Germany. Ad valorem component is set as a % amount (currently 27%) of maximum retail price (including VAT) and added to the specific component. It this resulting sum does not reach certain minimum value per cigarette, then the prescribed minimum is multiplied by number of cigarettes and used as the minimum allowed excise tax. The European Union declares also final intended excise tax burden across the member states – namely at least 90 EUR (for 1000 cigarettes) and minimum of 60% weighted average selling price. The minimum values are established as the ad valorem component might motivate the manufacturers to lower the retail selling prices across portfolio and thus hinder the original intentions of the regulation – decline of cigarette consumption.
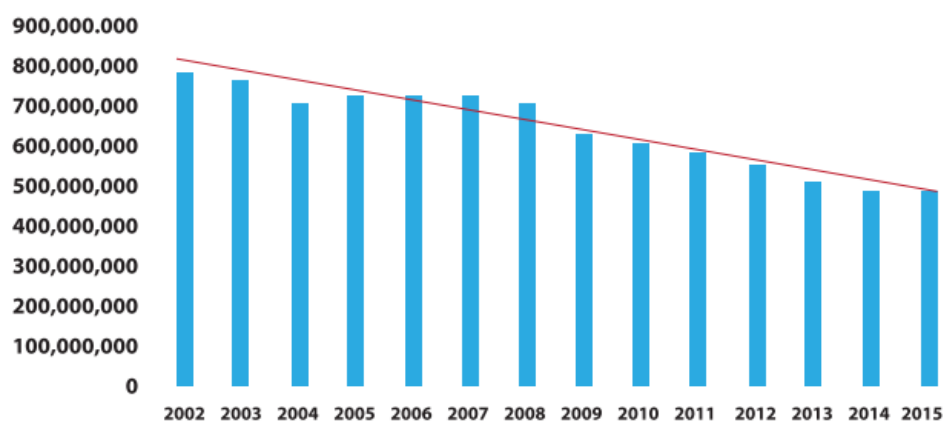
Figure 11: Consumption of cigarettes in the EU 2016 (thousands of pieces; source: European Commission 2016)

The specific and minimum components have been steadily increasing across the member states to synchronize the taxation and to reach the above-mentioned goals gradually, which led to increasing prices to a certain extent, certain decline in cigarette consumption (see *Figure 11*) and decreasing operating income of the tobacco industry as a whole as a result of these two reasons. This adds one more significant quantifiable motivation the companies had for investing in research&development of smokeless tobacco products.

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[48] Excise tax is a kind of tax imposed upon selected consumer goods either because of low price elasticity or due to intention to penalize the product because of its harmful nature (e.g. also mineral oils, alcohol, etc.)

One side effect caused by increased regulation (either on the EU or national) level is the fact that smokers have started switching from conventional cigarettes to other burning tobacco alternatives (since electronic cigarettes do not provide similar nicotine delivery) such as fine-cut tobacco or cigarillos[49]. This phenomenon is called „tax-induced" substitution and is caused by lower taxation of fine-cut tobacco compared to cigarettes (taxation is applied as a sum per a weight unit). The European Commission is trying to catch up on this and fix this effect by stipulating gradually increased minimum taxes on fine-cut tobacco as well. Currently the minimums are at least 46% of weighted average selling price (VAT included) or 54 EUR per kilogram. These rates are about to be increased to 50% and 60 EUR (respectively) by 2020.

Looking at this phenomenon, the legal adult smokers switching from cigarettes to fine-cut tobacco are mostly motivated by price since rolling or filling cigarettes has steadily been seen as inferior to conventional cigarettes[50]. Heat-not-burn tobacco sticks/cartridges are typically priced on level of premium od medium price segment so evidently the trend (as a response to increasing regulation and taxation) is decline in cigarette consumption but it is accompanied by hidden switching of economically-thinking LAS to fine-cut tobacco or premium/medium-oriented smokers to new smokeless products. This is something spotted by the European Commission and already intended for further revisions of regulations and taxations of tobacco products.

3.3 Tobacco regulation – Australia

Australian market is under more strict regulations with its introduction of plain packs in 2012 (as mentioned before) which resulted in a lawsuit by a tobacco company. The packaging, apart from being strictly dark-olive-colored and having a unified font of brand and cigarette variant name across all portfolio, must be covered by a combination of text and pictorial health warning at least 75% from the front, 90% from the back and fully from one side. Virtually all forms of promotion and sponsorship are forbidden (with certain exceptions of promotion in a specialized point of sale).

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[49] Cigarillos are, unlike cigarettes, wrapped in tobacco leaves instead of paper and often lack filters, which typically leads to taste coarser than classic cigarettes
[50] Even though in some countries, rolling one's own cigarette has become a non-mainstream trend

Smoking is banned in most indoor public spaces and restricted in the rest, smoking bans/restrictions also apply in outdoor places. The law varies across particular states and territories.

3.4 Tobacco regulation - USA

The tobacco regulation in the U.S. market is under supervision of the Center for Tobacco Products, which is a branch of the Food & Drug administration, founded in 2009 as a response to Family Smoking Prevention and Tobacco Control Act. This act also banned any synthetic or natural tobacco flavor (except for menthol).

In 2016, several changes were made to the area of the FDA jurisdiction since prior to the change, only conventional cigarettes, fine-cut tobacco, roll-yor-own tobacco and smokeless tobacco products were regulated. The FDA started to newly regulate all tobacco products including cigars, pipe and waterpipe tobacco or also so-called "electronic nicotine delivery systems" - most importantly meaning electronic cigarettes. Otherwise the rules resemble the European TPD – mandatory health warning (including a picture), ban on certain kind of promotion or sponsorship etc.

In 2016, Altria/Philip Morris International filed for the FDA's approval to launch iQOS in the U.S. market and currently investigations are being performed, with decision being expected to arrive as early as February 2018. Meanwhile, the company has started preparing for potential launch and the tobacco sticks should be branded under Marlboro. British American Tobacco has completed acquisition of Reynolds American six months ago and is likely preparing to file the approval as well.

4 METHODOLOGY

This chapter aims to explain what purpose the event study methodology serves, its core logic and implications, several different approaches that can be used and various different model it can be built upon and that are commonly used. It is supposed to serve both as an explanation of the analytic methods used in the Practical Part and as an overview of possible methods that may not end up as a fruitful solution in this case, to clarify possible options.

4.1 Event study – basic principles

Event study methodology has had a long history most likely traces back to as early period as 1930s. Regarding fields of accounting, finance or capital markets, event study methodology can be used for a wide range of events that can be either company-specific (or security-specific) or market-wide shocks. This causes the fact that there is no single strict order of steps to take and a chosen approach should be adjusted to character of the particular data, industry, market and event causing the shock.

The basic principle of event study is that a shock-inducing event influencing e.g. value of stock prices causes abnormal returns (either positive of negative) that can be measured and attributed to the event as its consequence. It is necessary to estimate so-called normal returns that would occur in case the event never happened and then obtain abnormal returns by deducting normal returns from actual returns. Resulting abnormal returns then can be depicted either as cumulative abnormal returns/losses or be directly calculated into monetary value of equity.

The basic assumption of the event study is that markets absorb new information quickly and fully (in other words that the markets are effective) and that systematic long-term abnormal returns do not exist. Another important assumption is that moment of the event can be established (potential problem with insider trading and other types of information leaks).

Normal returns are typically estimated by extrapolated ex-post predictions produced by an appropriate model. The model is estimated either on pre-event data or on both pre-event and post-event[51] data. The period for which normal returns are estimated and which is supposed to be affected by the event is called event window. It is necessary to state that establishing the extent of

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[51] Post-event meaning the time period when the target event is supposed to no longer influence the values

pre-event data period length and even more setting width of event window is quite arbitrary, subjective and depends on judgement of an analyst, while influencing results of the analysis profoundly. Another problem, not inherent for the methodology but rather market reality, is determining the date of event – especially since some events might first announced as an intention that does not have to come to fruition and then further phases of confirmation cause separate shocks or insider trading might come to the picture and the security prices start responding to the even information even before the official announcement.

The logic can be used in a cross-sectional simulation on a sample of multiple companies (more precisely, their security price data series) estimating a model that does not, on average, show statistically significant abnormal returns across the chosen portfolio of securities prior to the event[52] and thus estimate a typical response of a security to a particular type of an event such as merger, stock split, quarterly financial results etc. According to Kothari and Warner (2006)[53], another way is to use an analytical approach on a single security which is frequently used as a supplementary element, but often provides similar results – meaning the prices are simply projected by the model ex-post.

Regarding the cross-sectional approach, Brown and Warner (1985) mention several problems such as normal-distribution assumption for daily returns of the securities included in the sample, yet it is noted that as long as the excess returns across securities come from identical distributions with fixed variance and they are not dependent, the more securities are included in the sample the more the mean excess return distribution converges to normality (which is in line with the Central limit theorem). Another problem is connected to models involving market indices. If a market index is based on securities traded e.g. on NYSE or NASDAQ and some of the securities investigated are traded e.g. in a different time zone (non-synchronous trading), the Ordinary Least Squares (OLS method) can produce heavily biased estimates. Scholes and Williams (1977) therefore propose a modified approach to accommodate this this fact.

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[52] e.g. sample od data series of companies that underwent a merger
[53] For full citation please see Sources – item[17]

4.2 Normal Return Models

To estimate alleged normal returns without influence of the event, an appropriate model must be chosen. MacKinley (1997)[54] divides these models into two categories – statistical and economic. Statistical models rely heavily on statistical arguments and relationships and do not formulate any assumptions about economic behavior of capital markets or individual investors. This group of models is represented e.g. by constant mean return model, market model or other models such as those of ARMA family, ARMA-GARCH and their various combinations and modernizations. Economic models assume certain behavioral correlations of markets and the ones often used are Capital Asset Pricing Model (CAPM) and the Arbitrage Pricing Theory (APT).

4.2.1 Statistical models
4.2.1.1 Constant Mean Return Model

$$r_{it} = \mu_i + \varepsilon_{it}$$

r_{it} ...i-th return in period t

μ_i ...average return in the given period

ε_{it} ...random shock to the mean i-th return in period t

...where $E(\varepsilon_{it}) = 0$ and $var(\varepsilon_{it}) = \sigma^2$

Constant mean return model assumes that returns can be projected as a combination of mean return in the given period t and a random shock ε_{it} for each of the returns in period t. This model is more often used for returns in form of absolute numbers rather than percent values and of course it is highly dependent on choice of the t-period, random shocks in the period[55] and length of the set event window. However, Brown and Warner (1985) argued that more sophisticated models bring little enhancement to accuracy compared to the constant mean return model. However, Brown and Warner focus particularly on short-term event studies and the longer the event period, the more crucial the appropriate model.

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[54] For full citation please see Sources – item[15]
[55] Basically exceptional shocks violate the assumptions of zero mean and constant variance of ε_{it}

4.2.1.2 Market Model

Market model builds predictions on an assumption that a stock's price development can be explained by its correlation with an index representing the market development. Of course, the index should be representative enough (e.g. industry-specific indices should be generally more accurate than general market indices), yet not heavily influenced by the price development of the particular company[56].

$$r_i = \alpha + \beta * r_{market} + \varepsilon_i$$

r_i …return of a stock price

r_{market} …returns of a market index

εi …random shock

…where $E(\varepsilon_{it}) = 0$ and $var(\varepsilon_{it}) = \sigma^2$

Parameters of the model are estimated as a simple regression via OLS (Ordinary Least Squares) method and random shocks should have zero mean and constant variance. As it will be shown in the Practical Part, specifically tobacco company stock is bound to have troubles being estimated based on an industry-specific index, since number of the industry players is limited.

Market model is also a bit of an improvement company to constant mean return model since it captures influences of market fluctuation.

A certain simplification of market model is "market return model" which can be seen as its restricted version with zero alpha and beta coefficient equal to one (more in MacKinley (1997)). Logically, setting event window in this version is unimportant as any above-market return (minus the market return) is considered an abnormal gain and any below-market return (minus the market return) is seen as abnormal loss.

4.2.1.3 ARMA(p,q)/ARIMA(p,d,q) models

ARMA(p,q)/ARIMA(p,d,q) models stand for Autoregressive (Integrated) Moving Average models that try to capture dependence of time series values either on their past values (AR-Autoregressive part, order p) or past random shocks (MA-Moving Average part, order q). The time

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[56] This would be modeling dependence of a stock price on itself

series that ARMA(p,q)/ARIMA(p,d,q) models can be applied on first has to be stationary[57] and therefore sometimes various data transformations are required first – the basic choice being integration of time series. Integration in this context means working with differenced values of the original time series(1st degree integration), or with differences of the differences (2nd degree integration) and this degree of integration is market in the d-order. The model itself can be expressed in this general form the way it is outlined in Arlt, Artlová, Rublíková (2002)[58]:

$$\boldsymbol{y_t = \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + \ldots + \varphi_p y_{t-p} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots - \theta_q a_{t-q}}$$

y_{t-1} to y_{t-p} ...lagged values of the return series up to lag p

a_{t-1} to a_{t-q} ...lagged estimated random shocks up to lag q

The orders of the model are determined by the necessary order of integration to stationarize the series (d)[59], the necessary maximum order of lagged return values included in the model (p) determined by partial autocorrelation function (PACF) and the needed lags of a_t (q) set according to results of autocorrelation function (ACF). The residuals not captured by the model should have, once again, zero mean, constant variance, no autocorrelation left and ideally should come from normal distribution[60].

4.2.1.4 ARCH(q) and GARCH (p,q) models

ARCH(q) acronym stands for Autoregressive Conditional Heteroskedasticity and it represents a model capturing some patterns left in estimated random component of the model (or used on the data series outright). With certain simplification it can be compared to applying the ARMA structure/logic on conditional variance of the model which is supposed to capture and describe a phenomenon called volatility clustering.

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[57] Stationarity meaning quality of a time series that has its mean, variance and distribution independent of time
[58] For full citation please see Sources – item [19]
[59] Sometimes differentiating the series does not stationarize the data and a different form of data transformation is required – such as logarithmization, Box-Coxx transformation or others
[60] Residuals complying with these requirements are basically white noise

In certain periods of shock information[61], higher oscillation of security prices can be observed, especially in case of negative shocks. Intuitively, volatility likely increases also in case of positive shocks, but not as much as in case of panic sales. These periods of higher and lower volatility seem to group together and create so-called volatility clusters (periods with more frequent oscillation with bigger magnitude). To find out if volatility clustering can be further captured by a model, correlation functions of squared residuals need to be examined in a fashion similar to looking for AR(I)MA(p,d,q) orders. Autocorrelation in squared series (both in data or residuals), or in other words conditional heteroskedasticity, is usually labeled as ARCH effect. The ARCH(q) model can be written down as follows:

$$\varepsilon_t = \sigma_t z_t$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-2}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2$$

ε_t ...error term in a particular time series model

ε_{t-1} to ε_{t-q} ...lagged error terms up to order q

z_t ...from i.i.d $(0,\sigma)$

The model evidently builds upon assumption that serially autocorrelated squared residuals can be further modeled by including lagged error terms as explaining variables (analogy to modeling MA(q) processes).

An extension of ARCH(q) models is GARCH(p,q) model family, meaning Generalized Autoregressive Conditional Heteroskedasticity. Compared to ARCH(q), GARCH(p,q) also includes estimated conditional variance to lag p in the model as variables and it aims to capture conditional variance more accurately. The model can be written as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-2}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \beta_2 \sigma_{t-2}^2 + \ldots + \beta_j \sigma_{t-p}^2$$

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[61] A classic example is financial crisis 2008-2009 where volatility rapidly increased market-wide

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_i \sigma_{t-j}^2$$

ε_t ...error term in a particular time series model

ε_{t-1} to ε_{t-q} ...lagged error terms up to order q

σ_t^2 ...conditional variance in a particular time series model

σ_{t-1}^2 to σ_{t-p}^2...lagged conditional variances up to order p

In practice, ARMA and GARCH approaches are combined to maximize reliability of a model. First, ARMA structure is fitted on a stationary time series and then, if squared residuals show statistically significant autocorrelation, GARCH approach is used to model random shocks, thus creating an ARMA-GARCH model. However, it might happen that the data series shows no autocorrelation leaving no room for fitting an ARMA mean equation and then the data can be treated as residuals for GARCH.

4.2.1.5 Realized GARCH(p,q)

Obviously, the GARCH models are primarily used for conditional volatility predictions and do not provide joint solutions for forecasts of both volatility and expected returns. Additionally, recurring criticism of the very concept of GARCH models has been present for a few years. For instance, Andersen, Bollerslev, Diebold and Labys (2002)[62] argue that GARCH models based on use of moving averages (thus including lagged squares of returns[63]) are slow to catch up on suddenly increased persistent volatility compared to using realized volatility instead. It is stressed up that this effect is much more profound when dealing with high-frequency intraday data. However, even when using daily returns from closing prices, a measure of realized volatility is still a more accurate representation of volatility to model conditional variance.

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[62] For full citation please see Sources – item [21]
[63] Assuming that returns are used in place of error terms in the model

There have been several studies lately trying to merge modeling both volatility and returns into a single model and one of them is a new model of GARCH family – so called realized GARCH.

Realized GARCH is one of the newer GARCH-family models and it has been presented in past decade. The main focus will be placed on the form first published by Hansen, Huang, Shek (2011), a research team based at the Stanford University and the Peking University. Its main point lies in two aspects – realized GARCH replaces lagged error term (which is in this particular specification of model also a squared return) by an appropriate measure of realized volatility[64], which is further captured and explained by the model in a so-called measurement equation as a variable dependent on conditional variance and leverage function. The other aspect, as the researchers claim, is providing a joint solution also including returns. To explain the logic, the model in its general form can be written down in this form:

$$y_t = \sigma_t * z_t$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 r_{t-1} + \alpha_2 r_{t-2} + \cdots + \alpha_q r_{t-q} + \beta_1 \sigma_{t-1}^2 + \beta_2 \sigma_{t-2}^2 + \cdots + \beta_j \sigma_{t-p}^2$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i r_{t-i} + \sum_{j=1}^{p} \beta_i \sigma_{t-j}^2$$

$$r_t = \xi + \delta \sigma_t^2 + \tau(z_t) + u_t$$

...where $\tau(z_t)$ is the leverage function[65]:

$$\tau(z_t) = \eta_1 z_t + \eta_2 (z_t^2 - 1)$$

y_t ...stock price returns

z_t ...from i.i.d.(0,1)

σ_t^2 ...conditional variance

r_t ...measure of realized volatility

u_t ...from N(0,λ)

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[64] e.g. realized variance, realized kernel or bi-power variation
[65] Also called the „News Impact Function"

Leverage function captures relationship between typical future volatility change as a result of changing returns and is closely connected to „news impact curve" – a curve describing typical percent changes of future volatility after a unit of a price shock[66] (going from strongly negative to strongly positive). This can provide an interesting quantitative answer to question if markets respond with higher volatility to a positive or a negative shock of the same magnitude (e.g. in case of a particular stock, or industry).

Empirically, the study claims to obtain better fitting results with a log-linear specification of the model[67]:

$$log\sigma^2 = \omega + \sum_{i=1}^{q} \alpha_i \, log \, r_{t-i} + \sum_{i=1}^{p} \beta_i log \, \sigma_{t-i}^2$$

$$log \, r_t = \xi + \delta log \, \sigma_t^2 + \tau(z_t) + u_t$$

$$\tau(z_t) = \eta_1 z_t + \eta_2(z_t^2 - 1)$$

The definition of the model according to Hansen, Huang, Shek (2011) represents certain improvement in modeling volatility, but its proclaimed joint capturing of returns is limited. However, it may serve as an option in case the data series is not exhibiting any reasonable ARMA structure and mean equation cannot be fitted.

4.2.2 Economic models

As mentioned before, economic models work with certain assumptions about behavior of markets. A common economic model used for event study or (or any kind of predictions generally) is Capital Asset Pricing Model (CAPM) and its other forms. The basic form of the model is formulated in this way:

$$r_t = r_{RF} + \beta(r_M - r_{RF})$$

r_t …return rate of a security

r_{RF} …return rate of a risk-free asset

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[66] The units are same as for standard deviation
[67] Also, the log-linear form is built in the RUGARCH package in statistical software R which will be used in the practical part

r_M …market return rate

r_M - r_{RF} …market risk premium

ß …coefficient of sensitivity to market risk premium

The model defines returns on a security (or a portfolio) as a combination of a risk-free rate[68] and a risk premium (ß(r_M - r_{RF})). The risk premium consists of market risk premium (set as difference between general market return rate and return rate on a risk-free asset) and beta coefficient which expresses extent of the security/portfolio response to market risk premium and therefore it captures influence of systematic risk on the returns[69].

The basic point of the CAPM model is to capture systematic risk influence and it is important to keep in mind that the value of beta coefficient can change depending on length period over which it is estimated. Beta of a company's stock is likely to change e.g. if a company has started its business transformation with significant investments (such as in case of the heat-not-burn segment pioneered lately by the big players in the tobacco industry).

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[68] Risk-free rate is a theoretical concept but a frequently used empirical proxy are returns on state-issued securities, especially returns of the U.S. treasury bills

[69] Beta coefficient equal to 1 mean that risk premium of a security/portfolio is the same as market risk premium; with ß>1 a security/portfolio provides higher risk premium than market; 0<ß<1 means lower risk premium compared to market; negative ß hints that particular security/portfolio moves in the opposite direction compared to market

5 PRACTICAL PART

This chapter strives for quantification of losses inflicted on Philip Morris International Inc.'s stock prices because of British American Tobacco Inc.'s GLO announcement and prediction of normal returns and prices. Afterwards, it shortly presents the situation with BAT's stock price development and elaborates on why it is suitable for further investigation beyond the scope of this thesis. As well as that, even though having a look at a shock caused by Japan Tobacco International Inc.'s Ploom TECH on PMI stock prices might be fitting for a comparison, it was previously mentioned that there was little impact, therefore further analysis is pointless.

The Philip Morris International Inc. data used for the practical part are closing stock prices on NYSE from January 4th 2010 up to January 31st 2017[70]. This time range is chosen to exclude the biggest impact of the 2008-2009 financial crisis volatility and to prevent interference with response to financial results announcement and annual report 2016 typically published in February[71]. The data range for model estimation is shortened to period ending on November 7th 2017 prior to the shock event (British American Tobacco Inc.'s announcement of GLO launch in Japan) regardless of the model used and consequently ex-post predictions/simulations are performed for period starting on November 8th 2016.

As generally known, usability of predictions weakens with length of prediction period. As well as that, December data of PMI stock prices might already be influenced by the regular dividend announcement[72]. These reasons lead to cutting off the arbitrary event window at the end of November 2016 or even at the end of the particular trading week (November 11th 2016) when estimating the GLO-shock-induced financial loss[73].

The S&P 500 index used is not industry-specific and the values used also represent closing prices. The data is sourced from the database maintained by the Financial Times.

The models that focus is placed on in the further analysis are market model and realized GARCH (for reasons explained further on) and e.g. CAPM model is not used since its main point is capturing influence of systematic risk. However, with tobacco companies that have started

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[70]Older data was used implicitly e.g. for 10-day realized volatility for January 4th 2010 with the calculation being based upon past 10 trading days overreaching to 2009

[71] Published precisely on February 2nd 2017 and February 14th 2017, respectively

[72] Announced on December 7th 2016

[73] Even though returns themselves have predictions until the end of January 2017

investing great amount of resources into transformation of their businesses, company-specific risk is likely to have significantly changed and the analysis would require a more complex approach.

The realized GARCH model used is the one from Hansen, Huang, Shek (2011) specification and it also briefly states news impact curve.

5.1 PRACTICAL PART – MARKET MODEL

The growing trend in development of Philip Morris International stock price slows down as of the end of 2012 (*Figure 12*). The most prominent factor appears to be the introduction of a revision proposal for the original *Tobacco Products Directive (2001/37/EC)* outlined and published by the European Commission in December 2012 (further mentioned as „TPD"), affecting the EU region of PMI.
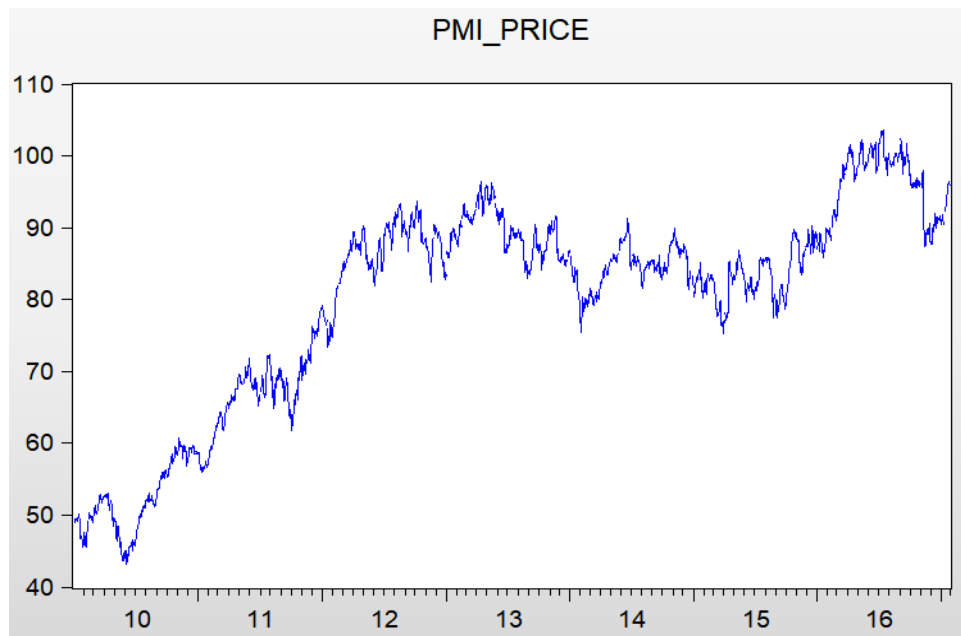
Figure 12: Philip Morris International Inc. stock price development (USD) 1/2010-1/2017

The ongoing revisions and negotiations of the TPD targeted matters from promotion rules of tobacco brands (impeding introduction of standardized plain packs across markets) through allowed stick count per package (placing ban on packages with less than 20 sticks) to restrictions placed upon popular cigarette formats – namely menthol-scented cigarettes and both menthol and fruity capsules.

The usual methods of event study used to determine normal returns[74] are a bit of a struggle when analyzing a tobacco company. The most frequently used market model focuses on modeling dependence of returns of a stock on a market index to predict normal return values. One option is to use an index representing the whole market, which, of course, will represent a looser inherent

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[74] As briefly listed in the Methodology chapter

dependence and therefore less precise ex-post prediction properties. Another option is to use industry-specific market indices either for „Tobacco" or „Food, beverage & tobacco". The obvious problem presents itself - nature of the tobacco industry (limited number of players in the game) inevitably makes a company as big as PMI constitute a big part of the industry index itself and thus warps sensibility of potential results. The Dow Jones Tobacco index is only focused on American tobacco companies, making Altria Group, Inc. and Reynolds American, Inc.[75] the main constituents. S&P 500 Tobacco index also includes foreign tobacco players traded on NYSE or NASDAQ, but this only adds Philip Morris International Inc. to the game.

Since the industry-specific indices are of little use, the market-model approach will be applied as a first estimation attempt. The chosen benchmark market index is S&P 500 which is robust enough to ensure that its values are not easily swayed by a particular company.

In its simplicity, the market model is unlikely to capture most of the PMI stock price influences and thus R-squared of the model cannot be expected high. However, it can capture fundamental relation to the market-wide mood and an ex-post prediction will help rule out a possibility that the PMI stock prices declined as a part of a more profound market shock than just a competitor's announcement. For the sake of estimation and knowing there are no other major shocks in a short run, the period until the end of November 2016 will be used. As generally known, the more long-term the prediction the less reliability it provides.

The relationship can be expressed as a simple regression in the following equation:

$$r_{PMI,t} = \alpha + \beta * r_{MARKET} + \varepsilon_t$$

...where ε_t from i.i.d.(0,1)

Since the constant has proven to be statistically insignificant[76], the regression is performed again without it providing the following estimation:

$$r_{PMI,t} = 0.69 * r_{MARKET} + \varepsilon_t$$

The R-Squared ratio is rather low (0.37) because of the above-mentioned reasons, yet residuals show no heteroskedasticity and are not serially correlated[77].

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[75] Now The British American Tobacco plc. (acquisition announced in January and approved in July 2017)
[76] Please see Appendix 2
[77] For all the tests please see Appendix 2
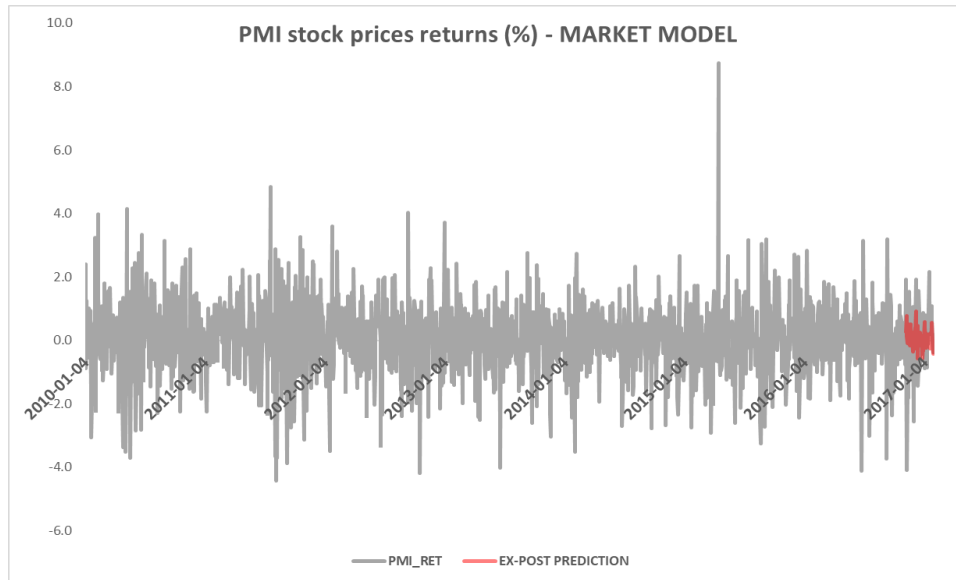
Figure 13: MARKET MODEL PMI stock price returns - actual vs. ex-post predicted (eViews 9; 10/4/2010 - 1/31/2017)

To estimate approximate normal values in the event period, ex-post prediction of the mean values will be used as a proxy.

Figure 13 depicts ex-post predicted values of PMI returns dependent on the market index by the end of January 2017 when a new major shock to stock prices typically occurs – an annual report. The ex-post predicted price for November 30th is 99.4 USD opposite to the actual price of 88.3 USD which represents around 11.2% loss of value because of the shock.
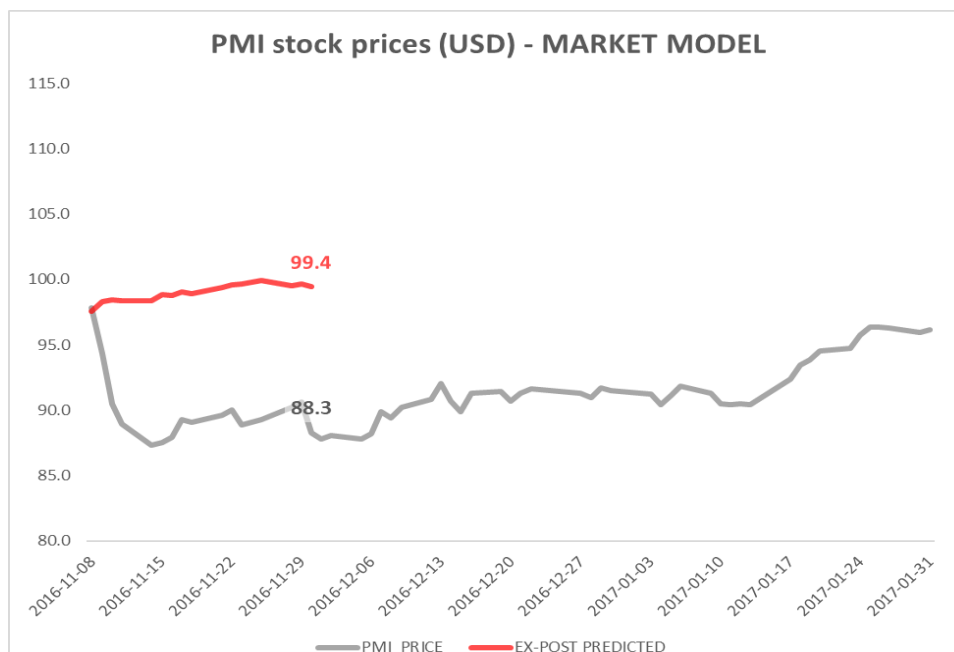
Figure 14: MARKET MODEL PMI stock prices - real vs. ex-post predicted (11/8/2016-1/31/2017)

Figure 15 shows specific daily losses calculated as shock-free ex-post prediction minus the actual returns. According to the model, the losses caused by the shock amount to up to 10-11 USD, more precisely up to 11.2 USD by the end of November which represents around 11.2% loss of value. Looking at a shorter period of time, the loss by the end of the trading week (November 11th) is 9.4 USD per stock (opposite to ex-post predicted value 98.4 USD) – around 9.6%.
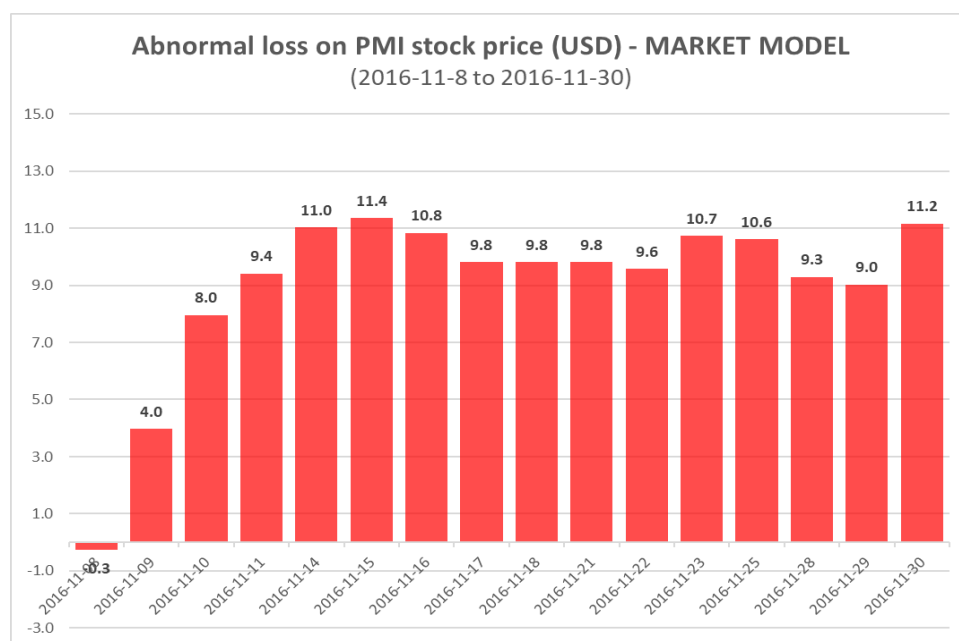
Figure 15: MARKET MODEL PMI stock prices - abnormal losses (11/8/2016-11/30/2016)

If the estimated loss is to be converted into an absolute sum of money, it needs to be multiplied by the number of shares in the market. The number of the shares outstanding which was 1,551,385,547 as of December 31st 2016[78] multiplied by an approximate shock-induced loss of 9.4 USD by the end of the trading week is in total around $14.61 billion. Extending this time period, until the end of the month the loss per share of 11.2 USD multiplied by the shares outstanding amounts up to approximately $17.32 billion.

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[78]Philip Morris International 2016 Annual Report, page 95; the number represents common shares outstanding; there no preferred shares issued by the end of 2016

5.2 PRACTICAL PART – REALIZED GARCH(p,q)

```
Null Hypothesis: PMI has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=24)
```

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.197312	0.4902
Test critical values:	1% level	-3.963393	
	5% level	-3.412427	
	10% level	-3.128160	

*MacKinnon (1996) one-sided p-values.

Figure 16: PMI stock prices ADF test (eViews 9; 1/4/2010 - 1/31/2017)

Another model idea that comes in handy relies upon Box-Jenkins methodology of applying autoregressive moving average (ARMA) on returns and/or the model residuals (known as GARCH – Generalized Autoregressive Conditional Heteroskedasticity. To estimate *normal* returns for PMI stock prices as of November 8th 2016 with these methods, first stationarity of the series must be examined. Judging visually from the chart in *Figure 12*, the series is likely non-stationary, which would subsequently require data series transformation before further analysis. To determine its stationarity/non-stationarity statistically, *Augmented Dickey-Fuller test* can be used to detect presence of a unit root, with a null hypothesis suggesting non-stationarity (*Figure 16*).
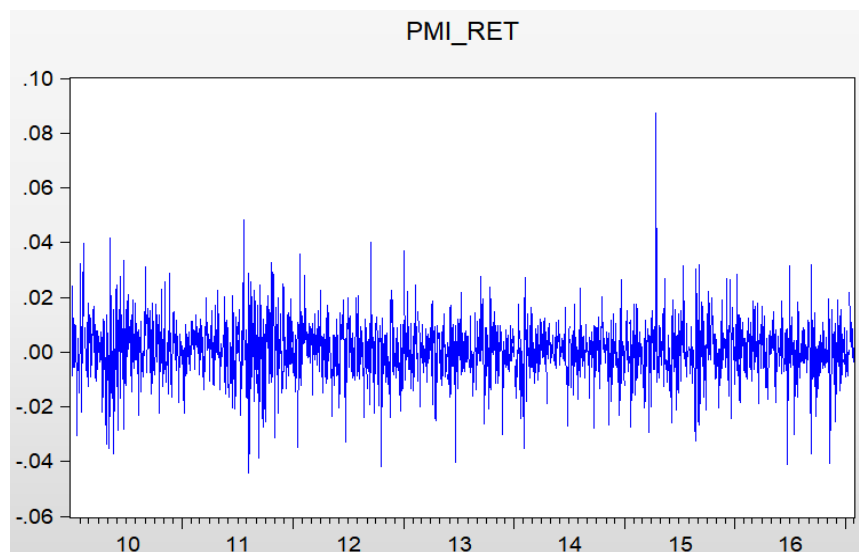

Figure 17: PMI stock prices returns 1/4/2010-1/31/2017 (eViews 9)

The conducted test with its p-value 0.4902 does not reject the null hypothesis (i.e. non-stationarity of the series is likely present, or more precisely not ruled out), therefore the data will be transformed to return values for further work.

The returns[79] in *Figure 17* already seem stationary. The ADF test is applied again, this time rejecting non-stationarity of the return series[80]. *Figure 17* chart shows certain volatility clustering and the variance is not constant (especially when dealing with shorter time spans), even though the effect is nowhere close to cases seen in the crisis period.

Sample: 1/04/2010 1/31/2017
Included observations: 1788

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.007	0.007	0.0861	0.769
		2	0.009	0.009	0.2230	0.894
		3	-0.023	-0.023	1.1322	0.769
		4	-0.014	-0.014	1.4838	0.830
		5	-0.033	-0.033	3.4699	0.628
		6	-0.010	-0.010	3.6430	0.725
		7	-0.011	-0.011	3.8791	0.794
		8	-0.012	-0.014	4.1540	0.843
		9	-0.045	-0.046	7.8437	0.550
		10	0.029	0.028	9.3504	0.499
		11	0.011	0.010	9.5774	0.569
		12	-0.005	-0.009	9.6159	0.650
		13	0.016	0.015	10.105	0.685
		14	-0.031	-0.033	11.850	0.618
		15	0.037	0.038	14.336	0.500

Figure 18: Correlogram of PMI stock price returns 1/4/2010-1/31/2017 - lags 1 to 15 (eViews 9)

Examination of a correlogram of return values in *Figure 18* seemingly shows no statistically significant dependence between the values in particular lags (the series do not seem autocorrelated). Since values are likely offsetting one another, the story might change when looking at a correlogram for squares of log returns in *Figure 19*.

Correlogram in *Figure 19* already shows not too big, but already statistically significant autocorrelation and partial autocorrelation of squares in first two lags. No significant correlation between non-squared values indicate that application of mere ARMA(p,q) models on returns would probably not be fruitful. These facts combined suggest that for prediction purposes, a ARCH/GARCH model for modeling conditional volatility are worth applying (and testing) attempting to model and ex-post predict the normal returns in the window period of the series. Even though classic ARCH/GARCH models are used for predictions of future volatility and not

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[79] Calculated as (return$_t$/return$_{t-1}$)-1
[80] For the full test, please see Appendix 2

for return forecasts, the new branch of this model family called *realized GARCH* (explained in the Methodology chapter[81]) will be used for joint modeling.
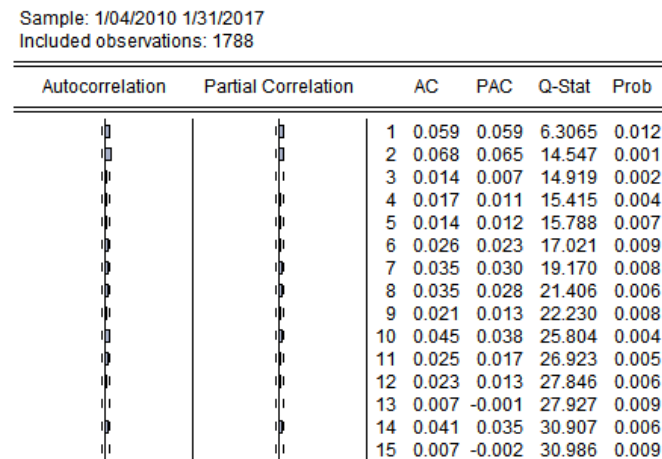

Figure 19: Correlogram of squares of PMI stock price returns 1/4/2010-1/31/2017 - lags 1 to 15 (eViews 9)

Since the return series does not exhibit any tendency towards a specific statistically significant non-zero constant, a trend or ARMA processes for the non-square values, the mean equation of the tested ARCH/GARCH models won't be fitted and thus the series itself will be treated as "residuals" in order to capture conditional volatility.

This model incorporating measure of realized volatility instead of mere squared returns will be used in its log-linear formulation along with 10-day standard deviation of returns as the measure of realized volatility. Since statistical software R already provides a „realGARCH" option for estimation, diagnostics and further predictions/simulations of the model in its RUGARCH package, it is used for creation of the following output estimating these orders: realGARCH(1,1), realGARCH(1,2), realGARCH(2,1) and realGARCH(2,2). It is up to discussion if realGARCH versions of greater orders are better to capture relationships in the data, but for the purposes of the thesis these options should be sufficient.

It turns out that the version of model with all parameters deemed as statistically significant is realGARCH (1,2)[82], which is in its own right insufficient to judge suitability of the model for predictions. Before using it for predictions, the next factors to judge qualities of the models are

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[81] Hansen, Huang, Shek (2011, JOURNAL OF APPLIED ECONOMETRICS)
[82] For estimations and tests of all the above proposed versions of the model please see Appendix 1

residual diagnostics (Ljung-Box residual and ARCH LM tests), maximum log-likelihood and Akaike and Bayesian Information Criteria.

	realGARCH(1,1)	realGARCH(2,1)	realGARCH(1,2)	realGARCH(2,2)
log-likelihood	-1447.938	-1449.098	**-1443.42**	**-1443.42**
AIC	1.6822	1.6847	**1.6781**	1.6793
BIC	1.7074	1.7131	**1.7065**	1.7108

Table 3: Log-likelihood and information criteria of the estimated realized GARCH up to order (2,2)

MODEL ESTIMATION

GARCH Model : realGARCH(1,2)
```
Mean Model       : ARFIMA(0,0,0)
Distribution     : norm

Optimal Parameters
------------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
omega    0.061249    0.019237   3.1840 0.001453
alpha1   1.000000    0.078601  12.7224 0.000000
alpha2  -0.723489    0.084970  -8.5146 0.000000
beta1    0.705637    0.073417   9.6114 0.000000
eta11   -0.008666    0.002890  -2.9984 0.002714
eta21    0.035902    0.001590  22.5791 0.000000
delta    0.978750    0.074234  13.1847 0.000000
lambda   0.121667    0.002095  58.0809 0.000000
xi      -0.207268    0.030203  -6.8625 0.000000
```

realGARCH(1,2)
Weighted Ljung-Box Test on Standardized Residuals
```
------------------------------------
                        statistic p-value
Lag[1]                     0.03864  0.8442
Lag[2*(p+q)+(p+q)-1][2]    0.27751  0.8084
Lag[4*(p+q)+(p+q)-1][5]    1.21244  0.8100
d.o.f=0
H0 : No serial correlation
```

Weighted Ljung-Box Test on Standardized Squared Residuals
```
------------------------------------
                        statistic p-value
Lag[1]                      0.1128  0.7370
Lag[2*(p+q)+(p+q)-1][8]     3.1563  0.6568
Lag[4*(p+q)+(p+q)-1][14]    5.0151  0.7676
d.o.f=3
```

Weighted ARCH LM Tests
```
------------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[4]     1.371 0.500 2.000  0.2417
ARCH Lag[6]     2.692 1.461 1.711  0.3565
ARCH Lag[8]     3.570 2.368 1.583  0.4427
```

It is necessary to note that the marking of GARCH(p,q) order is aligned with classic way in which it is used since R software marks the order as GARCH(q,p) both in its syntax and outputs.

All of the models display no autocorrelation either on normal or squared residuals and the ARCH LM test tracing any left ARCH effect in the residuals does not reject null hypothesis of absence ARCH effect.

As for Log-Likelihood, the model scoring the highest value is realGARCH(1,2). It is also scoring lowest for Akaike and Bayesian information criteria, even though realGARCH(2,2) scores just as low on the AIC. The combination of the tests and measures makes realGARCH(1,2) the most eligible option for the PMI stock price simulation[83]. The general realized GARCH (1,2) model specification can be expressed as follows[84]:

$$y_t = \mu_t + \sigma_t z_t$$

$$log\sigma^2 = \omega + \sum_{i=1}^{q} \alpha_i \, log \, r_{t-i} + \sum_{i=1}^{p} \beta_i log \, \sigma_{t-i}^2$$

$$log \, r_t = \xi + \delta log \, \sigma_t^2 + \tau(z_t) + u_t$$

$$\tau(z_t) = \eta_1 z_t + \eta_2(z_t^2 - 1)$$

...where:

y_t ...stock price returns

z_t ...from i.i.d.(0,1)

σ_t^2 ...conditional variance

r_t ...measure of realized volatility

u_t ...from $N(0,\lambda)$

$\tau(z_t)$ ... leverage function

The estimated realized GARCH(1,2) specification can be written down in this form:

$$y_t = \sigma_t z_t$$

$$log\sigma^2 = 0.061 + log \, r_{t-1} - 0.72 \, log \, r_{t-2} + 0.706 \, \sigma_{t-i}^2$$

---

[83] mostly because of having statistically significant parameters unlike the other versions of the model, other metrics do not show significant differences

[84] Please note that the signs used to represent variables differ from the ones in Hansen, Huang, Shek (2011) to align with methodology and marks incorporated to RUGARCH package in R

$$log\ r_t = -0.207 + 0.979\ log\ \sigma_t^2 + \tau(z_t) + u_t$$

$$\tau(z_t) = -0.009\ z_t + 0.036\ (z_t^2 - 1)$$
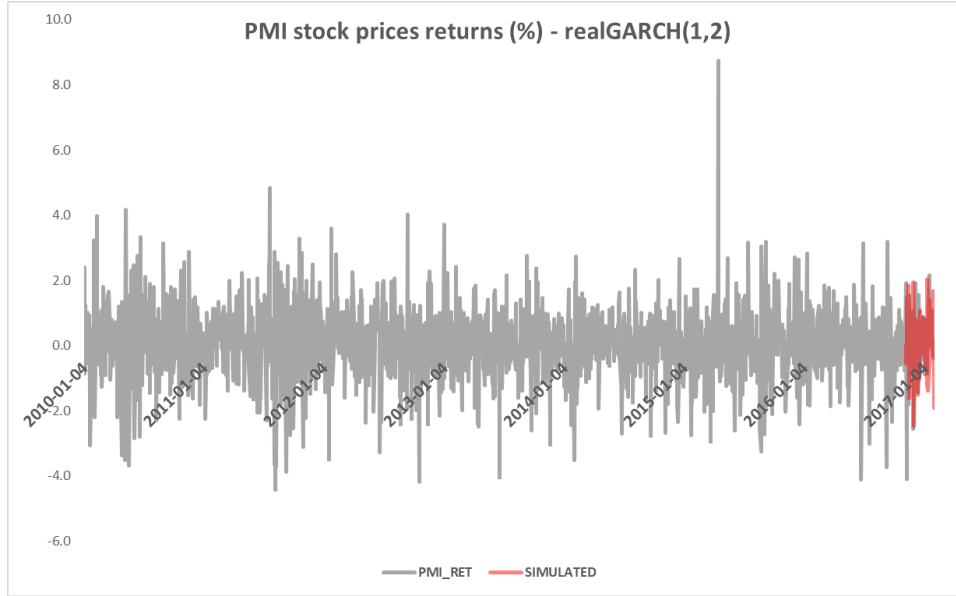
u_t ...from N(0,1.22)

Figure 20: Realized GARCH (1,2) PMI stock price returns - actual vs. ex-post simulation (1/4/2010-1/31/2017)

Since it was not possible to fit a mean equation for the model capturing an ARMA process and the Hansen, Huang, Shek (2011) specification of returns consists of conditional standard error and random innovation, data simulation available in RUGARCH R package will be utilized to get a more specific idea of shock-free normal returns. The simulation of the fitted values[85] of realGARCH(1,2) for returns (in %) is performed in and depicted price development for comparison of the simulated prices and the real performance including the shock.

In line with the basic event study premise, the model was estimated on the pre-event data since January 4th 2010 until November 7th 2016 and the red-line simulation in *Figure 20* begins as of November 8th 2016 to capture the event window. Apparently, the ex-post estimated normal returns show off higher volatility compared to the market model, which is understandable since the market model in this case settled for the mean values as opposed to realGARCH simulation (thus including simulation of random innovations).

---

[85] consisting of the estimated conditional sigma (standard error) and random innovation $\sim$ i.i.d.(0,1)
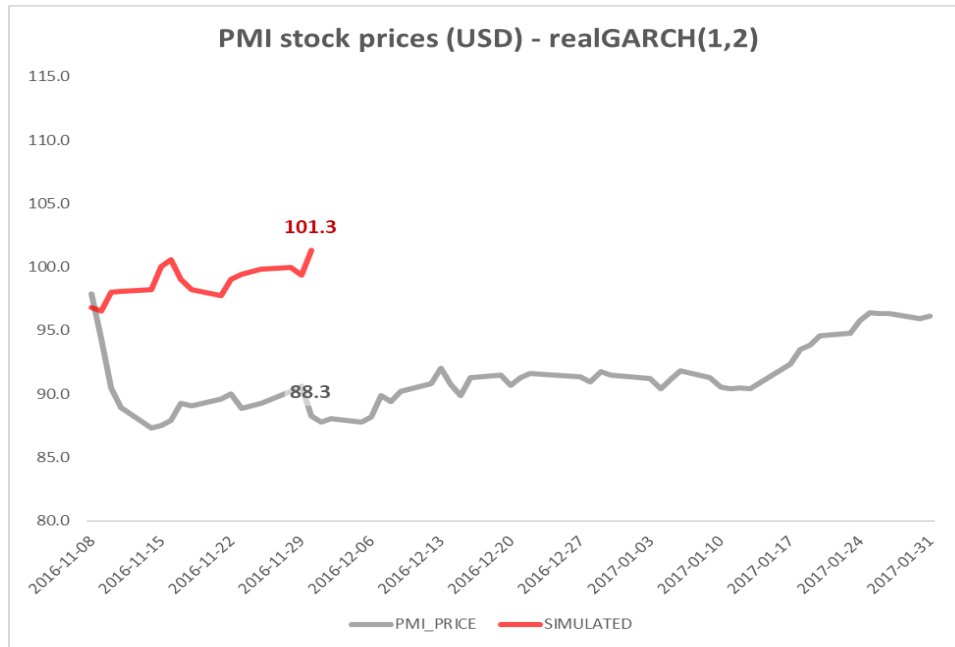
Figure 21: Realized GARCH(1,2) - PMI stock prices - real vs. ex-post predicted (11/8/2016-1/31/2017)

It is necessary to keep in mind that since the mean equation of realized GARCH consists of estimated conditional standard error and random innovation whose mean value is zero, the return simulation in R is the only reasonable choice to estimate hypothetical actual returns.
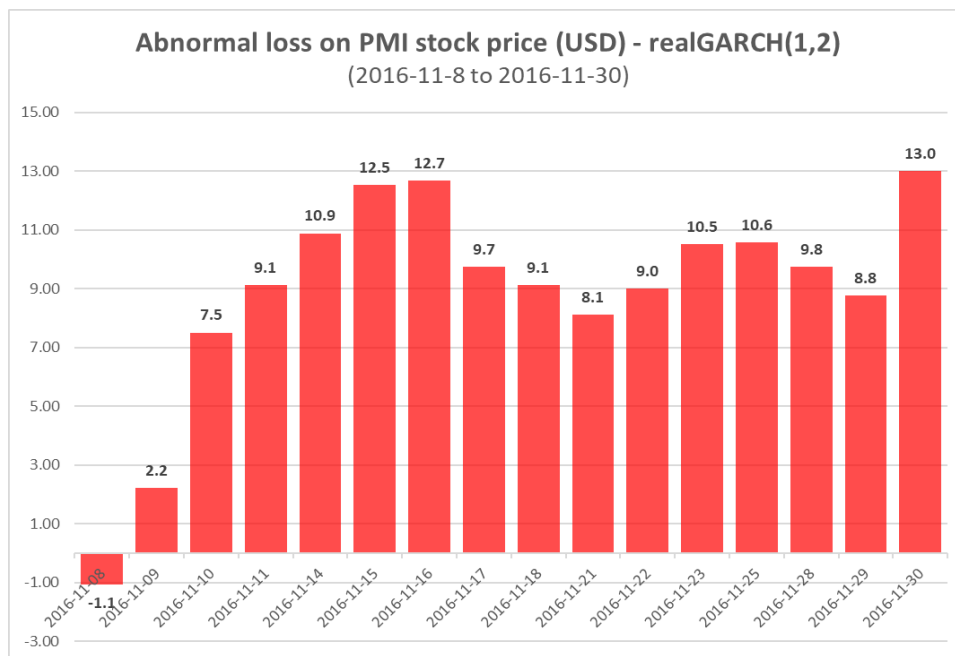

Figure 22: Realized GARCH(1,2) PMI stock prices - abnormal losses (11/8/2016-11/30/2016)

As visible from *Figure 21*, the simulated prices based on extrapolated conditional standard error insinuate a likely path of the price development without influence of the GLO announcement shock. Since this shock is one-of-a-kind[86], it does not interfere with historical price development upon which the model was built. *Figure 22* shows development of the abnormal daily losses[87] on a daily basis caused by the shock amounting up to 9.1 USD by the end of the trading week (9.3% of value opposite to simulated price 98 USD) and oscillating around 10 USD until the end of the month. The maximum goes up to around 13 USD and represents approximately 14.7% shock-induced loss of the stock value. Again, multiplying these losses by the number of shares outstanding brings the total sums of $14.16 billion by the end of the week and $20.18 billion by the end of the month.
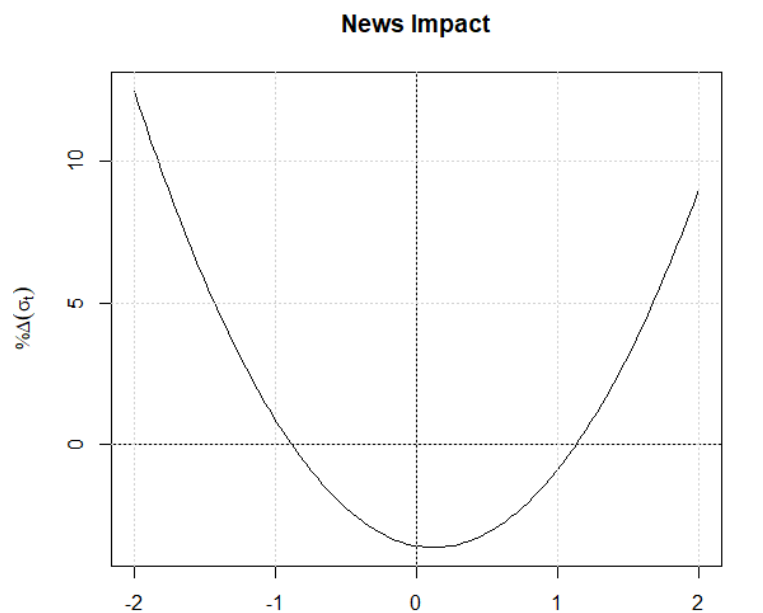
Figure 23: News Impact Curve (reaction of future volatility to random shocks)

Figure 23 provides one interesting additional information to describe general behavior of the PMI stock prices: impact of positive/negative shocks on future volatility of returns called News Impact Curve. This is represented as percent change of future volatility (y axis) in response to random shocks (x axis; measured in the same units as standard error). Apparently, in terms of volatility (and thus potential risk), PMI stock price returns respond to negative shocks more strongly than to positive shocks since we can see that 2p.p. positive shock to returns increases

---

[86] GLO is a second-to-market product of this kind, with iQOS considered to have created the „heat-not-burn" tobacco product market both in Japan and worldwide

[87] Calculated as daily simulated price minus daily realized price

standard error by around 9% whereas a negative shock of the same magnitude increases volatility by approximately 13%.

5.3 PRACTICAL PART – BRITISH AMERICAN TOBACCO IMPACT
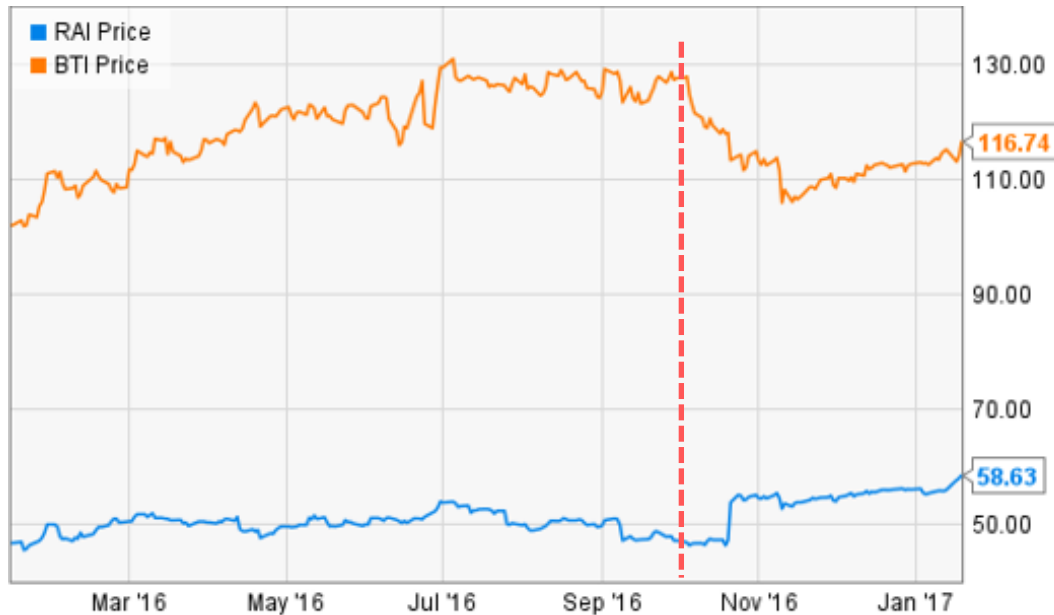
Figure 24: Reynolds American vs. British American Tobacco stock prices (source:YCharts)

It would be an interesting additional information on how much British American Tobacco Inc. gained from the announcement of GLO on November 8th 2016. However, BAT announced on October 21st the same year that it non-bindingly proposed acquisition of the remaining 58% of shares in Reynolds American Inc.[88] and the BAT's stock price slumped over the next month from its previous price of almost 130 USD per share below 110 USD, being accompanied by a sudden growth of Reynolds American. The acquisition intentions are highly likely to drive these significant price changes and in case of BAT surely interfere with possible positive effect of GLO announcement. Examining *Figure 24* a bit closer, it seems that the price fall slowed down a bit around the date of GLO announcement, but quantifying its impact separately from the acquisition message effect would be a longer process.

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[88] Controlling around a quarter of the U.S. market

This is where cross-sectional approach to event study would be appropriate – estimating an average response to an acquisition/merger of companies of similar size across industries to separate it from the effect of announcement of GLO. The trouble with attempts to apply the cross-sectional approach on the heat-not burn devices themselves is the fact that it is hard to find an appropriate sample of examples when launch of a new revolutionary product influenced the stock prices without making the sample biased or incompatible. Heat-not-burn devices have started shifting an industry heavily regulated worldwide and whenever they were launched for the first time with full force, the market of choice was Japan where the response is apparently overly enthusiastic thanks to absence of electronic cigarettes and the nation's reputation for loving novelty in electronics. A sufficient sample would require more than just a few examples and those would probably be influenced by completely different circumstances.

CONCLUSION

The tobacco industry is taking a serious shift in nature of business with the newly introduced heat-not-burn products and the main point of focus is the Japanese market. Philip Morris International Inc. had a good reason to choose this market as Japan belonged to the Asia region which was the biggest one for PMI in terms of cigarette shipments in 2015 (around the time of decision making and city testing) and within the region, Japan had a good share of market volume and solid PMI position in it. With its acquisition of 12% of the domestic market for the HEETS brand in just 2 years since nationwide launch, it attracted actions of competitors.

The domestic giant Japan Tobacco International (Japan Tobacco Inc.'s international division) was slow to catch up with their own device development and therefore quickly developed Ploom TECH device based upon patents and know-how acquired from Ploom start-up, launching it in a very limited way at the beginning of 2016 in just one city in Japan and its online store. Despite favorable price (approximately 90 USD for iQOS versus 36 USD for Ploom TECH), the announcement and market penetration caused no detectable harm to PMI stock prices (which is the reason it was not further investigated). The company is still struggling with Ploom TECH's nationwide distribution, the product receives subjective reviews as having not having satisfying taste and it does not seem as a strong rival for the other two devices. Since 33% of Japan Tobacco Inc. is owned by the Japanese government and JT controls 66% of the domestic tobacco market, their own Ploom TECH struggling is likely seen as a significant problem, especially taking into account strong growth of iQOS (PMI) and GLO (BAT). Voices asking for regulation of heat-not-burn devices in Japan have started to occur even though the country has relatively benevolent national regulations on conventional tobacco products.

Effect of announcement of GLO launch (November 8th 2016) on the PMI stock prices decline is the primary focus of this thesis. The device was launched with pricing below iQOS (90 USD for iQOS versus 72 USD for GLO) and again similar pricing of the tobacco sticks. GLO started the city test in one city, boasting 8% market share of a prominent key account chain store in Sendai in summer 2017, with nationwide launched planned for October 2017 (results will be published with the Annual report 2017). At the moment of announcement, the PMI stock prices went to down approximately from 98 USD per share to 87 USD by the end of the trading week. Other possible effects were ruled out since the PMI's quarterly report came in October 2017 and

dividend announcement in early December 2017 and no other significant news were found to cause such a decline other than the GLO press release. The better price, aiming at the market that seems to receive novelty in electronics well (as evidenced by iQOS), inability of Ploom TECH to catch up and much better supply-chain likely made GLO a capable rival to iQOS, thus influencing stock prices of PMI which is currently betting on smokeless tobacco products as its future for decades to come.

The logic for quantification of this financial impact was taken from event study methodology and analytical approach was applied on a single stock. Ex-post estimation of normal returns was performed using two chosen appropriate models – market model which describes dependence of stock prices on chosen market index (used general S&P 500 since the industry-specific index for tobacco was heavily biased by Philip Morris International itself). According to this estimation, the PMI shareholders lost 9.4 USD per share by the end of the trading week (November 11th 2016) and 11.2 USD per share by the end of the month (November 30th 2016) compared to what normal development of the prices would be. In absolute sums (after multiplication by number of shares outstanding) the losses were $14.61 billion and $17.32 billion respectively.

As for the second model used for estimation, realized GARCH(1,2) was chosen since, according to Hansen, Huang, Shek (2011), it provides a joint solution for both modeling volatility and returns[89] and the (1,2) order displayed the best statistical properties (all parameters significant, highest log-likelihood, lowest values of AIC and BIC criteria) and no ARCH effect left in the data. It is also supposed to provide better capture of the data series thanks to using realized volatility. The ex-post simulation (as well as the model estimation) was conducted in statistical software R (package RUGARCH). The results are loss of 9.1 USD per share by the end of the trading week ($14.16 billion in total) and 13 USD per share by the end of the month ($20.18 billion in total).

As well as that, when additionally investigating the situation from the opposite view - how much BAT gained from the announcement – it turned out that the period in which GLO was announced interfered with another major event for BAT – negotiations of proposed acquisition of Reynolds American. This was likely reason of longer lasting BAT's stock price decline and separation of these effects is a potential incentive for further, more extensive analysis.

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[89] The data series of returns showed no autocorrelation to fit any mean equation of ARMA structure

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APPENDIX 1

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-----------------------------------
GARCH Model         : realGARCH(1,1)
Mean Model          : ARFIMA(0,0,0)
Distribution        : norm

Optimal Parameters
-----------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
omega    0.236510    0.034498   6.8558 0.000000
alpha1   0.999997    0.075119  13.3122 0.000000
beta1    0.000000    0.020551   0.0000 1.000000
eta11   -0.008658    0.002930  -2.9550 0.003127
eta21    0.036977    0.001699  21.7581 0.000000
delta    0.936562    0.067332  13.9095 0.000000
lambda   0.121873    0.002101  57.9980 0.000000
xi      -0.224026    0.031017  -7.2227 0.000000


-----------------------------------
GARCH Model         : realGARCH(2,1)
Mean Model          : ARFIMA(0,0,0)
Distribution        : norm

Optimal Parameters
-----------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
omega    0.220661    0.033210   6.6444 0.000000
alpha1   0.964759    0.075150  12.8377 0.000000
beta1    0.000000    0.030648   0.0000 1.000000
beta2    0.000000    0.021755   0.0000 1.000000
eta11   -0.008721    0.002919  -2.9881 0.002807
eta21    0.036571    0.001650  22.1616 0.000000
delta    0.969366    0.072643  13.3443 0.000000
lambda   0.122107    0.002110  57.8571 0.000000
xi      -0.216805    0.030916  -7.0128 0.000000


-----------------------------------
GARCH Model         : realGARCH(2,2)
Mean Model          : ARFIMA(0,0,0)
Distribution        : norm

Optimal Parameters
-----------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
omega    0.061247    0.020477   2.9910 0.002781
alpha1   1.000000    0.078766  12.6958 0.000000
alpha2  -0.723495    0.091831  -7.8786 0.000000
beta1    0.705644    0.073641   9.5822 0.000000
beta2    0.000000    0.023449   0.0000 1.000000
eta11   -0.008666    0.002891  -2.9981 0.002717
eta21    0.035902    0.001600  22.4413 0.000000
delta    0.978749    0.074732  13.0967 0.000000
lambda   0.121667    0.002102  57.8735 0.000000
xi      -0.207265    0.030231  -6.8560 0.000000
```

realGARCH(1,1)
Weighted Ljung-Box Test on Standardized Residuals
----
                          statistic p-value
Lag[1]   0.04965 0.8237
Lag[2*(p+q)+(p+q)-1][2]   0.30343 0.7938
Lag[4*(p+q)+(p+q)-1][5]   1.24885 0.8013
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
----
                          statistic p-value
Lag[1]   0.1452 0.7031
Lag[2*(p+q)+(p+q)-1][5]   1.9612 0.6276
Lag[4*(p+q)+(p+q)-1][9]   3.8646 0.6119
d.o.f=2

Weighted ARCH LM Tests

            Statistic Shape Scale P-Value
ARCH Lag[3]   1.394 0.500 2.000 0.2378
ARCH Lag[5]   3.322 1.440 1.667 0.2464
ARCH Lag[7]   4.226 2.315 1.543 0.3152

realGARCH(2,1)
Weighted Ljung-Box Test on Standardized Residuals
----
                          statistic p-value
Lag[1]   0.04401 0.8338
Lag[2*(p+q)+(p+q)-1][2]   0.28854 0.8021
Lag[4*(p+q)+(p+q)-1][5]   1.23374 0.8049
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
----
                          statistic p-value
Lag[1]   0.1597 0.6895
Lag[2*(p+q)+(p+q)-1][8]   3.2379 0.6418
Lag[4*(p+q)+(p+q)-1][14]   5.1749 0.7476
d.o.f=3

Weighted ARCH LM Tests

            Statistic Shape Scale P-Value
ARCH Lag[4]   1.388 0.500 2.000 0.2388
ARCH Lag[6]   2.748 1.461 1.711 0.3471
ARCH Lag[8]   3.683 2.368 1.583 0.4243

realGARCH(2,2)
Weighted Ljung-Box Test on Standardized Residuals
----
                           statistic p-value
Lag[1]   0.03864 0.8442
Lag[2*(p+q)+(p+q)-1][2]   0.27751 0.8084
Lag[4*(p+q)+(p+q)-1][5]   1.21244 0.8100
d.o.f=0
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
----
                           statistic p-value
Lag[1]   0.1128 0.7370
Lag[2*(p+q)+(p+q)-1][11]   4.2071 0.7018
Lag[4*(p+q)+(p+q)-1][19]   7.3907 0.7427
d.o.f=4

Weighted ARCH LM Tests

            Statistic Shape Scale P-Value
ARCH Lag[5]   1.179 0.500 2.000 0.2775
ARCH Lag[7]   2.093 1.473 1.746 0.4839
ARCH Lag[9]   2.942 2.402 1.619 0.5760

APPENDIX 2

Sample: 1/04/2010 11/07/2016
Included observations: 1731

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000176	0.000211	0.833883	0.4045
SP500_GEN_RET	0.689240	0.021431	32.16110	0.0000

R-squared	0.374307	Mean dependent var		0.000468
Adjusted R-squared	0.373945	S.D. dependent var		0.011096
S.E. of regression	0.008780	Akaike info criterion		-6.631618
Sum squared resid	0.133274	Schwarz criterion		-6.625313
Log likelihood	5741.665	Hannan-Quinn criter.		-6.629286
F-statistic	1034.336	Durbin-Watson stat		1.984408
Prob(F-statistic)	0.000000			

Sample: 1/04/2010 11/07/2016
Included observations: 1731

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SP500_GEN_RET	0.690007	0.021409	32.22941	0.0000

R-squared	0.374055	Mean dependent var		0.000468
Adjusted R-squared	0.374055	S.D. dependent var		0.011096
S.E. of regression	0.008779	Akaike info criterion		-6.632371
Sum squared resid	0.133327	Schwarz criterion		-6.629219
Log likelihood	5741.317	Hannan-Quinn criter.		-6.631205
Durbin-Watson stat	1.983646			

Sample: 1/04/2010 11/07/2016
Included observations: 1731

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.007	0.007	0.0876	0.767
		2	0.007	0.007	0.1819	0.913
		3	0.005	0.005	0.2215	0.974
		4	0.001	0.001	0.2254	0.994
		5	-0.027	-0.027	1.4781	0.916
		6	-0.022	-0.022	2.3157	0.889
		7	-0.003	-0.002	2.3305	0.939
		8	-0.015	-0.014	2.7077	0.951
		9	0.003	0.004	2.7287	0.974
		10	0.032	0.032	4.5480	0.919
		11	0.011	0.010	4.7670	0.942
		12	-0.015	-0.016	5.1472	0.953
		13	0.014	0.013	5.4837	0.963
		14	0.007	0.007	5.5720	0.976
		15	0.019	0.021	6.2065	0.976

Heteroskedasticity Test: ARCH

| F-statistic | 0.403739 | Prob. F(10,1710) | 0.9454 |
| Obs*R-squared | 4.053788 | Prob. Chi-Square(10) | 0.9449 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 12/27/17   Time: 22:49
Sample (adjusted): 1/19/2010 11/07/2016
Included observations: 1721 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.25E-05	8.05E-06	9.011474	0.0000
RESID^2(-1)	0.028062	0.024176	1.160748	0.2459
RESID^2(-2)	0.013833	0.024184	0.571991	0.5674
RESID^2(-3)	-0.016203	0.024185	-0.669972	0.5030
RESID^2(-4)	-0.008985	0.024186	-0.371483	0.7103
RESID^2(-5)	-0.001890	0.024186	-0.078153	0.9377
RESID^2(-6)	0.012122	0.024186	0.501198	0.6163
RESID^2(-7)	0.012018	0.024187	0.496866	0.6193
RESID^2(-8)	-0.010798	0.024185	-0.446480	0.6553
RESID^2(-9)	0.007436	0.024185	0.307466	0.7585
RESID^2(-10)	0.024291	0.024176	1.004776	0.3151

R-squared	0.002355	Mean dependent var	7.72E-05
Adjusted R-squared	-0.003479	S.D. dependent var	0.000233
S.E. of regression	0.000234	Akaike info criterion	-13.87947
Sum squared resid	9.33E-05	Schwarz criterion	-13.84463
Log likelihood	11954.28	Hannan-Quinn criter.	-13.86658
F-statistic	0.403739	Durbin-Watson stat	2.000828
Prob(F-statistic)	0.945430		

APPENDIX 3

The code used for relGARCH generation in R RUGARCH:

```
PMI_ivar <- read.delim2("C:/Users/UserXY/Downloads/PMI_ivar.txt")
dates_ivar=as.Date(PMI_ivar$Date, format="%Y-%m-%d")
rm(PMI_ivar)
PMI_ivar <- read.delim2("C:/Users/Martina/Downloads/PMI_ivar.txt", row.names=
1)
library(rugarch)
require(xts)
ivar=xts(PMI_ivar,order.by=dates_ivar)
rG21 = ugarchspec(mean.model = list(armaOrder = c(0, 0), include.mean = FALSE
), variance.model = list(model = 'realGARCH', garchOrder = c(2, 1)))
setbounds(rG21)<-list(alpha2=c(-1,1))
fit_rG21 = ugarchfit(rG21, ivar[, 1] * 100, solver = 'hybrid', realizedVol =
ivar[,2] * 100)
T = nrow(ivar)
sim1 = ugarchsim(fit_rG21, n.sim = 57, m.sim = 1, n.start = 0, startMethod =
'sample', rseed = 57)
print(fitted(sim1))

ni=newsimpact(fit_rG21,z=seq(-2,2, length.out = 100))
plot(ni$zx,(ni$zy),ylab=ni$yexpr,xlab=ni$xexpr,type='l',main='News Impact')
abline(v=0)
abline(h=0)
grid()

rG11 = ugarchspec(mean.model = list(armaOrder = c(0, 0), include.mean = FALSE
), variance.model = list(model = 'realGARCH', garchOrder = c(1, 1)))
setbounds(rG11)<-list(alpha2=c(-1,1))
fit_rG21 = ugarchfit(rG11, ivar[, 1] * 100, solver = 'hybrid', realizedVol =
ivar[,2] * 100)
rG12 = ugarchspec(mean.model = list(armaOrder = c(0, 0), include.mean = FALSE
), variance.model = list(model = 'realGARCH', garchOrder = c(1, 2)))
setbounds(rG12)<-list(alpha2=c(-1,1))
fit_rG12 = ugarchfit(rG12, ivar[, 1] * 100, solver = 'hybrid', realizedVol =
ivar[,2] * 100)
rG22 = ugarchspec(mean.model = list(armaOrder = c(0, 0), include.mean = FALSE
), variance.model = list(model = 'realGARCH', garchOrder = c(2, 2)))
setbounds(rG22)<-list(alpha2=c(-1,1))
fit_rG22 = ugarchfit(rG22, ivar[, 1] * 100, solver = 'hybrid', realizedVol =
ivar[,2] * 100)
```