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AI IN BIG PHARMA AND GUIDELINES FOR SUCCESS – ADD-ON ANALYSIS ON A PREVIOUS STUDY AND ITS COMMENTARY

REFLECTION AND ANALYSIS DOCUMENT

BASED ON:

"THE UPSIDE OF BEING A DIGITAL PHARMA PLAYER" (SCHUHMACHER, A.; GATTO, A.; HINDER, M.; KUSS, M. AND GASSMANN, O., DRUG DISCOVERY TODAY, 2020 – ORIGINAL STUDY)

"DEEP DIVE INTO BIG PHARMA AI PRODUCTIVITY: ONE STUDY SHAKING THE PHARMACEUTICAL INDUSTRY" (ZHAVORONKOV, A., FORBES, 2020 - COMMENTARY)

ZURICH, AUGUST 2020

(DISCLAIMERS)

This document has been created by Zereon Associates GmbH ("ZA") as a reflection, analysis and further development of 1) a recent, top industry experts' study / paper on the use and application of AI by large global Pharma industry players, and 2) a commentary issued on such paper by a recognized industry player (specific references and authorship on the previous Title Page above). This document, with the ultimate aim to hopefully add some value and perhaps some additional insight to both pieces of work, is distributed for free and with "open source" spirit with no further counter-obligations whatsoever by the reader, except citation, document change protection and no occultation of our authorship, as described below. The document has been created voluntarily and is offered for divulgation, public reference and ZA's general promotion purposes only, without any gainful commercial payment involved in cash or in kind by any party. After-the-fact advisory business by the author to future and current Clients derived from later discussions might be possible if interested parties so request.

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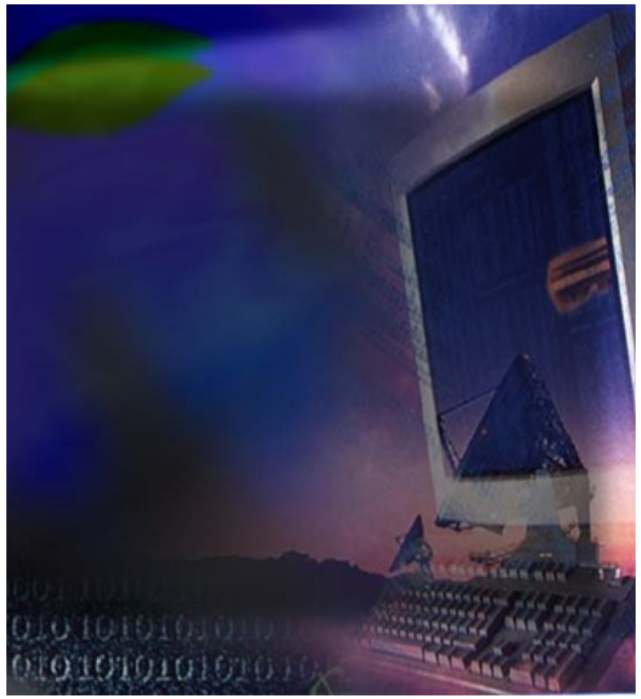

I. INTRODUCTION: THE PREVIOUS STUDIES (1)

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- This document by Zereon Associates GmbH intends to be a reflection, quantitative analysis and further development of two authoritative studies, as follows below.
- In the words of Dr. Alex Zhavoronkov, recognized expert in healthcare & biotech AI, Insilico Medicine Founder & CEO, and Forbes collaborator:

"Some (...) pharmaceutical companies managed to demonstrate very impressive results (**in AI since 2013-14**)".

"However, it was **not possible to get a comprehensive overview** and comparison of the **major pharmaceutical companies (in AI) (...) until now**".

"On June 15th (2020), one article (...) quietly went online in a reputable peer-reviewed journal (...)

Upon a closer look it turned out to be (...) a comprehensive research study with **a head-to-head comparison of the pharmaceutical companies** by their efforts in **AI in research and development**".

"The authors of the study certainly deserve to be referred to as industry experts in the pharmaceutical AI R&D as they did a **gargantuan amount of work** to compile the three relatively simple figures in the study and **at the moment no other study like that exists**".

"The upside of being a digital pharma player" (Schuhmacher, A.; Gatto, A.; Hinder, M.; Kuss, M. and Gassmann, O., Drug Discovery Today, 2020)

I. INTRODUCTION: THE PREVIOUS STUDIES (2)

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- Dr. Zhavoronkov, on top of the above quotes and in his own "**Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry**" (Forbes 2020), reflects profound commentary and interviews with the original paper authors, expanding on global Pharma AI "state of the art".

- The present document attempts to serve as quantitative **add-on analysis** to both works, and maybe **offer some more interesting insight and benchmark to industry players and/or interested parties**.

- To do so, we 1) review some additional literature, 2) take part of the data published in the studies referred, 3) add more stats, regressions, etc. and 4) generate conclusions on the analysis.

- Part of the analysis and conclusions might overlap with the published work – but we hope we have been able to provide a **new, complementary perspective** and obtain **relevant and useful findings**, nonetheless.

- In the next pages we offer an Executive Summary, and then details of our analysis. As Annexes, we show some additional information on AI funding and technological companies active in AI Life Sciences R&D.

II. EXECUTIVE SUMMARY (1)

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N. of AI-based scientific Publications for the 21 global Pharma companies studied:

In general explained away (80%+) simply by the N. of AI-related activities implemented.

(under the model used - statistically significant no-intercept linear regression and R^2 analysis).

Interestingly, however, N. of AI-external activities taken alone seem to be an even better predictor (85%+) of total N. of AI-based Publications than the total N. of AI activities.

("external activities": sum of joint ventures, alliances, acquisitions, cooperation with startups and other companies, etc.).

Companies can expect to get ca. 2.54 Publications per each AI-activity developed, on average

- but differences do exist b/w higher and lower apparent "AI Productivity" companies.

A closer analysis of regressions and R^2 shows that:

Drug Discovery Publications might be best pursued by a mix of preferentially AI External with some selective Internal initiatives.

Whereas Drug Development and Other AI could be done mostly externally.

Two clusters of companies, according to Publication Productivity Ratios (*N. of AI-based Publications per each AI-related activity*):

Higher Productivity Companies (10) **3.4-7.0 AI *publications*** *per each AI activity*; ***group average* = 4.4**	**Lower Productivity Companies (11)** **0.0-2.5 AI *publications*** *per each AI activity*; ***group average* = 1.5**
67% of their total AI activities are External, vs. 33% Internal. **8 of 10 companies have more External activities** than Internal. 7 of 10 companies are US/UK headquartered.	**53% of their total AI activities are Internal,** vs. 47% External. **8 of 11 companies have more Internal or at least an equal number of activities** than External. Almost equally US/UK and non-US/UK headquartered (6 vs. 5).

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

II. EXECUTIVE SUMMARY (2)

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Where to go ? Depends on Company strategy, business plans and objectives, etc., but three AI decision-making areas may be of interest:

Fundamental biological processes underlying human disease	Creating and developing treatments	Patient classification and categorization

Influencing factors to consider regarding External / Internal activities to undertake in those areas could be:

- Realistic assessments of project success likelihood and costs
- Right prospection and choice of external partners
- Internal teams' AI expertise AND teamwork skills
- Size and type of investments to be made
- Capabilities for flawless internal and external collaborations
- Overall organizational / processes / culture readiness & incentives

Our study concludes that **more successful Companies mostly liaise with External ones** - those may have **more immediate or superior AI technical firepower or data**, especially for Drug Development/Other AI. For Drug Discovery, preferentially External with selective Internal AI may work best.

Regarding specific companies' AI success, we would suggest the following guidelines / best practices (details in the document):

INITIAL STEPS – leverage externally more

PROSPECT THE MARKET – for key target liaisons

TRANSFORM INTERNALLY FOR "OPEN SOURCING"

BECOME MORE LIKE A PLATFORM – network effects

The most successful Companies are not waiting to leverage on External efforts for improved AI results. Those companies are, at the same time, transforming themselves quickly.

Such transformation requires add-ons to classic Pharma industry practices, new profiles / capabilities, and new ways of working. Companies will need to put agile change plans and initiatives in place, facilitated by internal and external experts to help with the journey.

The prize may not just be the delivery of an astounding economic value and a superior competitive position, but an opportunity to improve/save more people's lives – or even indeed win Nobel prizes and change the world itself.

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

III. CONTEXT: SOME PRIOR OVERALL INDUSTRY INFORMATION

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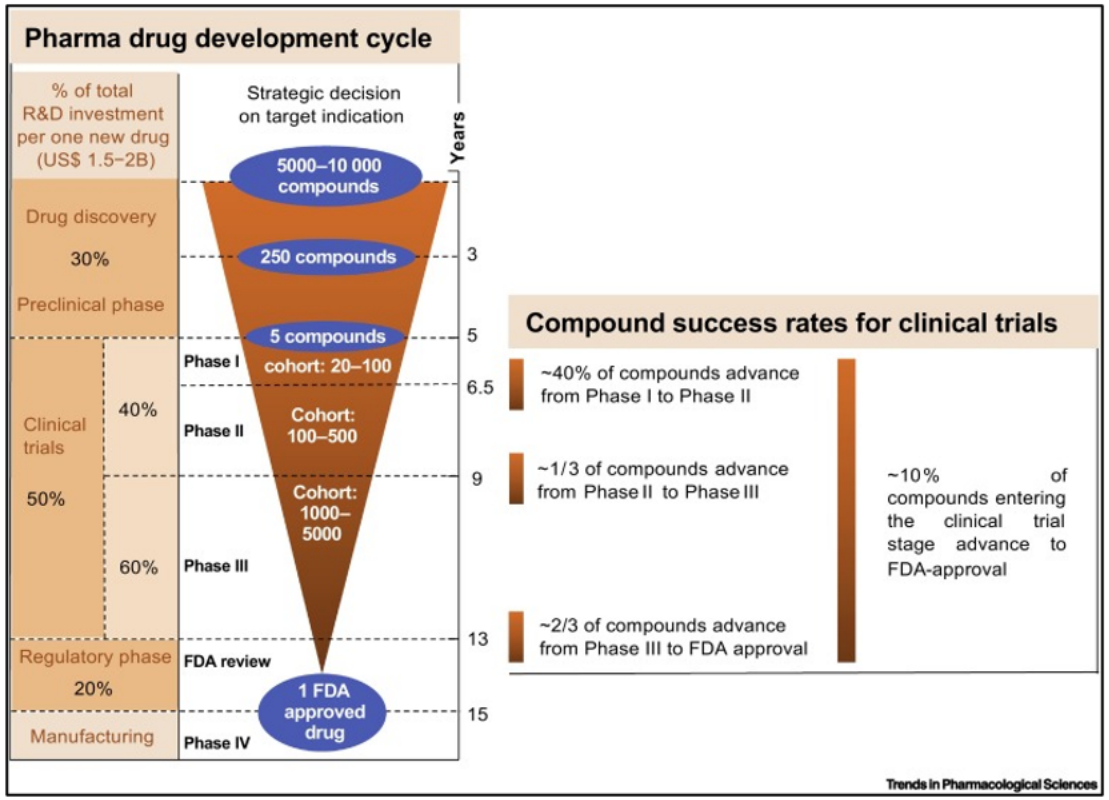
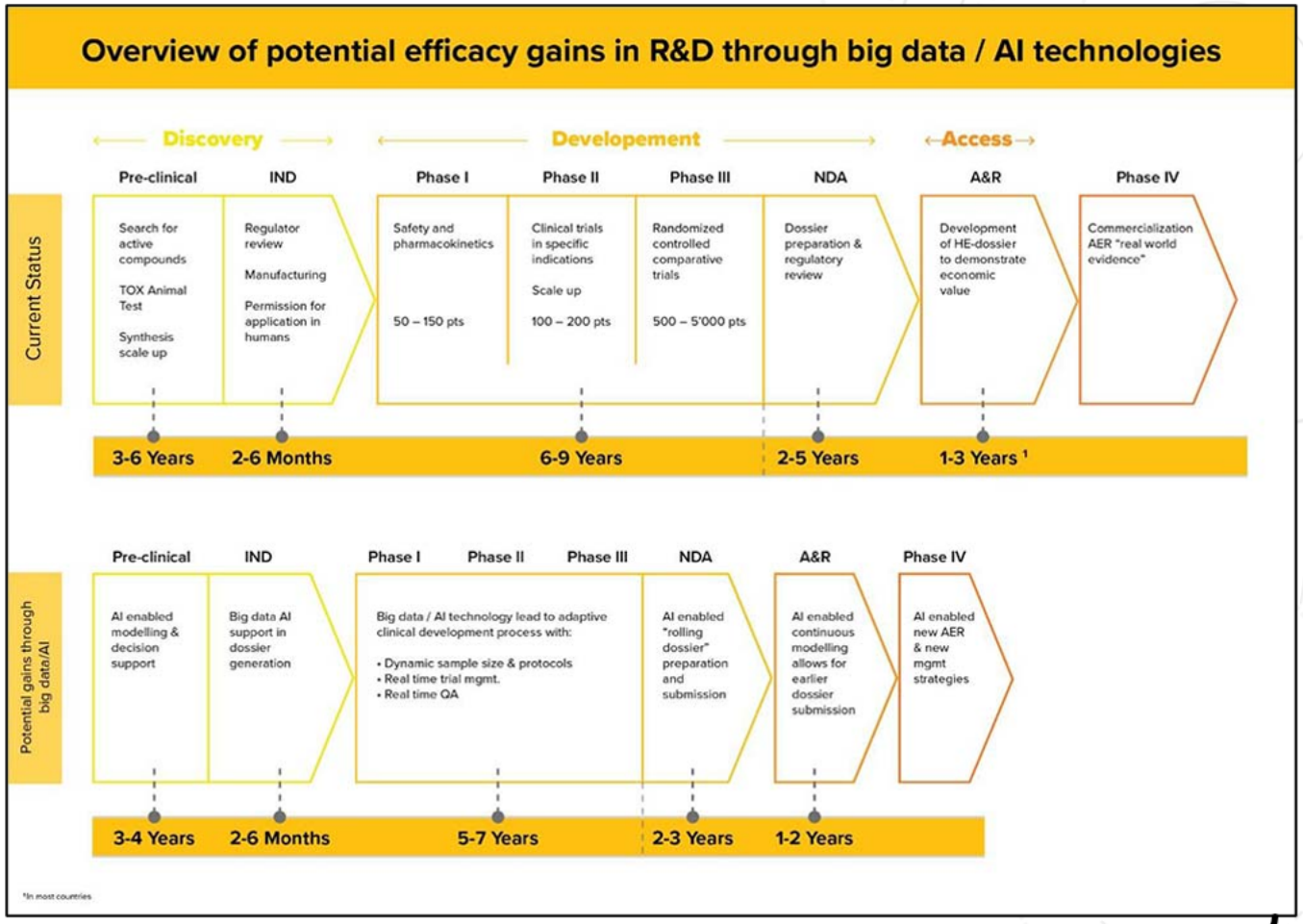




Sources: *"Artificial Intelligence for Clinical Trial Design"; Trends in Pharmacological Sciences; Harrer, S., Shah, P., Antony, B., Hu, J.; Aug. 2019.*

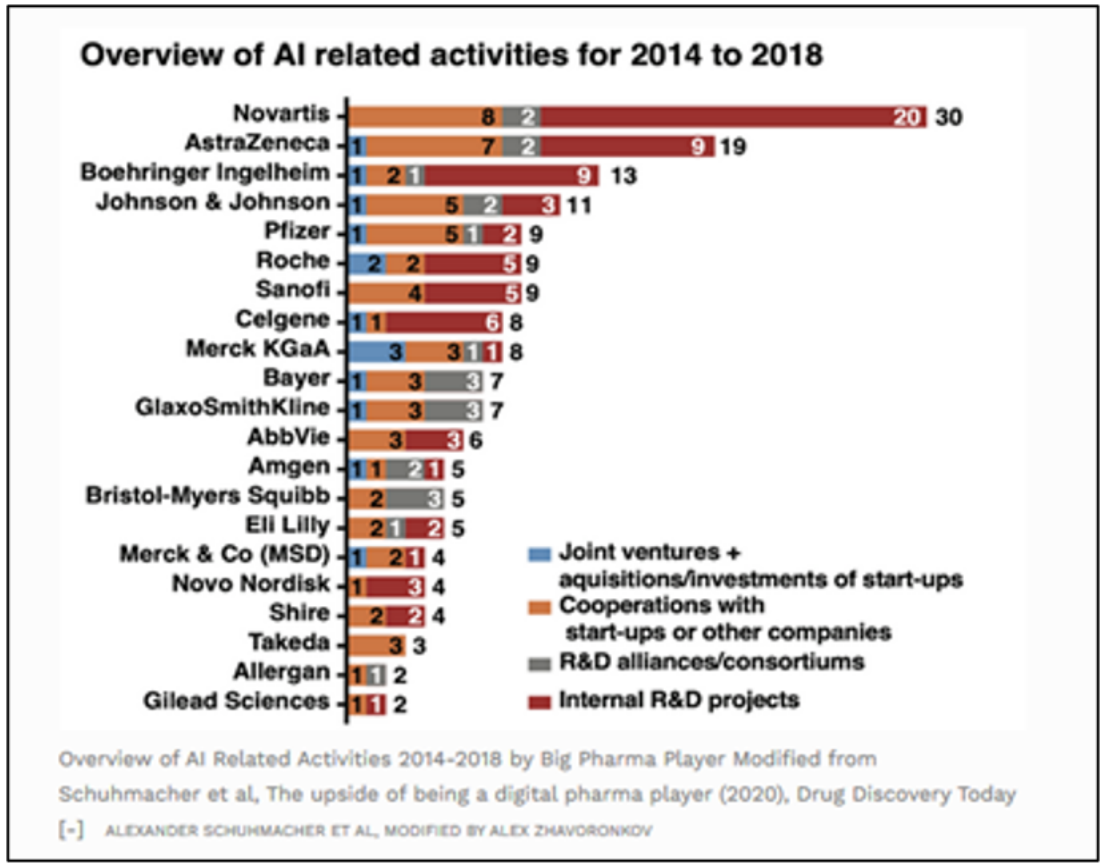
"The Impact of Digitalization and AI on Research and Development in the Biopharmaceutical Industry"; Innoplexus (blog), Jul. 2020.

"It takes up to 15 years and an average R&D of 1.5–2 bill. USD to bring a drug to market. In the US, only one of 10 compounds entering trials advances to FDA approval. High trial failure rates are one major cause."

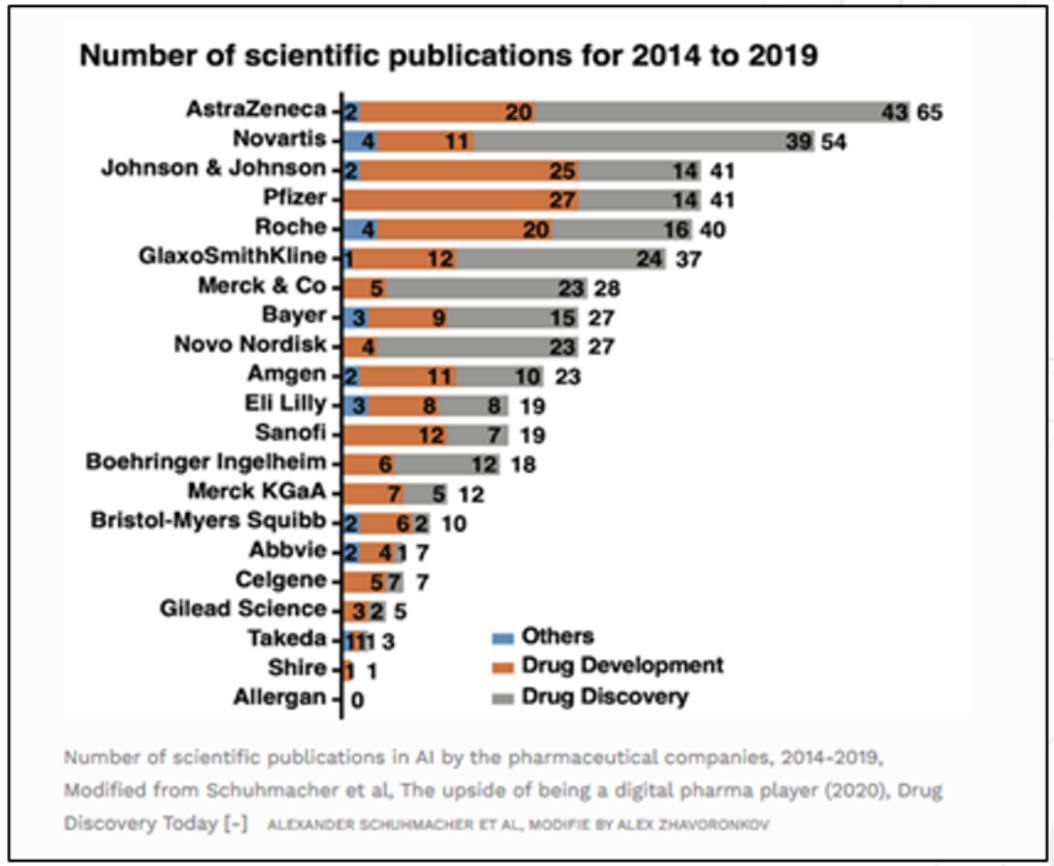
AI may shorten the whole cycle (and related cost) by 2-4 years – and is already helping discover, distribute and sell new compounds, realize trials, etc.

Global Pharma companies deploy different AI activities, which if successful are normally reflected on AI-related scientific Publications (see next slide).

IV. BASIC PHARMA COMPANIES' DATA USED (1)



Overview of AI Related Activities 2014-2018 by Big Pharma Player Modified from Schuhmacher et al, The upside of being a digital pharma player (2020), Drug Discovery Today [-] ALEXANDER SCHUHMACHER ET AL, MODIFIED BY ALEX ZHAVORONKOV



Number of scientific publications in AI by the pharmaceutical companies, 2014-2019, Modified from Schuhmacher et al, The upside of being a digital pharma player (2020), Drug Discovery Today [-] ALEXANDER SCHUHMACHER ET AL, MODIFIE BY ALEX ZHAVORONKOV

- These data pieces, in themselves, are already excellent findings on AI in the Pharma industry, as a whole and as per individual company.
- We proceed on from there to a) see if there is relevant correlation, or not, between N. of AI-related activities implemented 2014-18, and N. of AI-based scientific publications 2014-19, b) drill down by type of activity (external / internal) and type of publication, c) analyze apparent Productivity (Ratio of Publications' per each Activity) and d) see if there is some pattern / basic clusterization among companies.
- We will be mostly using no-intercept simple linear regression models, which reveal to be statistically significant in all cases. Other models such as logarithmic, multiple linear regressions, etc. could be applicable, but data shape generally indicates appropriateness of model overall.

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

IV. BASIC PHARMA COMPANIES' DATA USED (2)

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TABULATED DATA:

	Startups' Acq/JVs	Cooperation startup or Cny	R&D Alliances	External Activities	Internal Activities	E > I	AI-related activ. 2014-18	Drug Discovery	Drug Developm.	Other	AI-based Publi-cations 2014-19	Apparent Productivity Ratio
Astra Zeneca	1	7	2	10	9	1	19	43	20	2	65	3.4
Novartis	0	8	2	10	20	-10	30	39	11	4	54	1.8
Pfizer	1	5	1	7	2	5	9	14	27	0	41	4.6
Johnson & Johnson	1	5	2	8	3	5	11	14	25	2	41	3.7
Roche	2	2	0	4	5	-1	9	16	20	4	40	4.4
GlaxoSmithKline	1	3	3	7	0	7	7	24	12	1	37	5.3
Merck & Co (MSD)	1	2	0	3	1	2	4	23	5	0	28	7.0
Novo Nordisk	0	1	0	1	3	-2	4	23	4	0	27	6.8
Bayer	1	3	3	7	0	7	7	15	9	3	27	3.9
Amgen	1	1	2	4	1	3	5	10	11	2	23	4.6
Eli Lilly	0	2	1	3	2	1	5	8	8	3	19	3.8
Sanofi	0	4	0	4	5	-1	9	7	12	0	19	2.1
Bohringer Ingelheim	1	2	1	4	9	-5	13	12	6	0	18	1.4
Merck KGaA	3	3	1	7	1	6	8	5	7	0	12	1.5
Bristol-Myers Squibb	0	2	3	5	0	5	5	2	6	2	10	2.0
AbbVie	0	3	0	3	3	0	6	1	4	2	7	1.2
Celgene	1	1	0	2	6	-4	8	2	5	0	7	0.9
Gilead Sciences	0	1	0	1	1	0	2	2	3	0	5	2.5
Takeda	0	3	0	3	0	3	3	1	1	1	3	1.0
Shire	0	2	0	2	2	0	4	0	1	0	1	0.3
Allergan	0	1	0	1	1	0	2	0	0	0	0	0.0
TOTAL / AVERAGE	14	61	21	96	74	22	170	261	197	26	484	2.8

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

V. GENERAL REGRESSION ANALYSIS: N. OF TOTAL AI-RELATED ACTIVITIES VS. N. OF AI-BASED PUBLICATIONS

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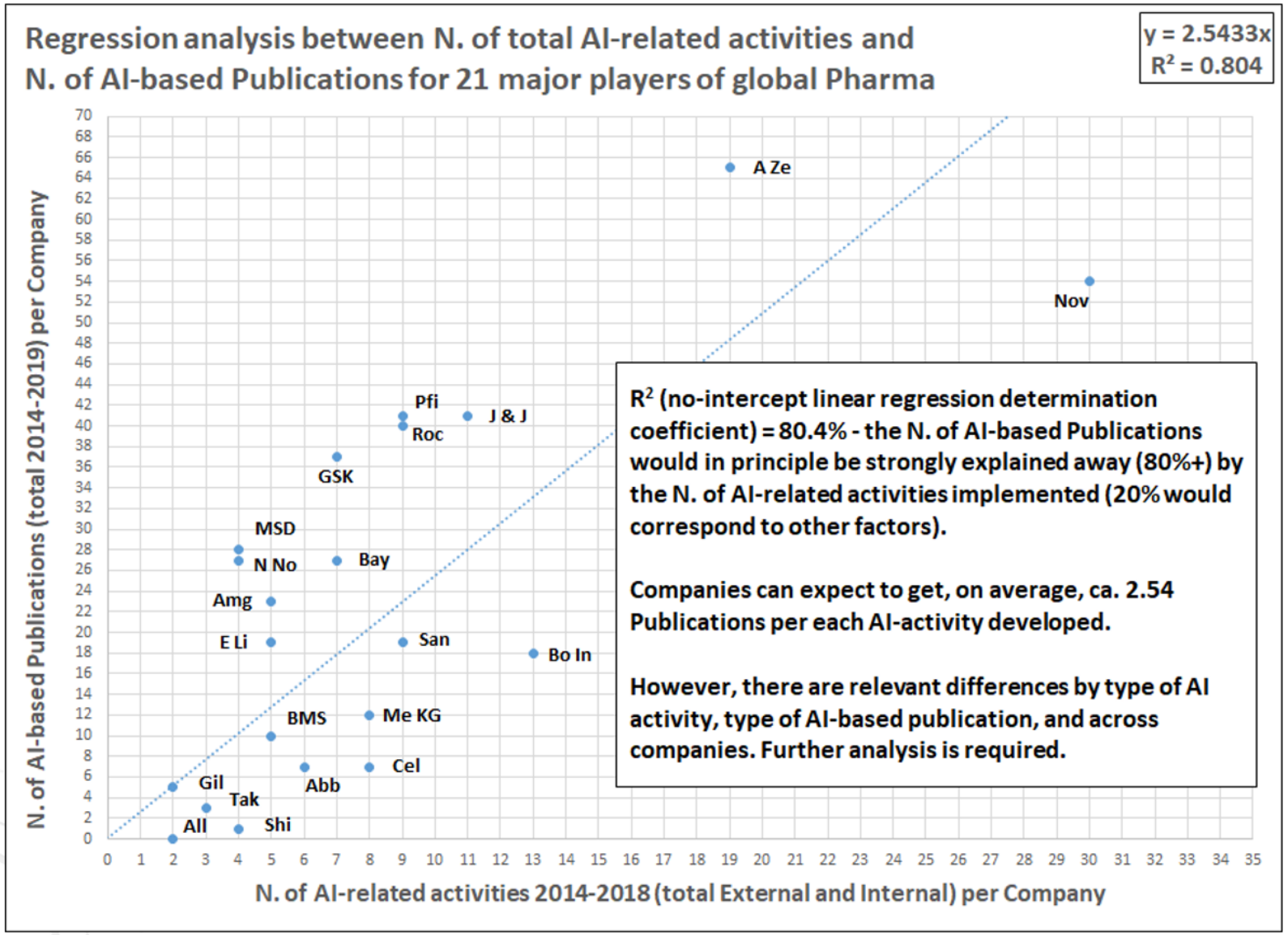

Even if some companies may be capitalizing previous years or different investment levels, expecting Publications later, etc., **intense, positive linear Correlation seems to be there**, and fits with the intuitive idea of, starting with zero, more AI-based Publications are obtained as more AI activities are put in place.

However, **the effects differ by individual company –** companies above and below the line seem to produce more or less Publications each for the same effort.

It is also **worth checking the type of activity** (external / internal), **and the type of publication** (AI in drug discovery, AI in drug development, other AI).

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

VI. DIFFERENTIATION EXTERNAL VS. INTERNAL AI ACTIVITIES

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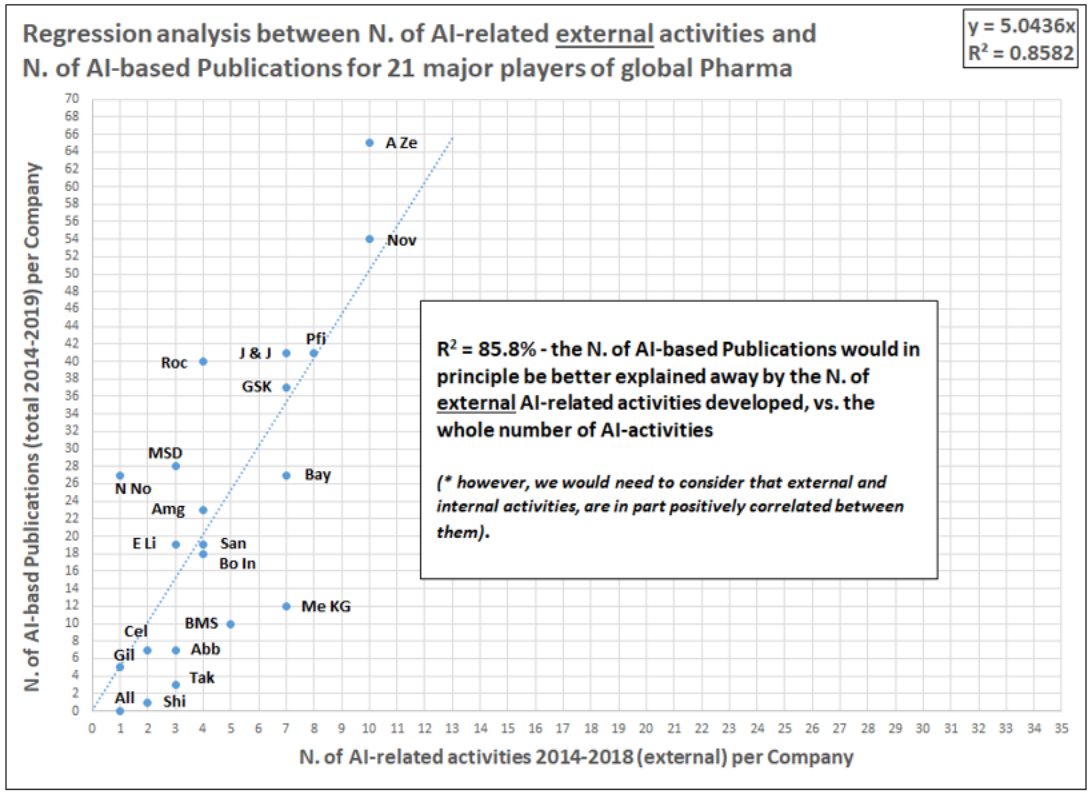

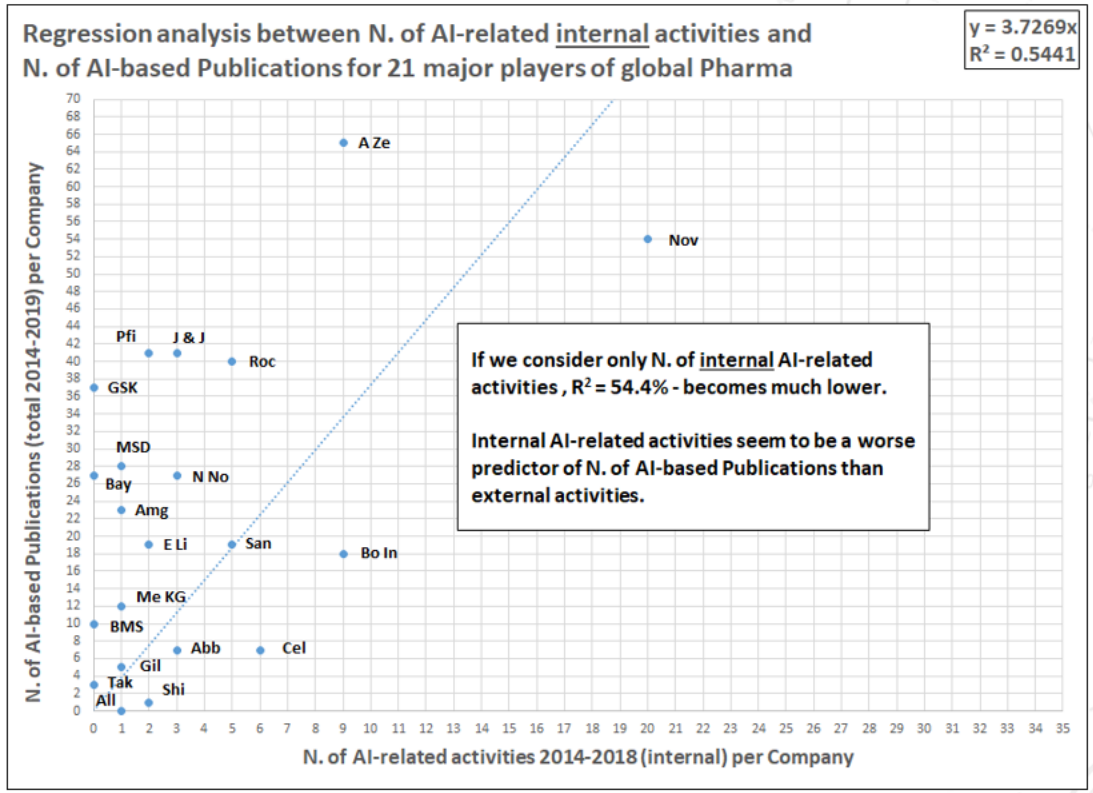

(We define "external activities" as the sum of JVs/Acquisitions of Startups, Cooperation with Startups or other Companies, and Participation in R&D Alliances)

N. of AI-external activities taken alone seem to be a better predictor of total N. of AI-based Publications than the total N. of AI activities. Internal activities alone are less accurate predictors of total Publications generated.

This fits overall with the conclusions of the main study and its commentaries.

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

VII. ANALYSIS OF IMPACT ON AI-BASED DRUG DISCOVERY, DRUG DEVELOPMENT AND OTHER PUBLICATIONS

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(Apparent strength of relationship - Determination Coefficients of No-Intercept Linear Regressions)	TOTAL OF AI-BASED PUBLICATIONS	*IN DRUG DISCOVERY*	*IN DRUG DEVELOPMENT*	*IN OTHER AI*
N. OF EXTERNAL AND INTERNAL AI ACTIVITIES	**80.4%**	***77.0%***	***62.0%***	***54.7%***
(Expected N. of Publications per Activity)	***2.54***	***1.48***	***0.93***	***0.13***
N. OF EXTERNAL ACTIVITIES ALONE	***85.8%***	*73.4%*	*78.6%*	*56.7%*
N. OF INTERNAL ACTIVITIES ALONE	***54.4%***	*59.0%*	*33.6%*	*38.2%*

(All figures statistically significant at the 95% confidence level)*

Out of 2.54 AI-based Publications on average expected per AI activity developed (apparent Productivity Ratio), in principle **we could expect 1.48 AI-based Drug Discovery Publications**, **0.93 Drug Development** ones, and **0.13 Others** (but obviously, this depends on specific activity developed, company, etc.).

N. of AI-based Drug Discovery Publications is in principle **best predicted by the N. of total AI activities** (external and internal) – (R^2= 77.0%), even if N. of External activities alone apparently also works well (R^2= 73.4%).

However, **N. of AI-based Drug Development and Other Publications is in principle best predicted by the N. of external AI activities alone** – (R^2= 78.6%/56.7%), vs. total N. of activities. Internal activities taken alone even seem to be weak predictors.

According to all this, **AI Drug Discovery Publications might be best pursued by a combination of predominantly External with some selected Internal initiatives,** whereas **Drug Development and Other AI could even be done mostly externally.**

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

VIII. APPARENT PUBLICATION PRODUCTIVITY AND COMPANY CLUSTERS (1)

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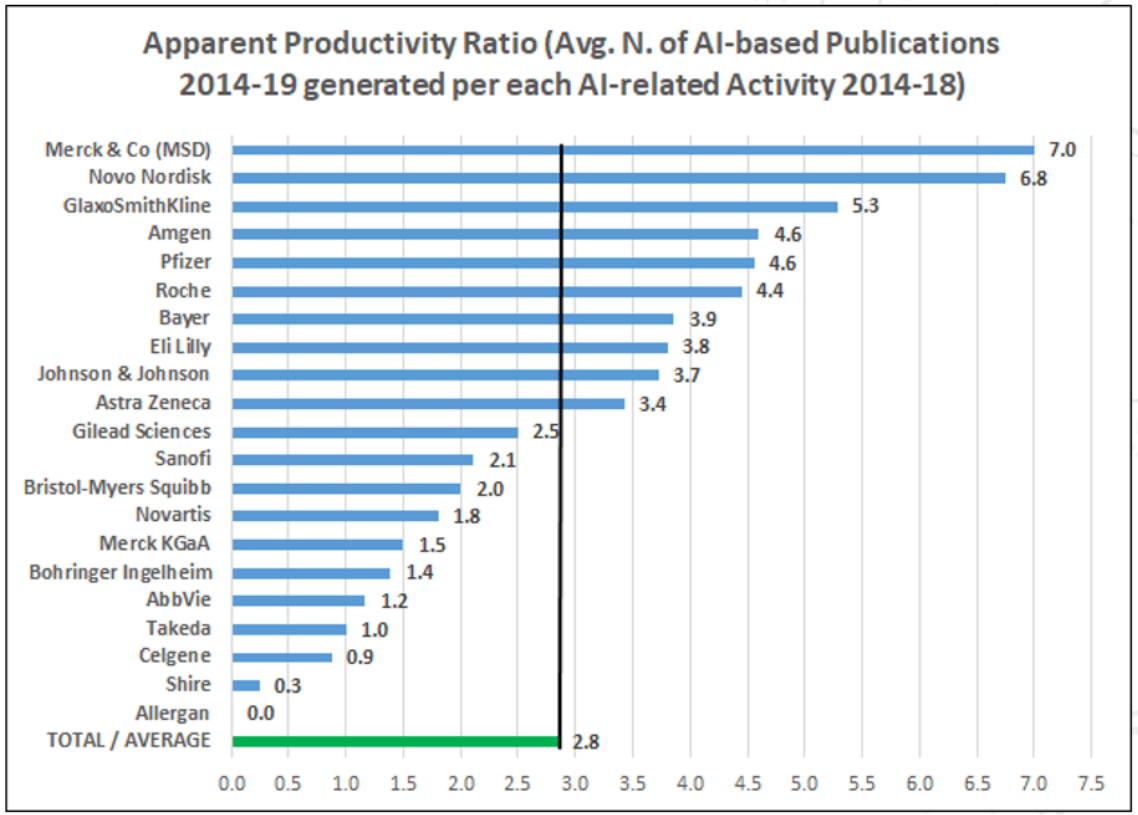
Higher apparent AI Productivity Companies

Lower apparent AI Productivity Companies

	AI-related activ. 2014-18	AI-based Publications 2014-19	Apparent Productivity Ratio	
Merck & Co (MSD)	4	28	7.0	
Novo Nordisk	4	27	6.8	
GlaxoSmithKline	7	37	5.3	
Amgen	5	23	4.6	
Pfizer	9	41	4.6	4.4
Roche	9	40	4.4	
Bayer	7	27	3.9	
Eli Lilly	5	19	3.8	
Johnson & Johnson	11	41	3.7	
Astra Zeneca	19	65	3.4	
Gilead Sciences	2	5	2.5	
Sanofi	9	19	2.1	
Bristol-Myers Squibb	5	10	2.0	
Novartis	30	54	1.8	
Merck KGaA	8	12	1.5	
Bohringer Ingelheim	13	18	1.4	1.5
AbbVie	6	7	1.2	
Takeda	3	3	1.0	
Celgene	8	7	0.9	
Shire	4	1	0.3	
Allergan	2	0	0.0	
TOTAL / AVERAGE	170	484	2.8	

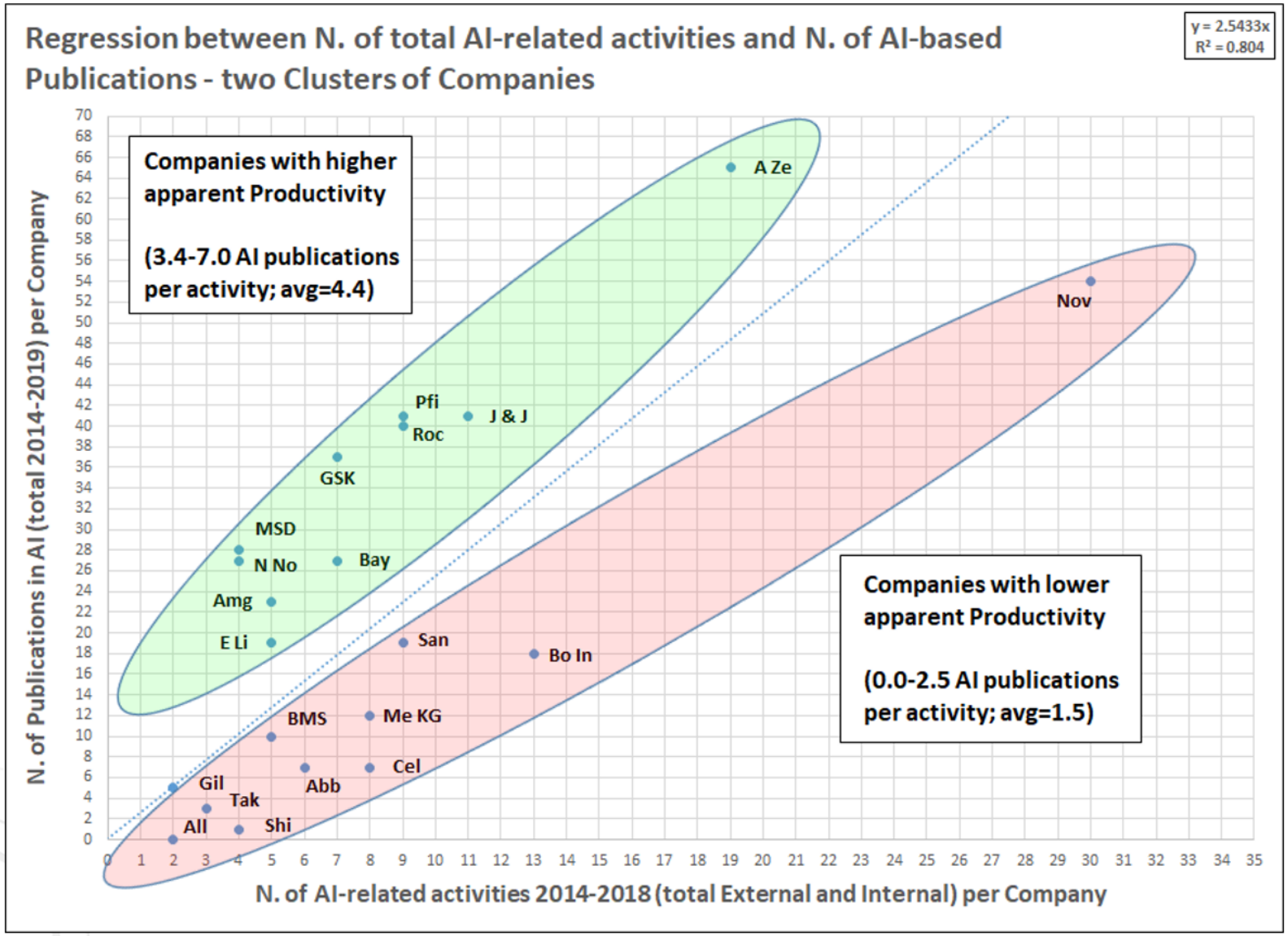


Looking into comparative apparent **Publication Productivity Ratios** (defined as avg. N. of AI-based Publications 2014-19 generated per each AI-related Activity 2014-18), **differences across companies seem to exist**.

We intend to find out if the **companies cluster themselves according to these ratios** in some way, and if there is some **"common denominator" in the companies inside** each of those possible clusters.

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

VIII. APPARENT PUBLICATION PRODUCTIVITY AND COMPANY CLUSTERS (2)



Choosing the no-intercept linear regression line as a very simple yet quite distinct way of separating companies, reveals that **there could basically be two company clusters as per Productivity Ratio.**

(* Other, more sophisticated Machine Learning clustering techniques such as k-means, support vector machines, etc. could be used – but the results might be similar, with the exception perhaps of Astra Zeneca and Novartis).

With these two basic clusters, **Publications would follow two Productivity patterns** (higher vs. lower) - and possibly **there can be differences in internal vs. external approach chosen, and other factors.**

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

IX. HIGHER/LOWER APPARENT PRODUCTIVITY COMPANIES' CHARACTERIZATION (1)

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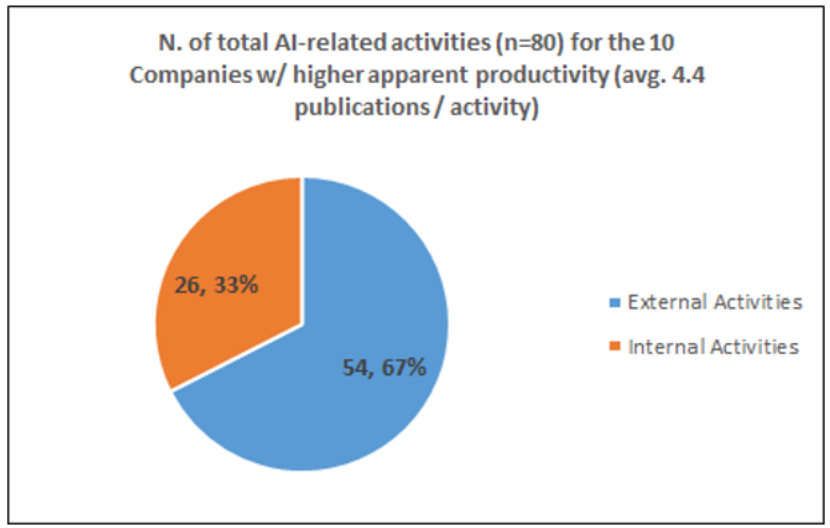

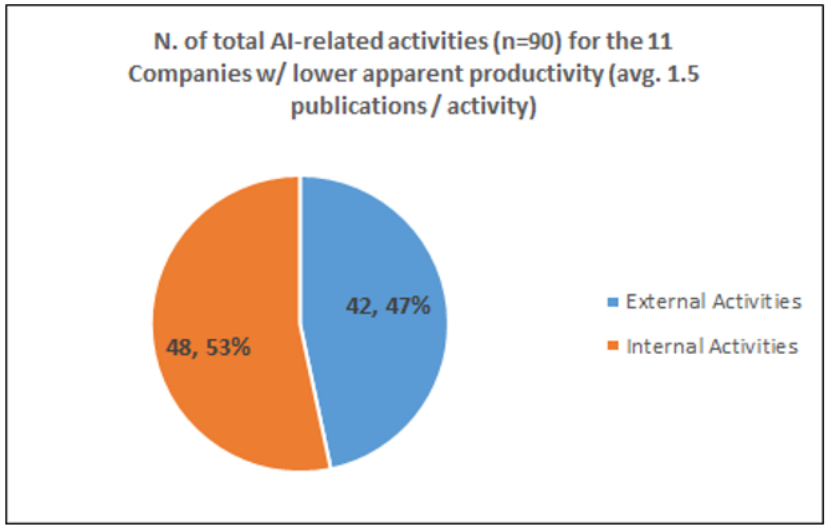

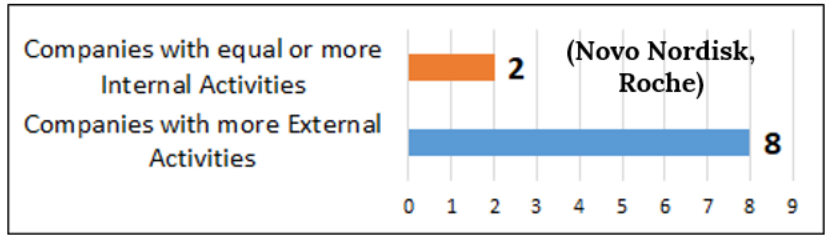

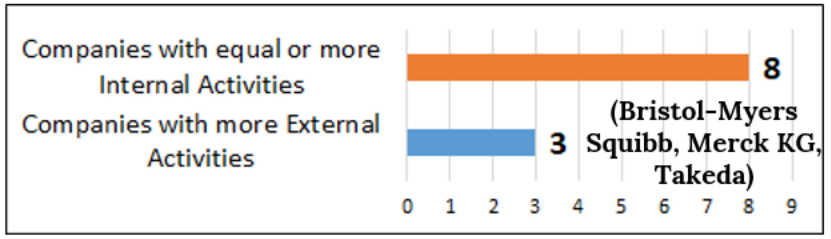

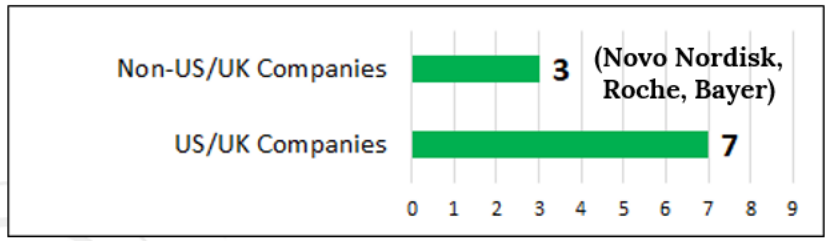

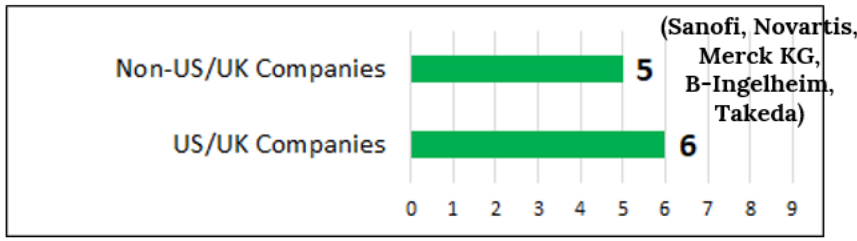

67% of the total AI activities by the companies with the higher Publication Productivity Ratios are External, and 33% Internal.

8 of 10 companies have more External activities than Internal.

Most companies in the first group (7 of 10) are US/UK headquartered.

As opposed to the above, 53% of total AI activities by companies with the lower Publication Productivity Ratios are Internal, vs. 47% External.

8 of 11 companies have more Internal activities, or at least equal, than External.

Companies in the second group are almost equally US/UK and non-US/UK headquartered.

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

IX. HIGHER/LOWER APPARENT PRODUCTIVITY COMPANIES' CHARACTERIZATION (2)

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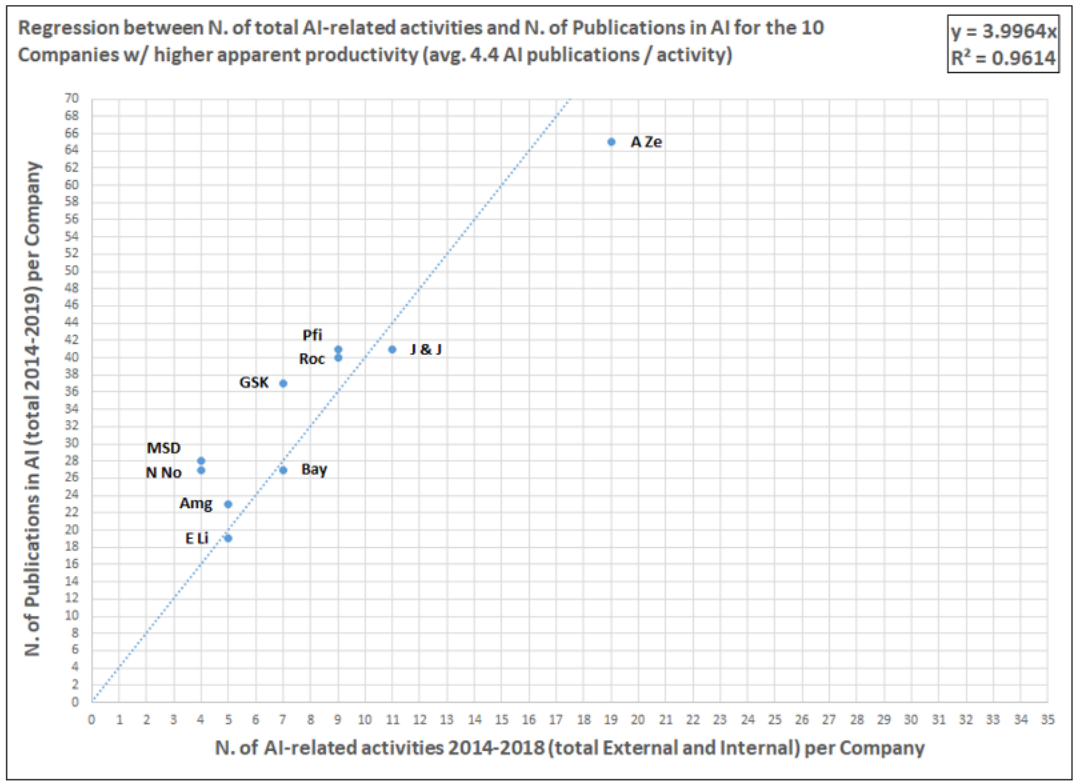

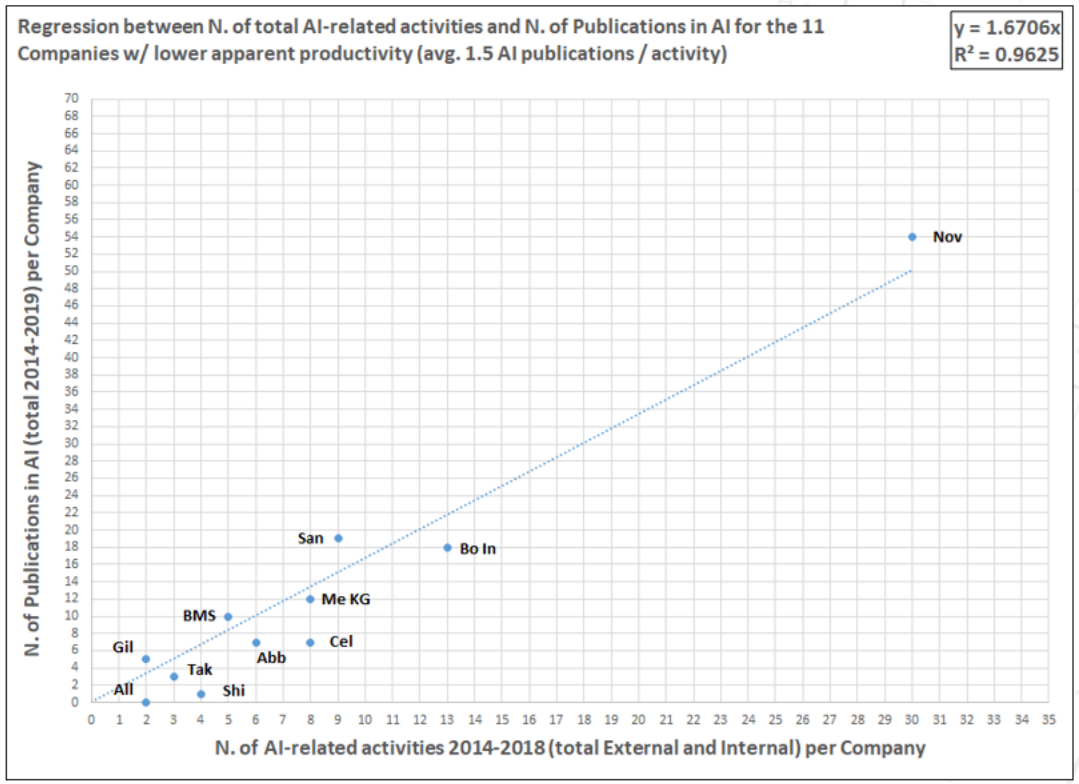

The clusterization made appears to have a very high degree of robustness if we separate higher and lower Productivity companies (R^2= 96.14% and 96.25%, higher than the unclustered 80.4%), in itself and on top of the respective different nature of activities (External vs. Internal) and to a lesser extent, company origin (UK/US vs. non-UK/US).

Higher Productivity companies may possibly expect ca. 4 AI-related Publications per each AI activity, vs. ca. 1.7 for lower Productivity ones.

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

X. POSSIBLE DECISION-MAKING AREAS FOR COMPANIES AND FACTORS TO CONSIDER

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Schuhmacher et al. (2020) very clearly put it forward, after their very exhaustive research comprising analysis of annual company reports, investor relations information, patent applications, and scientific publications, about the 21 Pharma 'blue chip" companies referred for the years 2014 to 2019:

1 **"The industry is in an 'early mature' phase** of using AI in R&D"

2 **"It is worthwhile to invest to become a 'digital pharma player' "**

Where to go ? Depends on Company strategy, business plans and objectives, etc., but three AI decision-making areas may be of interest:

(**Source**: *"Opportunities and obstacles for deep learning in biology and medicine"; Ching, T. et al. (crowdsourced paper); The Royal Society; April 2018).*

Fundamental biological processes underlying human disease	**Creating and developing treatments**	**Patient classification and categorization**
Examples: *deep recurrent neural networks to predict gene targets of microRNAs; deep learning to predict deleterious effects of nucleotide polymorphisms*	**Examples:** *deep learning on protein structures to predict drug interactions and drug bioactivity; restricted Boltzmann machines and deep belief networks to predict novel drug–target interactions*	**Examples:** *denoising autoencoders (type of neural network) used to better cluster breast cancer patients; convolutional networks to count mitotic divisions in different patients/tissue samples*

However, as we have seen and as far as AI Publications go, Companies have had different outcomes, for different reasons. Influencing factors to consider regarding External / Internal activities to undertake in those areas could be:

- Realistic assessments of project success likelihood and costs
- Right prospection and choice of external partners
- Internal teams' AI expertise AND teamwork skills
- Size and type of investments to be made
- Capabilities for flawless internal and external collaborations
- Overall organizational / processes / culture readiness & incentives

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

XI. PROPOSED GUIDELINES FOR SUCCESS, BEST PRACTICES AND CONCLUSIONS (1)

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Our study concludes that **more successful Companies mostly liaise with External ones** - those may have **more immediate or superior AI technical firepower or data sets**, especially for Drug Development/Other AI.

For Drug Discovery, preferentially External with selective Internal AI may work best.

This fits with other ideas and approaches on modern R&D / innovation :

Closed Innovation Principles
The smart people in our field work for us
To profit from R&D we must discover, develop, and ship it
If we discover it, we will get it to market first
If we are the first to commercialize an innovation, we will win
If we create the most and best ideas in the industry, we will win
We should control our Intellectual Property (IP) so that our competitors don't profit from our ideas

Open Innovation Principles
Not all smart people work for us*; so need to find and tap into outside knowledge (* Bill Joy of Sun Microsystems)
External R&D can create value; internal value is needed to do so
We don't have to originate the research in order to profit from it
Building a better business model is better than getting to market first
If we make the best use of internal and external ideas, we will win
We should profit from others' use of our IP, and should buy other's IP when it fits our business model

"While Facebook focused on (...) outside developers to build new applications(...), we tried to create every feature in the world and said, "O.K., we can do it, why should we let a third party do it?". We should have picked 5 to 10 key features that we totally focused on and let other people innovate on everything else".

- Chris de Wolfe, MySpace Co-founder

- Products, controlled by a single firm, can innovate only at a certain rate
- Platforms, by harnessing efforts of external actors, can overtake products in the long run

(**Source**: *"Digital Transformation: Platform Strategies for Success"; Parker, G. et al. (Executive Education Course); MIT Sloan-Emeritus Institute; April 2019).*

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

XI. PROPOSED GUIDELINES FOR SUCCESS, BEST PRACTICES AND CONCLUSIONS (2)

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For all of the above, and regarding specific companies' AI success, we would suggest the following guidelines / best practices:

INITIAL STEPS

- Be more open and public with AI publications (in a controlled way, obviously).
- Foster collaboration with AI startups; leverage on startup SW development and AI capability.

PROSPECT THE MARKET

- Build even more presence into the AI, biotech startup and VC communities.
- Aggressively seek the best technological Cooperation / JV / Merger / Acquisition targets (companies and individuals) – with a multidisciplinary, elite team.

TRANSFORM INTERNALLY FOR "OPEN SOURCING"

- Define what "being digital" really means.
- "Open discussion" Culture and Values
- Org Structure, Processes.
- People Capability.
- Resources (financial, physical, human).
- Accountability.
- Metrics.
- Incentives.

BECOME MORE LIKE A PLATFORM

- Create multi-sided network effects.
- Attract "the best and brightest" into your ecosystems.
- Give them the tools (SDKs, APIs, data, incentives).
- Ensure clever diversity, IP and Governance.
- Reward productive participation (and control the key products).

CONCLUSIONS :

The most successful Companies are not waiting to leverage on External efforts for improved AI results.

Those companies are, at the same time, transforming themselves quickly.

Such transformation requires add-ons to the classic Pharma industry mindset, new profiles / capabilities and new ways of working.

Companies will need to put agile change plans and initiatives in place, facilitated by internal and external experts to help with the journey.

The prize may not just be the delivery of an astounding economic value and a superior competitive position, but an opportunity to improve/save more people's lives – or even indeed win Nobel prizes and change the world itself.

Base data used for our analysis (source reference): *"The upside of being a digital pharma player" (op. cit.); Schuhmacher, A. et al., Drug Discovery Today, 2020; "Deep Dive Into Big Pharma AI Productivity: One Study Shaking The Pharmaceutical Industry" (op. cit.); Zhavoronkov, A.; Forbes 2020.*

ANNEXE 1: 50 BEST-FUNDED AI COMPANIES IN HEALTHCARE

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Exhibit 2.2 – Since 2010, $8.5 billion of VC funding has been invested in the 50 best-funded AI companies in healthcare

	Company	Headquarters	Total raised $ million
1	Ping An Medical and Healthcare Mgmt	China	1,150
2	Babylon Health	UK	635
3	Indigo Agriculture	US	621
4	Zymergen	US	592
5	Change Healthcare	US	557
6	Tempus	US	520
7	Recursion Pharmaceuticals	US	249
8	Accolade	US	240
9	iCarbonX	China	200
10	insitro	US	200
11	Synthego	US	162
12	GoForward	US	158
13	LinkDoc	China	151
14	Sophia Genetics	Switzerland	140
15	Beta Bionics	US	132
16	OrCam	Israel	130
17	Blackthorn Therapeutics	US	130
18	Verana Health	US	119
19	Augmedix	US	116
20	Clarify Health Solutions	US	108
21	Finch Therapeutics	US	105
22	MeMed Diagnostics	Israel	101
23	AI Therapeutics	US	98
24	caresyntax	US	91
25	HealthTap	US	88
26	Helian Health	China	84

	Company	Headquarters	Total raised $ million
27	Singlera Genomics	China	80
28	Viz	US	79
29	VoxelCloud	US	79
30	Healthy.io	Israel	78
31	Sight Diagnostics	Israel	77
32	Saama	US	76
33	PathAI	US	75
34	Infervision	China	74
35	AiCure	US	69
36	Olive (Robotic Process Automation)	US	68
37	Healx	UK	68
38	Frontier Medicines	US	67
39	XtalPi	US	66
40	Lark Technologies	US	64
41	TeraRecon	US	62
42	InSilico Medicine	US	61
43	Evidation Health	US	61
44	ImagenTechnologies	US	60
45	Mindstrong Health	US	60
46	Nuritas	Ireland	60
47	Paige.ai	US	59
48	Atomwise	US	58
49	K Health	US	56
50	GNS Healthcare	US	56

Total funding reported

Top 50	Top 10
$8,490 million	$4,964 million (58%)

Source: *PitchBook Data, Inc., http://pitchbook.com/research-process - cited in"Transforming Healthcare with AI – The impact on the workforce and organisations"; EIT Health-McKinsey; March 2020.*

ANNEXE 2: 30+ TECH COMPANIES IN AI LIFE SCIENCE R&D

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Arterys	Medical Imaging Cloud AI – The AI assistant for radiologists
Asimov	Programmes living cells with genetic circuits
Atomwise	Artificial Intelligence for drug discovery
BenevolentAI	Artificial Intelligence for scientific innovation
Berg	Therapeutic discovery using its unique AI-based Interrogative Biology® platform
Biovia	Collaborative, knowledge-driven innovation and predictive analytics
BioXel	AI and Big Data technologies to power the next wave of medicines
Cyclica Inc	Harnesses biophysics, bioinformatics and artificial intelligence (AI) to help pharmaceutical companies navigate the drug discovery pipeline by assessing the safety and efficacy of drugs
Deep 6 AI	Artificial Intelligence and natural language processing to medical records to find more patients for clinical trials
Deep Genomics	Geneticists, molecular biologists and chemists are supported by its biologically-accurate artificial intelligence technology
Digital Reasoning Syntheses	Reads and combines data from all sources, including human language to build a comprehensive picture of individual patients, revealing insights that aid clinicians' care decisions
Exscientia	AI-driven systems to automate drug design
Genpact Cora	An artificial-intelligence (AI)-based platform for digital transformation
Google DeepMind	Delivers tools that clinicians can use to make sense of the huge inflows of information which overwhelms them
Healx	To transform the lives of rare disease patients by intelligently matching drug treatments
IBM Watson	Machine learning capabilities to find unique connections between recorded symptoms and other clinical data, such as timing and dosing of medicine
Infosys Mana	A platform that brings machine learning together with the deep knowledge of an organisation, to drive automation and innovation
Insilico Medicine	Artificial Intelligence for drug discovery and ageing research
InveniAI	To extend the human experience in the use of artificial intelligence over the discovery process
Knowledgent	Enabling advanced and agile analytics, the digital enterprise and robotics
Microsoft Hanover	AI for precision medicine
Nference	AI to tackle the challenge of synthesising the world's biomedical knowledge
nQ Medical	Supports diagnosis of neurodegenerative disease years earlier than current gold standard tools
Palantir Technologies	Analysing real-world data for differentiated biomedical insight requires dealing with tremendous scale and complexity, as well as potential privacy concerns
Phenomic AI	State-of-the-art deep learning-based algorithms for analysing cell and tissue phenotypes in microscopy data
Precision Digital Health	Accelerates the adoption of digital health for researchers by providing a real-world evidence solution
QuantumBlack	In its raw form, data can be stubbornly unyielding. We use it to seek out the incisive insights and clear-cut response
Recursion Pharmaceuticals	Discovering transformative new treatments by leveraging the speed of automation with the intelligence of computers
Salesforce Einstein	A layer within the Salesforce platform that infuses Artificial Intelligence features and capabilities across all Salesforce Clouds. Einstein takes care of the data prep and modelling
Sema4	To revolutionise clinical diagnostics by combining comprehensive screening and diagnostic testing, predictive modelling, cutting-edge technologies and open-access data
Syntel SyntBots	Transform your business with intelligent automation
Transformative AI	Using cutting-edge artificial intelligence and novel analysis techniques to transform the treatment of serious medical conditions by collecting and translating clinical data into real-time, predictive assessments that guide the actions of patients and healthcare providers
twoXAR	Improving health on a global scale by building a profit-generating business utilising Artificial Intelligence
Viyasa	Enterprise scale deep learning platform, with consideration for Big Data scale data handling and provision to a range of deep learning approaches
WCG	Delivers transformational solutions that stimulate growth, foster compliance and maximise efficiency for those who perform clinical trials
Wellth	Application of behavioural economics through scalable technology to achieve better adherence, engagement and health
Wipro HOLMES	AI and automation
Zebra Medical Vision	Provides radiologists with the tools they need to make the next leap in patient care
...and many more!	

Source: *"Artificial Intelligence & Biopharma R&D IT"; The Prisme Forum; Drug Discovery World; Spring issue 2018.*

THE AUTHOR & ACKNOWLEDGEMENTS

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